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A Technique for Teaching Science in the Junior High School

Thomas S. Harro

A TECHNIQUE FOR TEACHING SCIENCE IN THE JUNIOR HIGH SCHOOL

by

Thomas S. Harro

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Thomas S. Harro

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CHAPTER I

THE PROBLEM AND ITS BACKGROUND

The Problem

The current era is called the Space Age--a time of phenomenal scientific progress. Accordingly, improvements in science programs at all levels of education are being urged and promoted on all sides. Federal grants are offered to motivate science teachers to improve their training; federal funds are available to aid school systems in the purchase of scientific equipment; and capable high-school and college students are urged to choose careers in the sciences.

Local administrators under the contemporary pressures have initiated overhauls of the science program. New subject matter is being assigned to science courses at various levels, more up-to-date books are being purchased, and coordination of science courses throughout the various grade levels is being attempted. All these efforts have produced change, although change may not mean improvement. A teacher who is well-informed about current scientific advances and who has the most modern equipment and textbooks may still fail to make science a pertinent, meaningful part of the life of his students. . Statistical data gathered by Ruffner[1] indicate that children in the ninth grade enthusiastically endorsed certain experiences, samplings in the science field, before being given any direction in the study and that this same enthusiasm waned after the direction. Mallinson,[2] in reviewing interest studies at the sixth- and seventh-grade levels, observes that more of these students indicate an interest in science than in any other subject. Yet, similar studies with ninth-grade students or those entering the tenth grade show that fewer students state an interest in science than in any other subject taught at these levels.

Can the junior-high-school science teacher ignore such an indictment? In the last analysis the success of science programs stands or falls with the science teacher in his classroom. The most urgent

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[1]Ruffner, Frances E., "Interests of Ninth-Grade Students in General Science." Science Education, XXIV (January 1940), 23-9.

[2]Mimeographed report entitled "Junior High School Science and the Implications of the Science Motivation Project" delivered by George G. Mallinson to the Wisconsin Conference on Science Instruction in the Elementary and Junior High Schools, at the University of Wisconsin, Madison, Wisconsin on August 21, 1962.

need therefore, is for a <u>technique of science teaching</u> that will allow young people to experience "true" science, discover underlying principles of life phenomena, and learn to apply these principles to new classes of problems.

In this study the writer will deal with the teaching of science at the junior-high-school level, will investigate a four-fold problem with which every science teacher is faced and will suggest a possible solution or technique for each aspect of this problem. The four aspects of the problem are these:

1. Fragmented content;
2. Experimentation without focus;
3. Ineffective student record of activity;
4. Lack of transfer.

Fragmented Content

History

As early as 1909 the need for an introductory science course at the level now known as the junior-high school was becoming apparent. Experiments were underway indicating that highly specialized sciences were not meeting the needs of the first-year pupils. However there was no agreement as to what the content of such a course should be.

In 1920 the National Education Association report,[1] Reorganization of Science in Secondary Schools, made definite recommendations as to the nature of such a general-science course. The content was to consist of topics or units related to the citizens' needs in science, and drew its materials from any of the specialized sciences which helped meet these needs.

With the development of the junior-high school, the organization of appropriate science courses for grades seven and eight as well as for grade nine became necessary. Finally, in 1932 with the publication of the Thirty-first Yearbook[2] of the National Society for the Study of Education entitled, A Program for Science Teaching, an authoritative statement was made concerning the need for an integrated program of science from kindergarten through twelfth grade. The Thirty-first Yearbook recommended general science as

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[1]Science Education in American Schools, National Society for the Study of Education, Forty-sixth Yearbook, Part I. Chicago: Distributed by the University of Chicago Press, 1947, p.153 citing Committee of the National Education Association, Commission on Reorganization of Secondary Education, Reorganization of Science. Washington: Government Printing Office, 1920.

[2]A Program for Teaching Science, Thirty-first Yearbook of the National Society for the Study of Education, Part I. Chicago: Distributed by the University of Chicago Press, 1932, 194.

a three-year sequence in grades seven, eight and nine. However the content at the various levels proved to be repetitious and failed to meet the objectives suggested for it. As Mallinson[1] points out, this situation still exists.

Present status

Studies by Pettit[2] and Hunter[3] of various general science textbooks reveals that there is little agreement as to the number of areas to be included, which may range from six to eighteen in any one grade. The topics are often unrelated, show little adaptibility for individual differences, tend to be superficial, and do not contain new, pertinent developments in science. Seeger[4] in his manuscript, On Teaching "All

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[1]A paper entitled "Motivation in Junior High School Science," presented by George G. Mallinson to the Twelfth Thomas Alva Edison Foundation Institute on Science Education at the Engineering Society of Detroit, Detroit, Michigan, November 13, 14, 1962.

[2]Pettit, Donald D., "The Content of Junior High School Science." School Science and Mathematics, XL (October 1940), 643-54.

[3]Hunter, G. W. and Parker, Alice L., "The Subject Matter of General Science." School Science and Mathematics, XLII (December 1942), 869-77.

[4]Fischler, Abraham S., "Science for Grades Seven, Eight and Nine." School Science and Mathematics, LXI (April 1961), 279 citing Seeger, Raymond J., On Teaching "All About Science," manuscript copy, September 4, 1960, 3, 4.

<u>About Science,"</u> concludes:

> "In looking over the various textbooks, I was completely at loss as to what had motivated the choice of the particular concepts and the grades assigned for teaching them. From the viewpoint both of logical and psychological presentation of scientific ideas much was obviously wanting. In some instances, indeed, fundamental concepts were incorrectly presented, and in many more cases incompletely. . . There is evidently a determined effort, increasing with grade level, to teach 'all about science', but not at all a hopeful desire to learn science as a way of understanding nature. What is worse, the same material is frequently repeated in consecutive grades with no obvious cumulative progress or curricular relation. Why then are particular topics selected for dominating ones? What about scientific goals? Evidently any answer to this basic question depends upon one's own conception of science itself."

Educators throughout the country have recognized these weaknesses, and various approaches are being tried. One pattern is a block program in which mathematics and science are both taught by one teacher for a year, or even longer. Another approach is the ungraded science program in grades seven and eight. Here grouping is done by ability and interest in science so that able students in the seventh grade may be working with eighth-grade students on a particular problem. In both cases, the teacher is the key to the success of the program. He must be trained in all branches of science, understand child behavior, and be operating in a functional laboratory.

Some communities are introducing a separate science in each grade--biology in grade seven, chemistry in grade eight and physics in grade nine. Many educators[1,2] believe that this is unwise. They argue that when a child looks at his environment he does not see it subdivided biologically, chemically, and physically. These separate disciplines are man-made and often prevent students from seeing the relationship between the various disciplines within the scientific enterprise.

Another approach is the introduction of biology or earth science in grade nine for the academically able student. This, too, has met with varying degrees of success. Brandwein[3] reports that of the number of students taking biology, earth science, or chemistry in grade nine, he found only an average of thirty-five percent were planning to take three more years of science as compared with eighty-five percent of the "controls" who had had "general science" in grade nine.

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[1]loc. cit., p.280.

[2]Mallinson, "Motivation in Junior High School Science," op. cit., p.7.

[3]Fischler, op. cit., p.281 citing Brandwein, Watson, Blackwood, A Book of Methods. New York: Harcourt, Brace, & Co., 1958, p.324.

Many curriculum workers in the field of junior-high-school science are now committed to a policy of spiralling placement.[1] In this scheme, many of the same concepts or generalizations of science are included in each year's work. The experiences of the pupils and their application of these principles vary from year to year, with the expectation that in succeeding years their understanding and control of the concept will be constantly enlarged.

Experimentation Without Focus

Lack of direct experience

Experimentation connotes actively securing knowledge by exploration and discovery. If students are to learn more than facts and the interpretation of principles, they must become actively involved in solving science problems. Curtis[2] points out:

> "Within the past two decades, . . . there has been an increasing tendency to teach science vicariously, rather than experientially. . . the all-too-common practice is to have pupils read or be told about science rather than have them experience science through observing and experimenting."

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[1]Forty-sixth Yearbook of the National Society for the Study of Education, Science Education in American Schools, op. cit., p.158.

[2]Curtis, F. D., "Basic Principles of Science Teaching." The Science Teacher, XX (March 1953), 58.

Schwab[1] proposes that the conventional classroom be transformed into a completely inquiring one in which lecture and textbook are challenged. For the student, this means relinquishment of habits of passivity and dependence on teacher and textbook in favor of an active learning "where lecture and textbook cease to be authoritative sources of information and become materials to be dissected and analyzed."

For the teacher this attitude of inquiry requires new skills and habits. The student does not learn to "learn for himself" without help. It is the responsibility of the teacher to aid him in discovering what to look for during scientific inquiry, and what questions to ask of the material he is reading.

The fact that many students do not, in their courses, deal directly with life itself is pointed up in a study by Abbott[2] to determine the relative demand for commercial products by high schools in biological studies. In a random sampling of over one-hundred schools throughout the United States, he found

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[1] Schwab, Joseph J., and Brandwein, Paul F., The Teaching of Science. Cambridge, Massachusetts: Harvard University Press, 1962, 66.

[2] Abbott, Cyril, "Do Biology Teachers Use Live Materials?" American Biology Teacher, XVI No. 1 (January 1954), 15.

that biology teachers lean heavily on charts and "pickled" specimens (59%) and that living organisms (8%) are scarcely ever used.

Misconception of the function of experiments

Experiments are used by teachers for a variety of purposes. For some an experiment is simply an attention getter; others seem to have little more than entertainment in mind. The more serious teacher, hopefully, tries to relate his experiment with the material being studied. Even here the true function of experimentation may not be taking place. The authors of the Forty-sixth Yearbook[1] observe:

> "It is regrettable that, in a majority of science classrooms in which demonstrations and individual pupil experiments are performed, the chief, if not the sole function served by these activities is to verify facts and principles already learned."

This results in pupils' attempting to "make the answer come out right," and telling "what ought to have happened," instead of what did happen. Since the primary purpose of experimentation is to secure answers to problems, this practice is the antithesis of inquiry.

Writing in this regard, Alberg[2] says:

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[1]Forty-sixth Yearbook, op. cit., p.51-2.

[2]Alberg, B., "Any Old Experiments?" Science Teacher, XXX (October 1963), 28.

"The 'legitimacy' of the experiment as an experiment (and not a directed exercise to be followed) is quite questionable if all the answers can be found in the book. The question here is whether the so-called experiment really poses a problem or a situation to be investigated by the students, requiring the collection of data and their analysis and interpretation."

Poor choice of experiments

What shall determine the choice of experiments for junior-high-school science? Shall it be those that teachers learned to do in college science classes? Hilgers[1] found these to be the experiments or demonstrations most commonly used. Obviously this is a poor basis for choice.

Shall it be an experiment carried down from a high-school-science course, and simplified for junior-high-school students? Little has been done with the planning of science experiences suited to the needs of young people at varying levels of maturity. The Forty-sixth Yearbook[2] calls for this kind of planning.

"Instead of placidly accepting trite science experiences pushed down from the grade levels above, good teaching demands

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[1]Hilgers, Robert J., "Practices and Techniques in Science Teaching." Science Education, XXVI (January 1942), 16-21.

[2]op. cit., p.157.

that science experiences be planned for the maturity of the particular pupils involved."

For learning to be effected, the student must be intellectually involved as well as physically involved. It would seem, therefore, that experimentation needs to be focused on important, basic relationships in the student's immediate environment--relationships in which he is involved but which he does not understand. The Forty-sixth Yearbook[1] concludes:

> "There is a great need for the development of an adequate series of demonstrations to be used in junior high school classes for building up very specific understandings of particular science concepts, principles and applications."

Ineffective Student Recording of Activity

<u>Time-consuming and irrelevant records</u>

In speaking of a record of student activity the writer refers to those activities assigned students as a means of aiding organization and recording of observations.

If an exercise is worth performing it is worth recording. What kind of record should be required of a student? A practice often employed by junior-high-

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[1]loc. cit., p.160.

school teachers is the reporting of an experiment in "story" form. Commenting on this student activity, the Forty-sixth Yearbook[1] states:

> "Rarely is the reporting of an experiment in complete 'story' (expositional) form justified, because of the great amount of time required for the pupil to write it and for the teacher to give the report the careful and detailed reading it should have."

Another student activity frequently required is the making of representative drawings of apparatus set-ups and biological specimens. Reviewing the relatively extensive research on this issue, the writers of the Forty-sixth Yearbook[2] found an inverse relationship between the degree of attention focused upon artistic and exact reproduction and the attainment of the goals of science teaching.

Research further indicates that the inking or coloring of laboratory drawings is likewise wholly ineffective as a means of realizing major objectives of a science course.

Requiring pupils to trace drawings from textbooks, as is frequently observed in ninth-grade and high-school biology classes, is without justification and can only be condemned. A more beneficial prac-

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[1]loc. cit., p.55.

[2]ibid.

tice is that of having students make diagrams or sketches to record their observations.[1]

Meaningless records

A study of the secondary schools of Minnesota by Hilgers[2] indicated that in general science the most commonly used method in recording laboratory work was having the students answer a series of questions about the experiment. In biology, chemistry and physics the combination laboratory manual and workbook was used most frequently.

The use of the published workbook came into great favor in the 1930's. Powers[3] in an experiment involving twenty-eight pupils in ninth-grade general science, found the self-made manual slightly superior to the commercially published laboratory manual. However, the difference was not great enough, in view of the small number of cases, to be reliable.

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[1]loc. cit., p.56.

[2]op. cit.

[3]Peterson, George W., and Douglass, Harl R., "Published Workbooks versus Pupil-Made Notebooks in Ninth-Grade General Science." The School Review, XLIII (October 1935), 609 citing Powers, Stuart C., "A Study of the 'Self-made' Pupil Laboratory Manual versus the Traditional Laboratory Manual." Unpublished Master's Thesis, Ohio State University, 1931.

Peterson and Douglass[1] found little demonstrable difference between the relative efficiency of the workbook and of the notebook as a device for learning general science in grade nine, although the results suggest the probable but slight superiority of the notebook technique.

The important issue is how meaningful to the student is the workbook or notebook? Some workbooks use almost exclusively the device of having pupils record their observations by filling in blanks with single words or phrases. Although this practice is an attempt to lighten the teacher's load it has met with "vigorous and merited criticism."[2] A poor workbook may be a hindrance to the teacher rather than a help.

Lack of Transfer

The meaning of transfer

> "Transfer of learning occurs when a person's learning in one situation influences his learning and performance in other situations."[3]

In its broadest meaning, transfer of learning is basic to the whole idea of schooling. Knowledge is of du-

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[1]loc. cit., pp. 612-13.

[2]Forty-sixth Yearbook, op. cit., p.52.

[3]Bigge, Morris L., Learning Theories For Teachers. New York: Harper & Row, 1964, p.243.

bious value unless its possessor is able to recognize the situations in which to use it and knows how to use it. Facts, principles and broad understandings must be made functional in the student's life or he and the teacher are, essentially, wasting their time.

However, the ability to apply facts depends on one's ability to recall them, and this ability deteriorates unless the facts are constantly reviewed. Striking evidence of this high rate of forgetting is provided by the studies of Tyler[1] and others. The results of these researches revealed that within a year after high school pupils and college students had completed courses in science, they had forgotten as much as seventy-seven percent of the facts they knew on completing these courses.

In contrast, however, with the rapid rate of forgetting of facts is the high degree of retention of the ability to apply mastered scientific principles. These same studies show that while three years after the end of one course, the students had forgotten about seventy-two percent of the facts, they had gained fifty-eight percent in their ability to apply principles.

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[1]Curtis, op. cit., p.57 citing Tyler, Ralph W., "Permanence of Learning." Journal of Higher Education, IV (April 1933), 203-04, and "What High School Pupils Forget." Educational Research Bulletin, Ohio State University, IX (November 19, 1930), 490-92.

A mastery of scientific principles and the ability to apply them in life situations depends on the extent to which problem-solving is made a real part of the science teaching program. Fischler[1] observes:

> "In the past in our schools, we have emphasized experimental facts. We have taught children, as Professor Schwab states, 'the rhetoric of conclusions.' Questions posed to the children were of the type, 'What is the name of? What is the distance to? How many electrons? Or, What is the valence of?' It is time for a change. . . .Questions asked ought to be of the 'how' or 'why' variety. Measurement ought to be incorporated and used wherever possible. Students must understand the principle before they can understand its application."

In an effort to determine to what extent problem-solving takes place in the teaching program, Newton[2] made a survey of teacher-made science tests in junior-high-school general science, on the theory that a teacher's method of teaching will be reflected in his tests. From seventeen public school systems in fifteen geographically distributed states he tabulated fifty-seven tests on the basis of two classes of questions: (1) those which require the statement of a principle or fact; (2) those which require an answer arising

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[1]Fischler, Abraham S., "Junior High School Science." <u>School Science and Mathematics,</u> LXIV (January 1964), 23.

[2]Newton, David E., "The Problem-solving Approach--Fact or Fancy?" <u>School Science and Mathematics,</u> LXI (November 1961), 619-22.

from the application of some principle or from a process of reasoning. In order to provide a basis for comparison, a group of ten textbook company tests were also surveyed in the same manner.

Results of the survey indicate that both teacher-prepared tests and published tests rely heavily on straight factual, memorization-type questions. Less than one-fifth of the questions reviewed could conceivably be classed as "thought" questions.

It is most gratifying to realize that students want material that is functional rather than merely factual. Their interest is on "our side." Keislar[1] exhorts teachers to dispense with attempts to reinforce study with such things as high marks, cash, trinkets or prizes. The excitement of the resolution of a paradox, or an intriguing question is sufficient reinforcement. What is more, Keislar believes that when students are guided to discover for themselves the principles that underlie a group of problems, there is some evidence that they solve new classes of problems more quickly than when they are "simply given the rule."

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[1]Keislar, Evan R., "The Learning Process and the Teaching of Science." Science Teacher, XXIX (December 1962), 21-25.

Summary

The four-fold problem with which every junior-high-school teacher of science wrestles has been examined. In order to teach effectively, to make science "matter" to his students, he must find a way to organize a fragmented content into broad, basic principles and relationships; he must bring every experimental activity into direct focus with these basic relationships; he must devise a method of student-recording of these principles and relationships discovered which is brief but relevant and meaningful; and he must construct problem-solving experiences which will develop a mastery of these principles to the extent that they will be applied in daily living.

CHAPTER II

TEACHING METHODS EMPLOYED

The Problem

The problem of this chapter is to describe a teaching technique for junior-high-school science that may remedy the deficiencies implied in Chapter I. These deficiencies are:

1. Fragmented content;
2. Experimentation without focus;
3. Ineffective student recording of activity;
4. Lack of transfer.

Pertinent Content

Selection of basic relationships

The junior-high-school science teacher needs to accept some criteria for selecting broad principles of science that will help students understand themselves and their environments. It is on these broad principles that more specialized concepts may later be built. The investigator suggests that the selection be guided with what he terms a basic relationship.

As applied to science, the term "basic relationship" implies a relationship from which the development of understanding of a specific area, topic or concept of science emerges. Four criteria of a basic relationship were accepted for this study.

1. The relationship should involve a minimum of factors, yet a maximum of variation when one factor changes. For example, in this study, the basic relationship between the sun's rays and the earth's axis was used. Three factors, the sun, earth and the inclination of the earth's axis are involved. As the inclination of the earth's axis changes with respect to the sun, the rays of the sun strike the earth at different angles to the perpendicular and for different periods of time. This variation within the relationship between the sun's rays and the earth results in changes of seasons and length of day and night.

2. The relationship must be demonstrable and observable in the classroom. Relationships in which the varying of a factor and the resultant changes could not be observed directly during the class hour were considered supplementary rather than basic.

3. The relationship must be one in which changes observed by the alteration of a factor are evident in a great number of instances in one's environment. For

example, in comparing bodily structures of insects one factor, ten or more varieties of wings, would be observed. Since each type can be illustrated by several common insects, this structure was considered appropriate for comparison.

4. The relationship must be one which occurs in phenomena common to the students' experience.

The basic relationships selected on these criteria were as follows:

I. Biology Unit: The relationship between phylogenetic groups of animals and plants and the external structure that is distinctive to each group.

II. Light Unit: The relationship between the distance of an object (light source) from an aperture, lens or mirror, and the nature and position of the image formed.

III. Physical Relationships: The relationship between moving objects and their weight and distance moved (work), their velocity and their acceleration.

IV. Chemical Elements: The relationships among elements with respect to the proportions in which they combine, their ionization in compounds, and their relative weights.

V. Earth Science: The relationship of the earth and the inclination of its axis to the direct rays of the sun.

Organization of content

The basic relationships just listed were the focal points for classroom activity. Thus it was necessary to deviate from the regular textbook presentation. In a series of lessons on light, for example, the investigator wished to teach the relationships among the image formed by a convex lens, the object, and the distance of the object from the lens. Since four different images are formed as the distance is varied, the material was organized into four lessons.

Experimentation as Inquiry

In this study a legitimate experiment or observation for junior-high-school students is considered to be one that involves them actively in discovering and developing understandings of fundamental principles and relationships in their environments. Two criteria for devising experiments--direct experience and problem-solving--are implicit in this definition.

Direct experience

In order to enable science students to deal directly with life, the investigator, whenever possible, brought live animals and plants into the classroom and also provided opportunity for the students to observe the reactions between chemicals and selected experiments in which physical relationships could be observed directly.

Problem solving

Experimentation as a problem-solving technique implies direct observations that enable students to answer the pertinent questions about a phenomenon. Thus, the experiment or demonstration is a means of discovering and clarifying the basic relationship that the junior-high-school student might otherwise not notice. For example, in learning about the different proportions of materials in complex molecules, one decomposition experiment that resulted in liquid or solid products did not clearly demonstrate decomposition for junior-high-school students. However, electrolysis of water, a decomposition experiment whose products are gases, did provide observable evidence of proportions of the components. Thus, the electrolysis experiment was used since it provided observable evidence of proportions of components.

Effective Student Recording of Activity

For the purpose of this study, the function of student records was to involve students in analyzing data related to the central concept of the lesson. In order to record data about a concept they had to be aware of the factors to be observed. For example, a basic concept related to refraction of light is that light rays are bent away from the normal when entering a substance of less optical density. Most students had observed many common examples of this phenomenon. However, the drawings made of the light rays as they were observed helped develop an understanding of the concept. Records made were expected to be brief and accurate. These were kept in a notebook and used for review at the end of the year.

Transfer

The three factors discussed thus far are dependent on one another. They are also related to the factor of transfer. Transfer occurs when learning in one situation facilitates learning in another. Thus, it was considered essential that students understand science concepts sufficiently well to enable them to identify situations in which the concepts apply.

No particular position of a lesson can be isolated and identified as "accomplishing transfer." In some cases, transfer may be accomplished by timely selection of content. For example, the identification of evergreens was presented just before Christmas. In other cases it may be accomplished by pointing out the significance of a concept to some related area of life, for example the application of relative weights to the quantity of a toxic or potent drug found in the home. However, it was considered necessary to stay within the perimeter of the students' experience if transfer was to occur.

Tests indicated, to some extent, the degree to which transfer had taken place. Fischler[1] states that a mastery of scientific principles and the ability to apply them in life situations depends on the extent to which problem-solving is made a real part of the science program. Therefore, tests employed in this study required students to apply principles rather than recall details.

Development of Teaching Units

The four basic criteria just described were used to develop five experimental units for use with the

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[1]op. cit.

investigator's seventh-grade general science students. One of these units follows; copies of the others appear in the appendix.

The units prepared were taught during the school year 1965-66. The insect unit presented in the text was taught in the fall when live insects were plentiful. Monocotyledonous flowers were studied in the late spring when they were available for observation in the classroom. The winter solstice was chosen as the most feasible time to present earth-sun relationships, since the greatest difference between the times of day and night (during the school year) exists at that time.

For each unit the general type of experimentation and student record is explained, together with a broad outline of the unit, and specific lessons illustrating the methods used in the unit. In each case the basic relationship for the lesson is stated; the specific experiment or demonstration is explained; and an example of the student record is included. Note that each student activity is a record of direct observation or experimentation. Suggestions regarding application conclude each lesson.

A Unit In Biological Structural Relationships

The basic relationship of this unit is a distinctive superficial structure of a group of plants or animals, compared to that same structure in other plants or animals. This serves to introduce elementary taxonomy and comparative anatomy.

Slide projection is the basic technique for direct observation of these structures. Most of the structures can be mounted on an ordinary microscope slide with transparent tape, placed in a clear plastic envelope and inserted into a filmstrip projector in the place designed for 35 mm. slides. Structures too large for projecting can be directly examined by each individual student.

The student's record of what he has observed involves a sketch of the structure, illustrating the origin of the scientific name.

Application of this to past experience allows the student to systematize his knowledge of living things and acquaints him with their most interesting structures.

Organization of Biology Unit

Living plants and animals	Comparative structures
I. Plant Groups	seeds
A. Seedless plants	principal parts
B. Seed plants	seeds
1. Naked seed plants	cones, needles
2. Single seed plants	flowers
3. Double seed plants	flowers, fruits
II. Animal Groups	skeleton
A. No skeleton	body
B. External skeleton	number of walking legs
1. Insects	wings
2. Spiders	eye pattern
3. Cray fish	leg type
4. Millipedes	legs per body segment
C. Internal skeleton	appendages
1. Fish	fins
2. Amphibians	body
3. Reptiles	scales
4. Birds	beak, feet
5. Mammals	teeth, feet

Comparison of insect wings (sample lesson)

A comparison of insect wings from the more common orders shows a basic structural relationship between these animals. The wings of a box elder bug mounted on a microscope slide with transparent tape may be used to represent the technique. Placed in a slide projector, these are projected on the wall for direct observation. The division of the fore wing into two distinct textures, leathery and membranous, is the significant taxonomic point of interest and also explains why the true bugs are named Hemiptera (half-wing).

Recording the observation requires the use of sketching to indicate (1) the size of the structure, (2) comparison of textures, (3) color and (4) labeling of the significant structure and the animal from which it came.

This experience in comparison may lead the student to interest in the major groups of bugs or to a bug collection.

The series of lessons on insects may be organized as follows.

Organization of lessons on insects

	Wing type	Order	Example
1.	Wings scaly	Lepidoptera	Butterfly
2.	Wings straight	Orthoptera	Cockroach
3.	Wings laced	Neuroptera	Laced wing fly
4.	Wings sheathed	Coleoptera	Beetle
5.	Wings membranous (2)	Diptera	Fly
6.	Wings membranous (4)	Hymenoptera	Bee
7.	Wings leathery and membranous	Hemiptera	Bug
8.	Wings uniform	Homoptera	Cicada
9.	Wings equal	Isoptera	Termite
10.	Wings unequal	Anisoptera	Dragonfly
11.	Wingless	Siphonoptera	Dog flea

HEMIPTERA

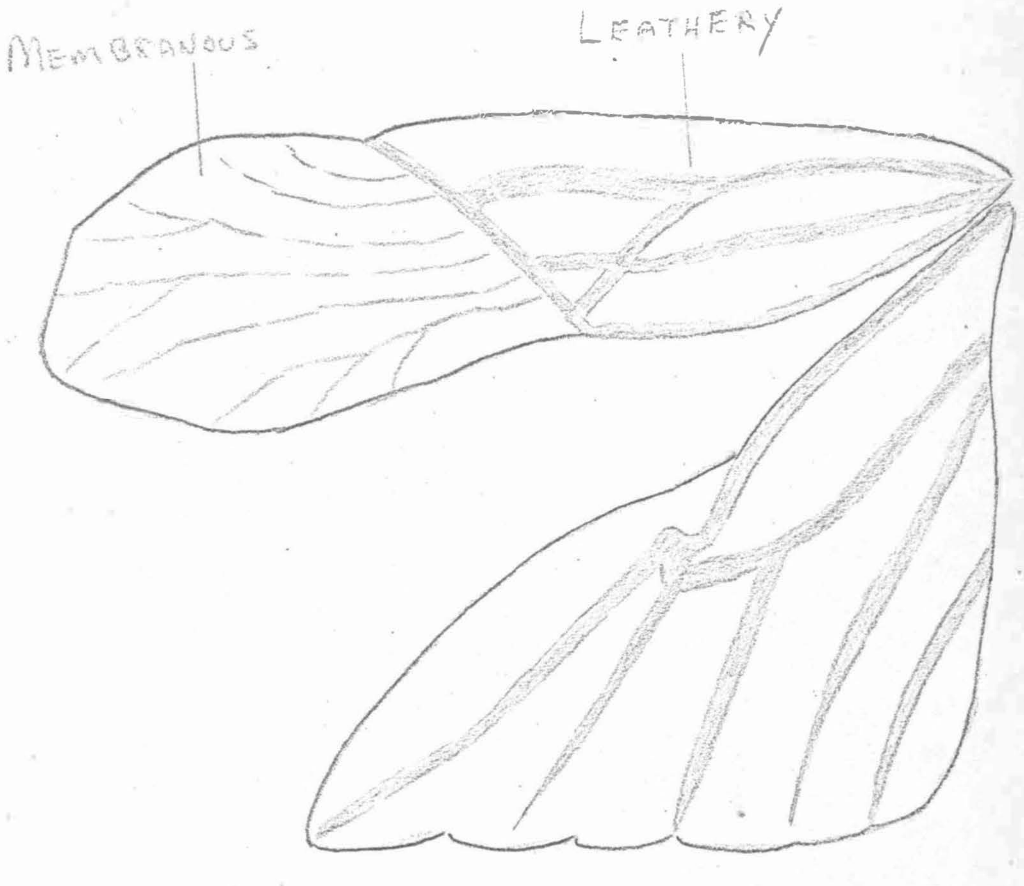


FIG. 1
BOX ELDER BUG WINGS

Comparison of monocot flowers (sample lesson)

The flowers of monocotyledonous plants display clear structural relationships. By comparing the principal types of flowers, a distinctive structure of most common orders is observed.

The distinctive structure of the lily order may be observed by mounting the ovary and stamens of a tulip on a microscope slide. Projected on a wall or screen, this provides the basis for a cross-sectional sketch of the tulip. The sketch is simplified by representing the petals and sepals with a single line. Construction of this requires understanding of the position of a superior ovary. Students are interested to discover that these same characteristics are found in the flowers of common garden plants such as the onion, garlic and asparagus, as well as the familiar Easter lily and the hyacinth.

Organization of lessons on monocot flowers

	Distinctive structure	Order	Example
1.	Flower-superior ovary 6 stamens	Liliales	Tulip
2.	Flower-inferior ovary 6 stamens	Iridales	Irises
3.	Flower-inferior ovary 1 or 2 stamens	Orchidales	Orchids
4.	Flower-mounted on fibrous spike	Graminales	Grasses
5.	Flower-mounted on fleshy spike	Pandanales	Cat-tails
6.	Flower-mounted on spadix	Arales	Jack-in-the-Pulpit

LILIALES.

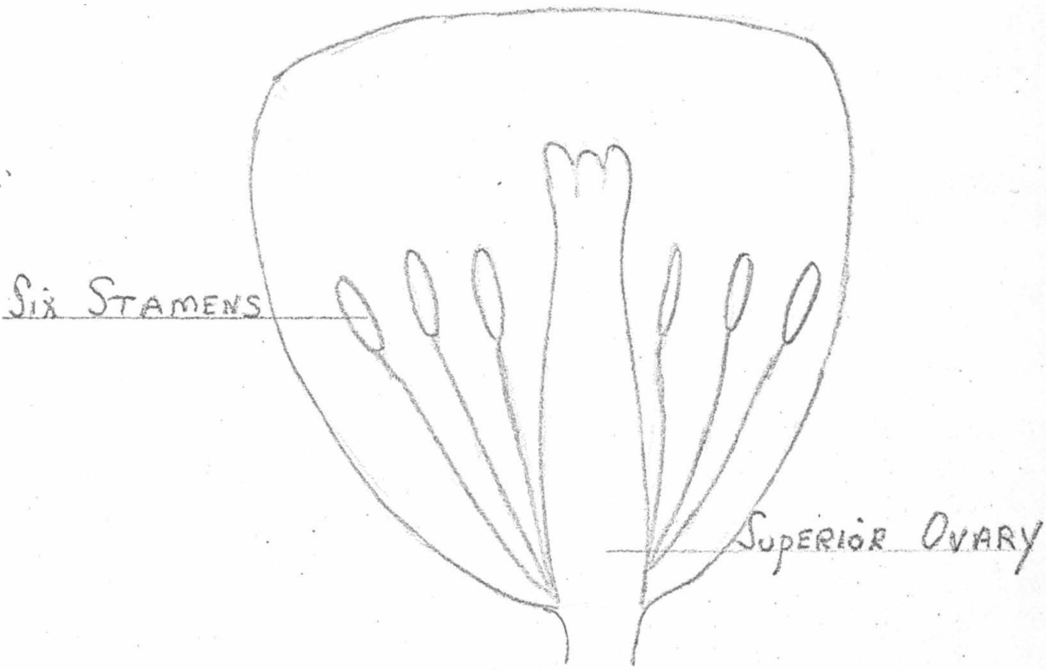


FIG. 2
TULIP FLOWER

CHAPTER III

TESTING METHODS EMPLOYED

The Problem

The problem of this chapter is to describe (1) the groups under study and (2) the methods used in measuring the achievement in general science of the experimental and control groups.

The Experimental Group

The study was conducted in one of two junior high schools in a northern Illinois city with a population of approximately 26,000. The city is highly industrialized, attracting many people of the laboring class. There is also a large segment of middle class business and professional men and a large Negro population. The students, therefore, come from a heterogeneous background.

Of the eight hundred students who attend this junior high school, approximately 20 percent are Negro. Many pupils travel to and from school on busses.

The experimental group consists of six sections of seventh-grade students, totaling 123 students. Three of these sections are so-called "bright" or "average" pupils; three sections are considered to be "slow learners." Most of the students in the group have been together in this school system throughout their grade-school years. Hence their science backgrounds are similar. Prior to the seventh grade, they had used the Macmillan Science-Life Series for three years.

The Control Group

In order to compare the results obtained with the experimental group, a control group was used and administered the same test.

The control group was composed of the remaining five sections of the seventh-grade general-science classes and consisted of ninety-seven students. Their backgrounds were similar to those of the test group. Like the experimental group, these students consisted of "bright," "average" and "slow learners." Their previous training in science was similar.

Data concerning the levels of intelligence of the students in both groups are found in Table I.

TABLE I

PERCENTILE RANKS OF THE SCORES ON TOTAL MENTAL FACTORS ON THE CALIFORNIA TESTS OF MENTAL MATURITY

Experimental Group			Control Group		
Ranges of Percentiles	Frequency	Percent	Ranges of Percentiles	Frequency	Percent
91 - 100	24	19.83	91 - 100	14	14.43
81 - 90	19	15.70	81 - 90	15	15.46
71 - 80	18	14.88	71 - 80	14	14.43
61 - 70	11	9.09	61 - 70	8	8.25
51 - 60	16	13.22	51 - 60	8	8.25
41 - 50	8	6.61	41 - 50	9	9.28
31 - 40	12	9.91	31 - 40	9	9.28
21 - 30	4	3.31	21 - 30	5	5.15
11 - 20	4	3.31	11 - 20	10	10.31
0 - 10	5	4.13	0 - 10	5	5.15

Table I shows that the scores of 72.72 percent of the experimental group lie above the fiftieth percentile whereas 60.82 percent of those of the control group are in that range.

The Learning Program

The basic text used by both the experimental and control groups was Living Things by Holt, Rinehart and Winston, and an unpublished syllabus used in the school system, "Science and the Science Student," prepared under the direction of Harold Hungerford.

The experimental group used the five units described earlier in this study. The following typical lesson illustrates the teaching technique that was used with the experimental group.

The goals of this lesson are to (1) observe the structures that are used to classify an insect as a fly, (2) observe other unique structures of the fly, and (3) recognize the relationship of the fly to man's welfare.

The class began with the reading of the appropriate pages in the text introducing the topic of the lesson. Several live flies were then captured for observation later in the class period.

The membranous wings of a fly, mounted on a microscope slide, were projected on a screen, observed, and recorded individually my means of sketches. It was noted that any insect with two membranous wings belongs to the fly order, Diptera. Students were encouraged to recall other examples of insects that have two membranous wings. These were listed with the sketches of the membranous wings of the fly as insects that have this type of wing.

The live flies that the students captured were then placed in glass tubes and observed under the binoculars. Each student was given an opportunity to observe the compound eyes, mucous mouth parts, wing stubs and feet pads. The significance of these structures to the survival of the fly was discussed.

A short classroom film entitled, "The House Fly" was used to show how many of these same structures make the fly detrimental to man's welfare.

The control group, taught by a different instructor, received lessons in order of the sequence in the textbook. A descriptive lecture method of presentation was used, with occasional direct observation of natural phenomena. Student records required were written reports.

The Achievement Test

In order to select an appropriate measuring device of the results of the investigation, a survey of available standardized tests for seventh-grade science was made. Since none of them seemed entirely suitable, it was decided to use an experimental test published by the Scholastic Testing Service, Bensenville, Illinois. This test is easily administered with a sixty-minute period and may be hand-scored with the aid of a scoring stencil.

The test, which has two forms, is composed of five-choice multiple-choice items and is divided into two parts. The first form is designed for students in the fourth through sixth grades. The first items are designed to test familiarity with facts and principles. The second items require responses to problems or anecdotes, thus testing problem-solving abilities. The second form is designed for grades six through nine and consists of the same two types of items. Both of these experimental forms were consolidated into one test for the purposes of this study to provide measurements for a broad range of achievement.

The Administration of the Test

The test was administered to both groups at the beginning of the first semester of the seventh grade year, in the same room, proctored by the author. An exception was a very slow-learning class, part of the experimental group, which was tested alone.

The test was administered in two sessions, covering two days. The less difficult section (designed for grades 4-6) was administered first. The more difficult section was administered the second day. Students were able to complete the test in almost all cases. At each session assurance was given that this test would not affect the students' grades. A copy of the test is found in the Appendix.

At the end of the second semester the test was administered to both experimental and control groups. The same procedure was followed, and students were again assured that the results of the test would not affect their grades.

CHAPTER IV

ANALYSIS OF THE SCORES ON THE SCIENCE ACHIEVEMENT TEST

The Problem

The problem of this chapter is to (1) tabulate the data obtained in the study and to (2) analyze the data with appropriate statistical techniques.

Raw Data

As stated in Chapter III, an experimental science test was administered at the beginning of the first semester of the seventh grade to both experimental and control groups, and again at the end of the second semester.

The raw scores for both groups on the pre- and post-test appear in Table II, together with the intelligence quotient for each student. The I.Q. was derived from the total raw scores from the language and non-language scores on the California Tests of Mental Maturity administered in the sixth grade.

The data were programmed for the IBM 1620 computer system at Western Michigan University for an analysis of covariance weighted for I.Q.

TABLE II

INTELLIGENCE QUOTIENTS AND RAW SCORES ON SCIENCE TEST OF THE EXPERIMENTAL AND CONTROL GROUPS

Test Group	I.Q.	Pre-Test	Post-Test	Control Group	I.Q.	Pre-Test	Post-Test
A	120	53	67	A'	124	67	74
B	106	36	42	B'	91	44	55
C	152	88	104	C'	90	43	46
D	114	46	52	D'	90	36	42
E	136	56	75	E'	112	48	75
F	103	55	59	F'	79	46	28
G	90	30	44	G'	121	63	89
H	107	51	71	H'	92	40	58
I	108	70	78	I'	131	70	73
J	118	74	91	J'	119	53	66
K	115	68	84	K'	78	36	31
L	110	35	46	L'	90	40	43
M	120	71	76	M'	119	45	66
N	126	40	65	N'	100	25	40
O	92	30	45	O'	102	61	60
P	131	60	64	P'	123	55	69
Q	114	43	55	Q'	118	54	59
R	93	68	66	R'	110	36	45

TABLE II (Cont.)

Test Group	I.Q.	Pre-Test	Post-Test	Control Group	I.Q.	Pre-Test	Post-Test
S	99	47	59	S'	114	49	59
T	113	56	63	T'	83	45	45
U	128	64	87	U'	101	38	71
V	94	33	44	V'	104	33	53
W	106	47	46	W'	114	41	67
X	96	52	54	X'	97	37	43
Y	132	60	62	Y'	144	63	87
Z	115	59	65	Z'	147	71	83
AA	116	55	76	AA'	97	30	35
BB	112	63	64	BB'	97	34	31
CC	115	49	68	CC'	101	50	55
DD	109	45	56	DD'	105	56	57
EE	94	27	29	EE'	86	34	40
FF	110	42	64	FF'	121	49	65
GG	100	32	34	GG'	151	77	84
HH	100	37	40	HH'	127	45	56
II	113	41	57	II'	84	33	42
JJ	103	30	41	JJ'	120	53	56
KK	96	37	39	KK'	93	40	42
LL	79	22	45	LL'	109	29	56

TABLE II (Cont.)

Test Group	I.Q.	Pre-Test	Post-Test	Control Group	I.Q.	Pre-Test	Post-Test
MM	87	36	24	MM'	128	41	51
NN	125	74	91	NN'	104	34	55
OO	99	39	32	OO'	88	29	56
PP	106	52	55	PP'	113	43	53
QQ	107	37	40	QQ'	110	37	62
RR	117	50	62	RR'	133	62	70
SS	96	61	68	SS'	110	53	63
TT	101	50	54	TT'	115	57	82
UU	123	60	83	UU'	122	57	83
VV	111	43	52	VV'	100	55	63
WW	98	31	37	WW'	111	33	43
XX	127	48	55	XX'	111	36	35
YY	104	35	55	YY'	102	39	57
ZZ	119	43	51	ZZ'	103	53	51
AAA	102	43	31	AAA'	94	37	59
BBB	114	38	46	BBB'	114	51	76
CCC	105	38	60	CCC'	122	48	62
DDD	105	36	43	DDD'	100	27	35
EEE	118	42	52	EEE'	89	39	41
FFF	126	43	62	FFF'	119	34	55

TABLE II (Cont.)

Test Group	I.Q.	Pre-Test	Post-Test	Control Group	I.Q.	Pre-Test	Post-Test
GGG	124	51	73	GGG'	118	52	66
HHH	88	41	35	HHH'	113	37	36
III	118	26	44	III'	97	33	45
JJJ	128	69	71	JJJ'	105	47	65
KKK	117	41	54	KKK'	92	26	27
LLL	136	38	57	LLL'	115	41	41
MMM	107	45	52	MMM'	77	16	43
NNN	125	37	59	NNN'	115	45	57
OOO	109	52	70	OOO'	113	35	61
PPP	114	38	51	PPP'	129	47	49
QQQ	134	41	53	QQQ'	124	67	70
RRR	110	61	65	RRR'	121	61	63
SSS	107	35	53	SSS'	111	65	68
TTT	122	39	56	TTT'	91	38	52
UUU	145	88	99	UUU'	105	29	45
VVV	136	46	68	VVV'	102	23	36
WWW	130	63	85	WWW'	126	58	71
XXX	119	65	72	XXX'	125	78	84
YYY	108	46	50	YYY'	133	56	68
ZZZ	138	48	57	ZZZ'	92	34	43
AAAA	95	37	51	AAAA'	127	68	81

TABLE II (Cont.)

Test Group	I.Q.	Pre-Test	Post-Test	Control Group	I.Q.	Pre-Test	Post-Test
BBBB	94	35	25	BBBB'	114	40	64
CCCC	99	54	65	CCCC'	144	81	83
DDDD	111	36	42	DDDD'	114	43	50
EEEE	144	52	47	EEEE'	116	64	74
FFFF	112	50	68	FFFF'	103	30	37
GGGG	123	55	58	GGGG'	109	29	53
HHHH	108	49	64	HHHH'	89	33	39
IIII	126	34	44	IIII'	95	40	57
JJJJ	96	46	51	JJJJ'	105	36	52
KKKK	109	33	40	KKKK'	130	60	71
LLLL	114	42	49	LLLL'	112	25	41
MMMM	79	38	35	MMMM'	100	40	51
NNNN	117	39	72	NNNN'	82	32	38
OOOO	117	70	76	OOOO'	85	22	29
PPPP	122	34	40	PPPP'	93	40	33
QQQQ	116	50	63	QQQQ'	98	32	33
RRRR	101	31	40	RRRR'	109	68	75
SSSS	119	44	51	SSSS'	62	31	29
TTTT	131	81	97				
UUUU	136	88	96				
VVVV	124	83	88				

TABLE II (Cont.)

Test Group	I.Q.	Pre-Test	Post-Test	Control Group	I.Q.	Pre-Test	Post-Test
WWWW	93	37	22				
XXXX	104	19	43				
YYYY	128	54	65				
ZZZZ	124	67	70				
AAAAA	104	27	54				
BBBBB	148	56	79				
CCCCC	125	63	70				
DDDDD	85	32	41				
EEEEE	82	40	20				
FFFFF	85	43	35				
GGGGG	114	52	58				
HHHHH	111	44	61				
IIIII	88	24	38				
JJJJJ	99	46	64				
KKKKK	118	55	70				
LLLLL	101	61	62				
MMMMM	96	26	30				
NNNNN	76	24	30				
OOOOO	139	36	55				
PPPPP	102	32	39				
QQQQQ	105	41	45				

Analysis of the Test Scores

Table III summarizes the gains for the experimental and control groups. For the experimental group the gain was 9.18 points and for the control group, 11.22 points.

TABLE III

SUMMARY OF GAINS ON THE SCIENCE ACHIEVEMENT TEST

Group	Mean on Pre-test	Mean on Post-test	Mean Difference
Experimental	47.04	56.22	9.18
Control	44.51	55.73	11.22

The significance of the difference between the mean gains of the two groups was calculated by an analysis of covariance. From this calculation the "F" value was found to be 2.9718 which fails to indicate the difference is significant at the five percent level. The summary of these calculations is found in Table IV.

TABLE IV

SUMMARY OF ANALYSIS OF COVARIANCE

Source of Variation	df	Mean Square	F
Between groups	1	191.9160	
Within groups	216	64.5775	2.9718
Total	217		

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The Problem

The problem of this study was to determine how effective a suggested technique for teaching general science to junior-high-school students might be as compared with the traditional method.

Techniques Employed

The study was carried on with the seventh-grade classes in a junior high school in northeastern Illinois. Six sections of students (one-hundred twenty-three students), taught by the investigator, were designated the experimental group. The other five sections (ninety-seven students), taught by another instructor, made up the control group. Both groups were administered an experimental science achievement test at the beginning of the seventh grade and again at the end of the second semester.

During the school year, the experimental group was taught the five science units in the manner described in Chapter II. A sample lesson illustrating the application of this technique appears in Chapter III. The control group was taught by the traditional text-book method.

Because of differences in intelligence between the two groups, the significances of the difference between the mean gains of the two groups was computed by means of an analysis of covariance. The weighting factor was the I.Q. scores obtained by the students on the California Tests of Mental Maturity.

Conclusions

In so far as the techniques used in this study may be valid, the following conclusions seem justified:

1. An analysis of covariance was used to compensate for the difference in intelligence between the two groups as indicated by the scores on the California Tests of Mental Maturity.

2. The mean gain in the total scores of the control group was 2.04 points higher than the mean gain in the total scores for the experimental group. However, the difference was not statistically significant. Hence, it cannot be assumed that the control group had greater achievement in seventh-grade general science than the experimental group.

3. From the conclusion just stated, it seems reasonable to assume that the experimental technique for teaching general science suggested in this study does not produce a greater gain in achievement in general science than the traditional method used with the control group.

Recommendations

In so far as the conclusions in this study are valid, the following recommendations are offered:

1. Although the experimental teaching technique did not prove to be particularly effective in this study, it is suggested that the technique should be reviewed to determine whether certain modifications might not be made in its classroom application.

2. It is recommended that, in view of the fact that the test used was designed as a general measure for general science, some other testing technique, oriented toward the experimental effort attempted here might be used, if such a test becomes available.

3. In order to eliminate the personality variable involved in having a different instructor for the control group, it is recommended that in another study some design be used for weighting the effect of different instructors.

BIBLIOGRAPHY

Books

Bigge, Morris L., Learning Theories For Teachers. New York: Harper & Row, 1964. Pp. xiv + 366.

Brandwein, Watson, Blackwood, Teaching High School Science: A Book of Methods. New York: Harcourt, Brace & Co., 1958. Pp. xxi + 568.

Schwab, Joseph J., Brandwein, Paul F., The Teaching of Science. Cambridge, Massachusetts: Harvard University Press, 1962. Pp. 152.

Bulletins, Yearbooks, Unpublished Material

Mimeographed report entitled "Junior High School Science and the Implications of the Science Motivation Project" delivered by George G. Mallinson to the Wisconsin Conference on Science Instruction in the Elementary and Junior High Schools, at the University of Wisconsin, Madison, Wisconsin on August 21, 1962.

Paper entitled "Motivation in Junior High School Science," presented by George G. Mallinson to the Twelfth Thomas Alva Edison Foundation Institute on Science Education at the Engineering Society of Detroit, Detroit, Michigan, November 13, 14, 1962.

____________, Reorganization of Science in Secondary Schools. Committee of the National Education Association, Commission of Reorganization of Secondary Education. Washington: Government Printing Office, 1920.

Noll, Victor H. (Chairman), Science Education In American Schools. Forty-sixth Yearbook of the National Society for the Study of Education, Part I. Chicago: Distributed by the University of Chicago Press, 1947. Pp. xii + 306.

Powers, Ralph S. (Chairman), A Program For Teaching Science. Thirty-first Yearbook of the National Society for the Study of Education, Part I. Chicago: Distributed by the University of Chicago Press, 1932. Pp. xii + 370.

Powers, Stuart C., "A Study of the 'Self-made' Pupil Laboratory Manual versus the Traditional Laboratory Manual." Unpublished master's thesis, Ohio State University, 1931.

Seegers, Raymond J., On Teaching "All About Science." Manuscript copy, September 1960.

Periodicals

Abbott, Cyril, "Do Biology Teachers Use Living Materials?" American Biology Teacher, XVI, No. 1 (January 1954), 15.

Alberg, B., "Any Old Experiments?" Science Teacher, XXX (October 1963), 28.

Curtis, F. D., "Basic Principles of Science Teaching." The Science Teacher, XX (March 1953), 55-59.

Fischler, Abraham S., "Junior High School Science." School Science and Mathematics, LXIV (January 1964), 21-30.

Fischler, Abraham S., "Science for Grades Seven, Eight and Nine." School Science and Mathematics, LXI (April 1961), 271-85.

Hilgers, Robert J., "Practices and Techniques in Science Teaching." Science Education, XXVI (January 1942), 16-21.

Hunter, G. W. and Parker, Alice L., "The Subject Matter of General Science." School Science and Mathematics, XLII (December 1942), 869-77.

Keislar, Evan R., "The Learning Process and the Teaching of Science." Science Teacher, XXIX (December 1962), 21-24.

Newton, David E., "The Problem-Soving Approach--Fact Or Fancy?" School Science and Mathematics, LXI (November 1961), 619-22.

Peterson, George W., and Douglass, Harl R., "Published Workbooks versus Pupil-Made Notebooks in Ninth-Grade General Science." The School Review, XLIII (October 1935), 608-13.

Pettit, Donald D., "The Content of Junior High School Science." School Science and Mathematics, XL (October 1940), 643-54.

Ruffner, Frances E., "Interests of Ninth-Grade Students in General Science." Science Education, XXIV (January 1940), 23-9.

Tyler, Ralph W., "Permanence of Learning." Journal of Higher Education, IV (April 1933), 203-04.

Tyler, Ralph W., "What High School Pupils Forget." Educational Research Bulletin, Ohio State University, IX (November 19, 1930), 490-92.

Appendix

A Unit In Relationships of Light To Image Formation

Image formation related to the fundamental laws of light provides the basis for the concept in this unit. A clear light bulb filament of V shape (Westinghouse 200 watt) is used as the object for real images in the basic experiment. Almost any object may be used for virtual images.

Light ray diagrams constructed by the students provide tangible evidence of how the image is formed. Real light rays are represented by solid line segments, virtual ones by dotted lines. The amount of geometry applied may be varied according to the background and abilities of the class. Materials for this activity consist only of a compass, ruler, pencil and plain white paper.

Application of these principles may lead to further experimentation such as the construction of a microscope or telescope from two convex lenses or a camera from a cardboard box, lens and photographic printing paper. Organization of unit lessons is shown in the following outline.

Organization of a unit on light

I. Aperture images

II. Plane surface images

- A. Reflective images--mirrors
- B. Refractive images--lenses

III. Curved surface images

- A. Reflective images--mirrors
  1. Concave
  2. Convex
- B. Refractive images--lenses
  1. Concave
  2. Convex

Aperture image

The light rays reflected from an object to form an image in a single medium will serve to introduce the facts that (1) light rays travel in a straight line, (2) light rays can be seen only when they are reflected from an object, and (3) the image is inverted. An experiment to illustrate these characteristics consists of a filament from a clear light bulb as the object, a small hole in the bottom of a box as the aperture and the ceiling as the screen. The student represents the partition by a straight line, the aperture by a break in that line at the center. The light rays from the object are constructed from the extremities of the object to form an inverted, real image. This construction provides a visual aid in understanding these three factors of light ray behavior.

APERTURE

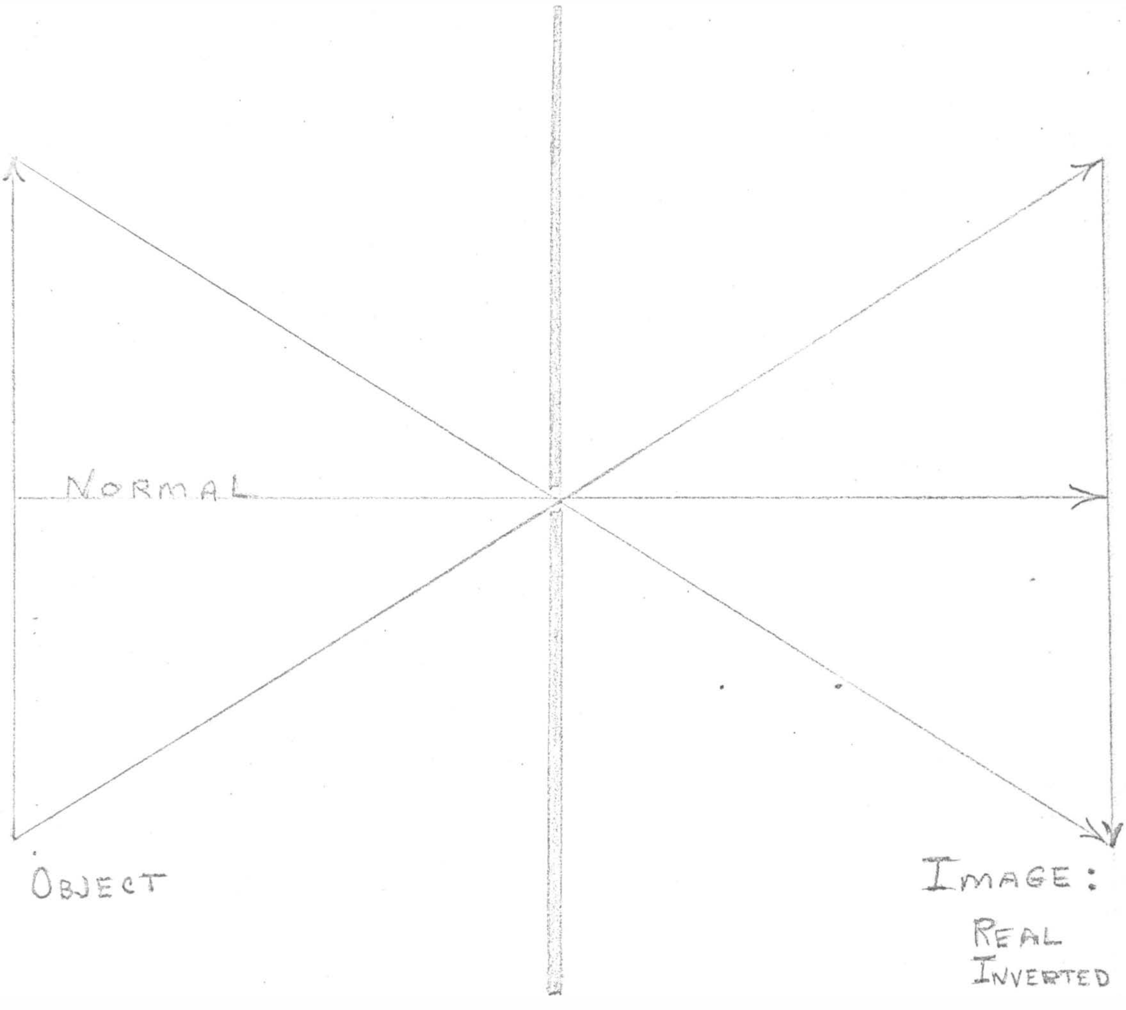


FIG. 3
APERTURE IMAGE

Plane surface reflective images

The relationship of reflected light rays to a plane reflective surface may be illustrated by the image formed in a plane mirror. A beam of light from a flashlight or slide projector is used as the light source or object. Reflected from a plane mirror at an angle, the angle of incidence can be observed to be equal to the angle of reflection.

The student represents the mirror with a straight line and the reflected light rays by line segments. By copying the angle of reflection from the angle of incidence for each light ray, he makes a tangible representation of the law of reflection. These reflected light rays, extended beyond the mirror as dotted lines (virtual light rays), form the comparable points of the image.

Students are encouraged to discover applications of this principle such as the periscope, galvonometer and ordinary dresser mirrors. Later this same principle will form the basis for the construction of all images formed by curved mirrors.

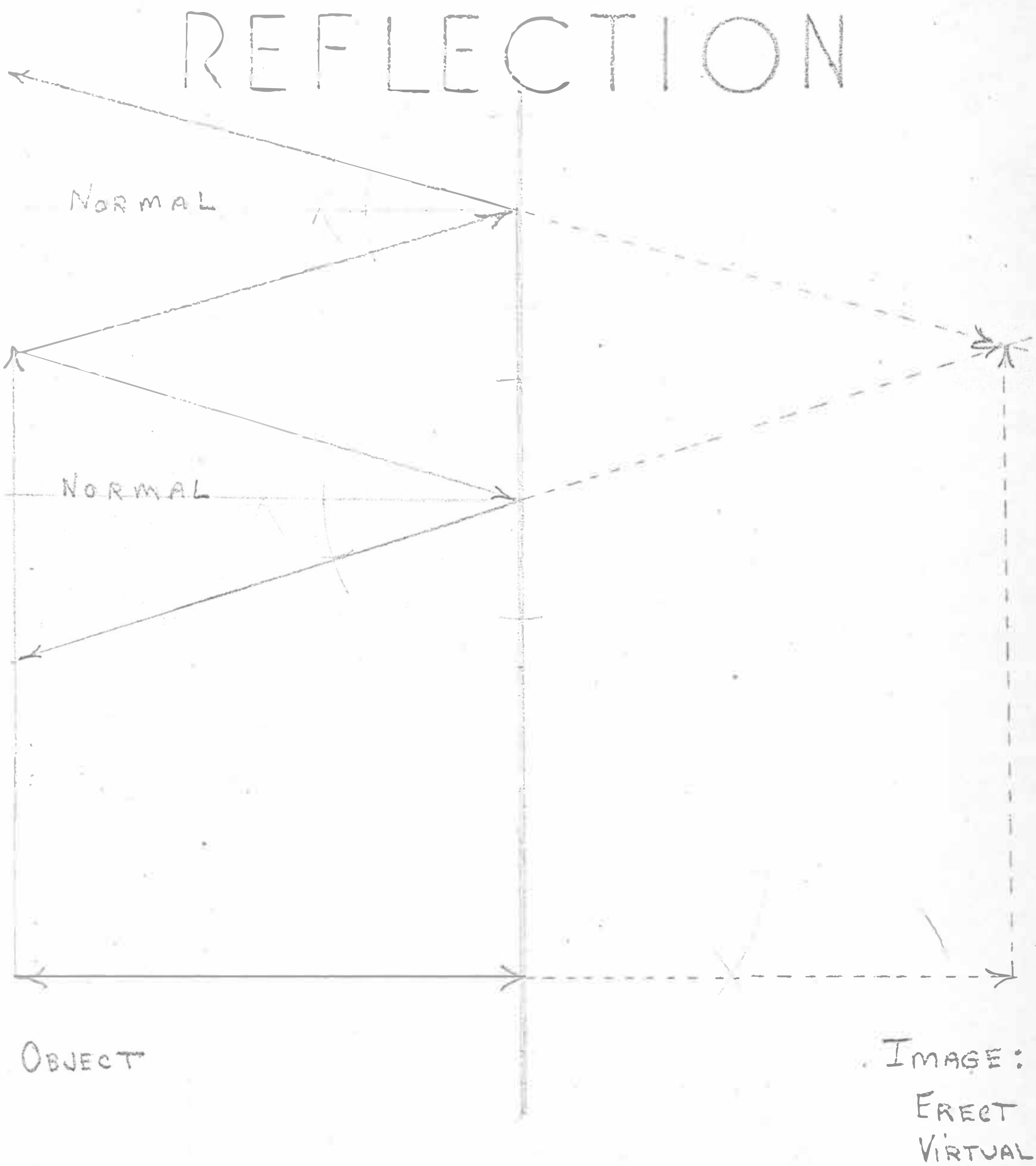


FIG. 4
MIRROR IMAGE

Plane surface refractive images

The relationship of refracted light rays to a change in optical density can be illustrated by the image formed by light rays reflected from an object under water. If an object is placed on the bottom of an aquarium filled with water, the image is seen about one-fourth of the depth from the bottom. It will be observed that light rays are bent away from the normal when leaving the water and toward the normal when entering the water.

An understanding of this basic law of refraction is required in order for the student to record what he has observed. With a rectangle to represent the aquarium and a point source for the object, he must then construct line segments representing the refracted light rays. His drawing will make clear why a swimming pool appears to be more shallow than it is, thus necessitating the labeling of depth as a safety precaution.

REFRACTION

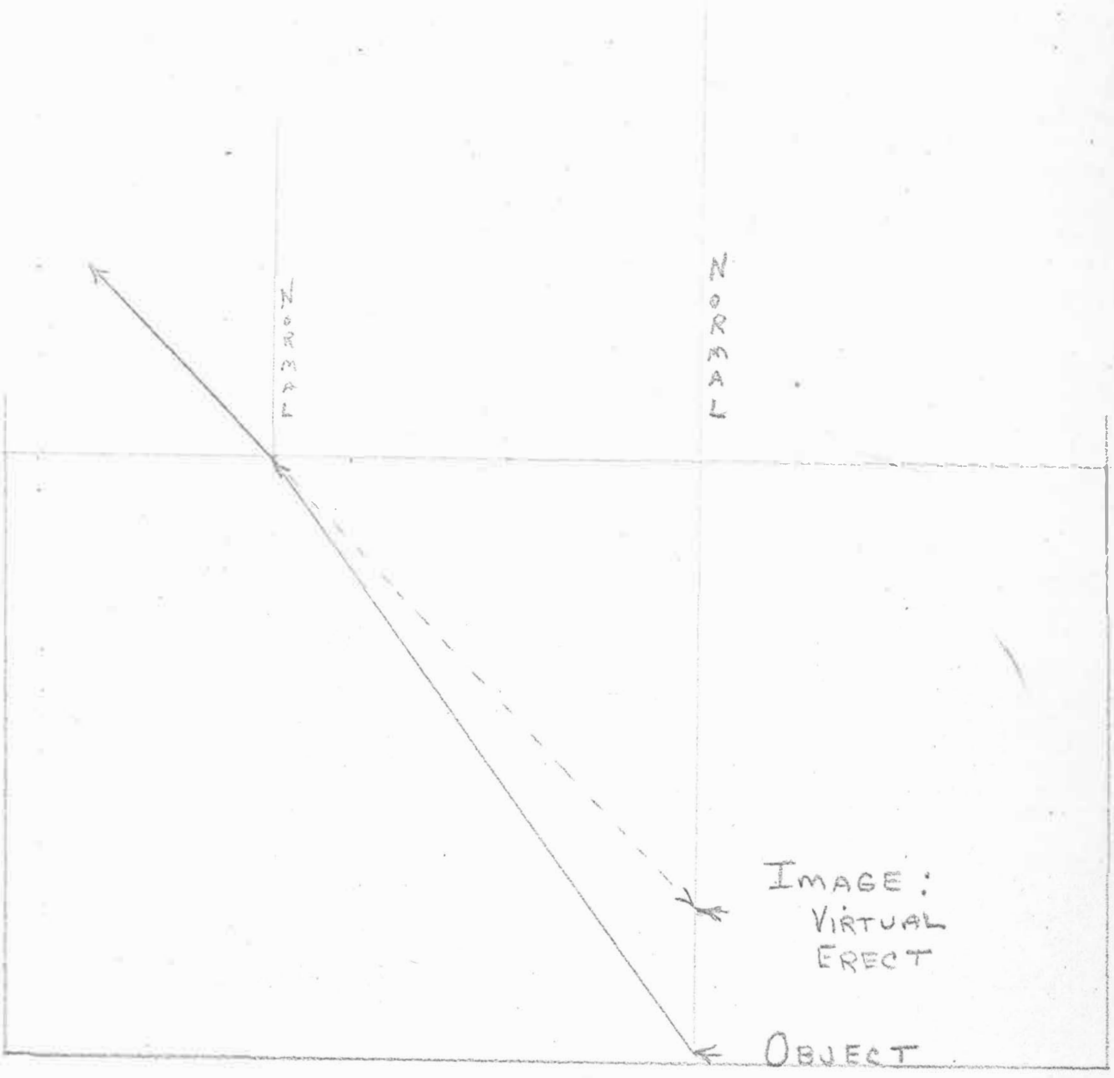


FIG. 5

WATER IMAGE

Curved surface reflective images

Light rays reflected from an object to a curved reflective surface may be used to show how images are formed by the law of reflection. This can be demonstrated by placing a clear light bulb filament between the focal point and center of curvature of a concave mirror, projecting the image on a wall of the class room. An enlarged, inverted, real image is observed by the class.

The concave mirror can be diagrammatically represented by an arc whose chord is perpendicular to a horizontal line, the principal axis. The reflection of the light ray parallel to the principal axis from a given point on the object is shown to be following the law of reflection by constructing a normal to the curved mirror at the point where the light ray strikes the curved mirror. The angle of incidence is thus constructed and the angle of reflection copied. The second light ray is represented as the normal, intersecting the first to produce the comparable point of the object on the image. An image analysis correlates the experiment with the construction.

The reflective telescope is a notable application of this principle. Projectors, microscopes and dresser mirrors are other examples of the use made of curved mirrors.

Organization of curved surface reflective images

1. Concave mirrors

   a. Object beyond center of curvature

   b. Object at the center of curvature

   c. Object between the center of curvature and the focal point

   d. Object between the focal point and the mirror

2. Convex mirror

CURVED MIRROR

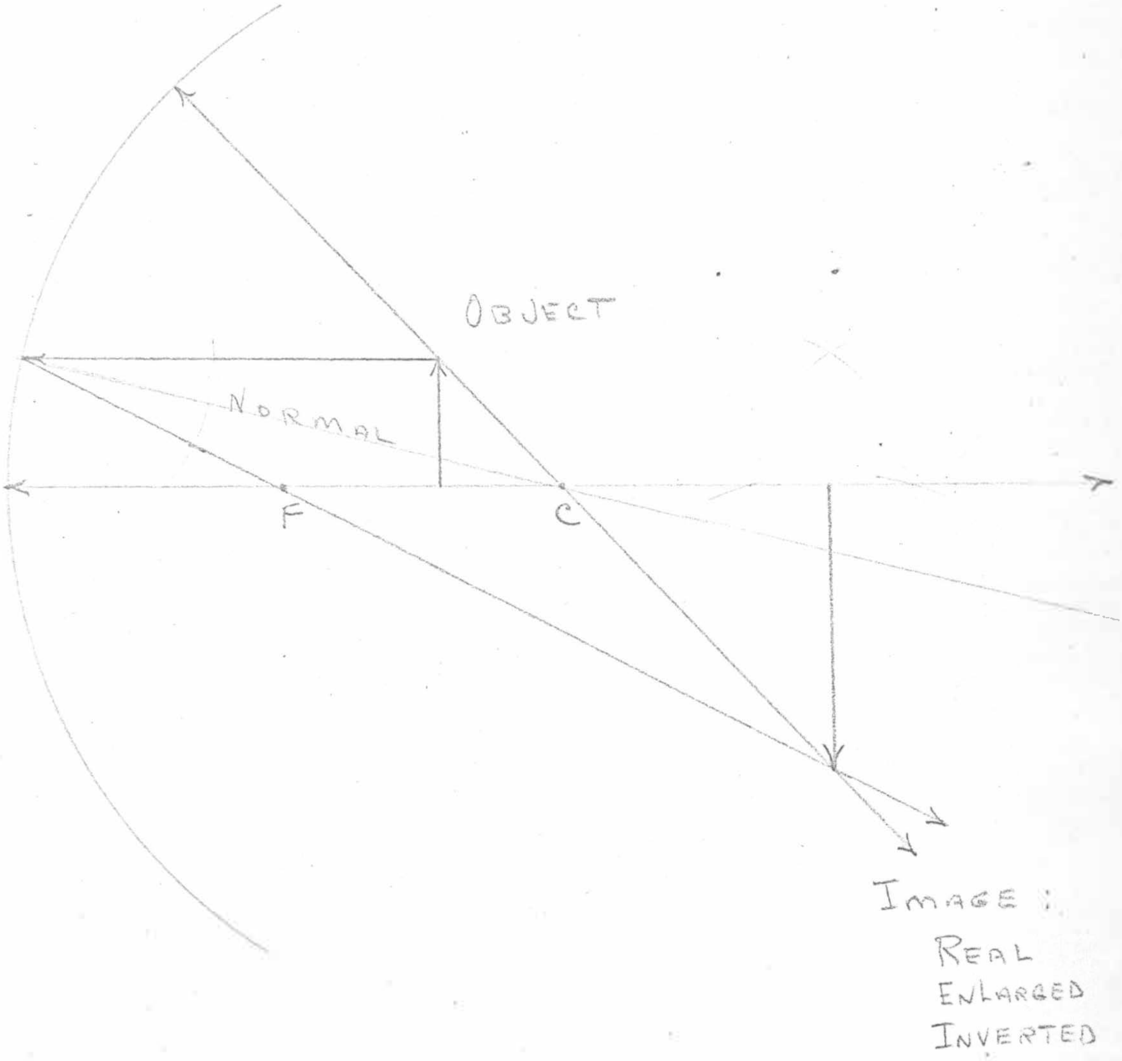


FIG. 6
CONCAVE MIRROR IMAGE

Curved surface refractive images

The image formed by light rays reflected from an object through a curved lens will illustrate the relationship between the law of refraction and images formed by lenses. Place the filament of a clear light bulb at the center of curvature of a convex lens and project the image onto a screen. A real, inverted image is observed by the class.

For the student record the convex lens is diagrammatically represented by two arcs whose common chord is a perpendicular bisector of a horizontal line, the principal axis. An understanding of the law of refraction is required in order to construct the line segments which represent light rays as they enter and leave the surface of the lens at an angle to the normal (a line segment from the center of curvature of the lens to the point where the light ray parallel to the principal axis of the lens strikes the lens surface). The law of refraction is illustrated by the light ray bending toward the normal as it enters the lens and away from the normal as it leaves the lens, thus pass-through the focal point. The second light ray is constructed to the center of the lens as a straight line segment. By the convergence of these two light rays a comparable point on the image is formed. The principal axis may be used to represent the formation of the other extremity. An image analysis correlates the experiment and the student activity.

This type image is used in reproductive processes where a real image identical to the object is desired.

<u>Organization of curved surface refractive images</u>

1. Convex lens

   a. Object beyond center of curvature

   b. Object at center of curvature

   c. Object between center of curvature and the focal point

   d. Object between the focal point and the lens

2. Concave lens

CURVED LENSE

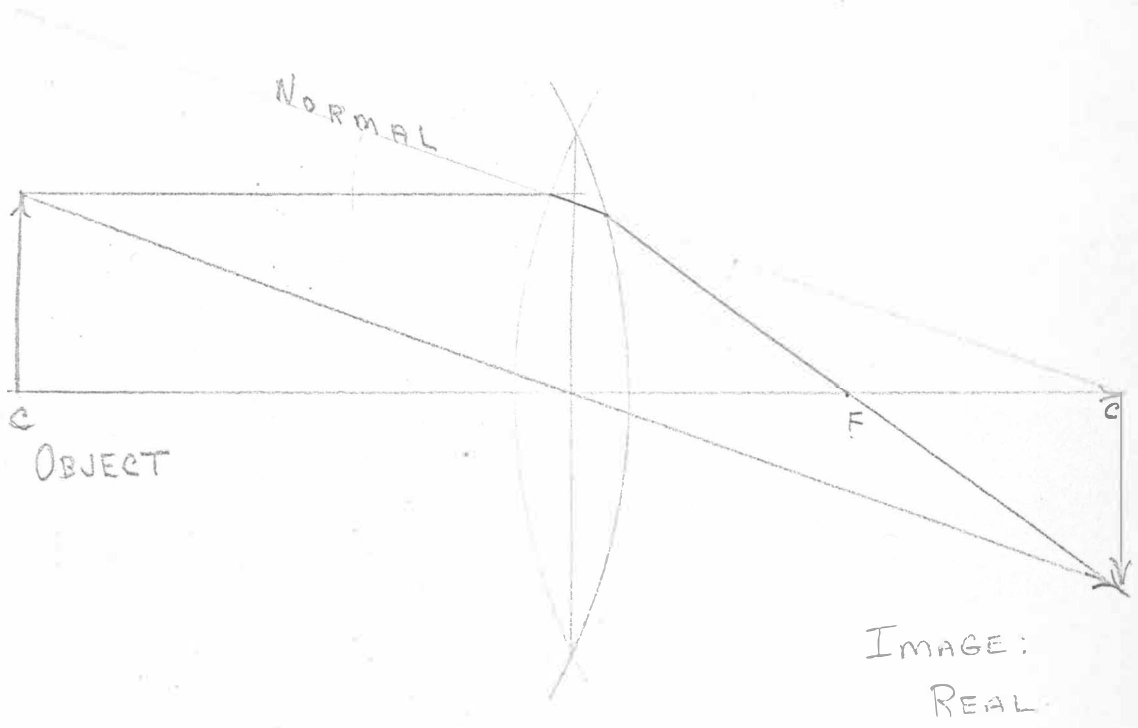


FIG. 7
CONVEX LENS IMAGE

A Unit In Motion Relationships

The relationship of motion to objects introduces the physical concepts of velocity, power and acceleration. Each of these relationships will be demonstrated or experienced experimentally. The materials necessary for these experiments are a stop watch and a variety of objects in motion. Before the experiment is begun, the procedure for solving the problem algebraically is outlined. Each student represents the problem diagrammatically and solves it individually, using that system of mathematics which he prefers (fractions, decimals, etc.). He then makes a mathematical record of the demonstrated experiment.

Applications of the principles studied in this unit enable pupils to understand many of the basic motion phenomena of the physical universe. The practical nature of the experiments and student involvement in them help to make pupils aware of areas in which these principles apply in their daily life.

Organization of a unit in physical relationships

1. Speed . . . . Linear
   Circular

2. Work. . . . . Work quantity
   Work timed

3. Acceleration. . . Linear
   Circular

Uniform speed

Distance and time relationships serve as an interesting basis for a study of uniform speed. A typical experiment might consist of producing a sharp sound at the end of a long corridor. With the length of the hall and the speed of sound given, the time interval between the source and echo sounds can be observed. Then the interval may be checked experimentally by measuring the time with a stop watch.

Each student shows tangible record of the relationship by his mathematical prediction of the results. The long distance traveled in a short time helps to clarify the relationship of speed to distance traveled. Application of this speed to jet planes and rockets and the consequent necessity of instrument flying could be pursued.

Organization of uniform speed

Linear Uniform Speed

Speed	$S = D \div T$	Ball throw
Distance	$D = S \times T$	Battery-driven toy car
Time	$T = D \div S$	Sound echo

Circular Uniform Speed

Speed	$S_c = D \div T$	Earth's surface speed
Distance	$D = S_c \times T$	Earth's revolution distance
Time	$T = D \times S_c$	Moon's revolution of earth time

SPEED

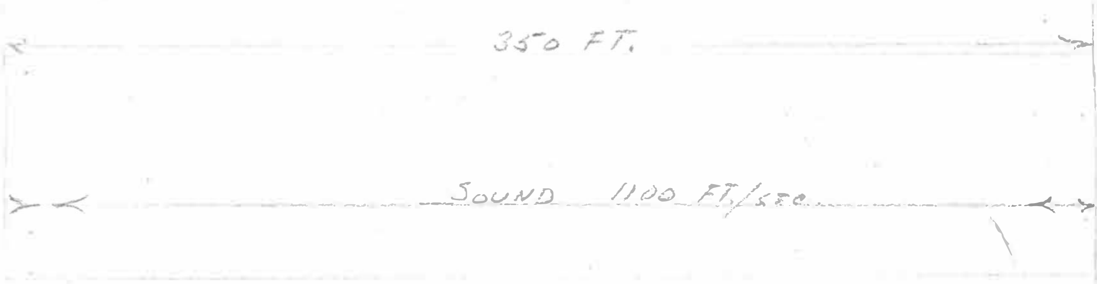


FIG. 8
SOUND ECHO TIMED

DISTANCE = 700 FT.

SPEED = 1,100 FT./SEC.

TIME = $\frac{700 \text{ FT.}}{1100 \text{ FT/SEC}}$ = .63 SEC.

∴ TIME $\propto$ SPEED

Work

Distance, weight and time relationships are studied to understand the physical meaning of work and power. A student contest of speed in climbing a staircase may serve as an experiment in time rate of doing work. The procedure is outlined with the students and the data filled in as the information is obtained. With the vertical height of the staircase and the student's weight recorded, he then measures the climbing time. Each student may use his own time or the shortest time attained by a class member.

This concept helps pupils understand the relationship between the weight of any vehicle and its power.

Organization of work

Work Quantity

Work	Wk = Wt x D	Student climbing
Weight	Wt = Wk ÷ D	1 : 4 pulley system
Distance	D = Wk ÷ Wt	Inclined plane

Work Timed

Power	P = (Wt x D) ÷ T	Student climb timed
Work	Wk = PT	Rated motor in operation
Time	T = Wk ÷ P	Rated rocket with given weight and altitude

WORK

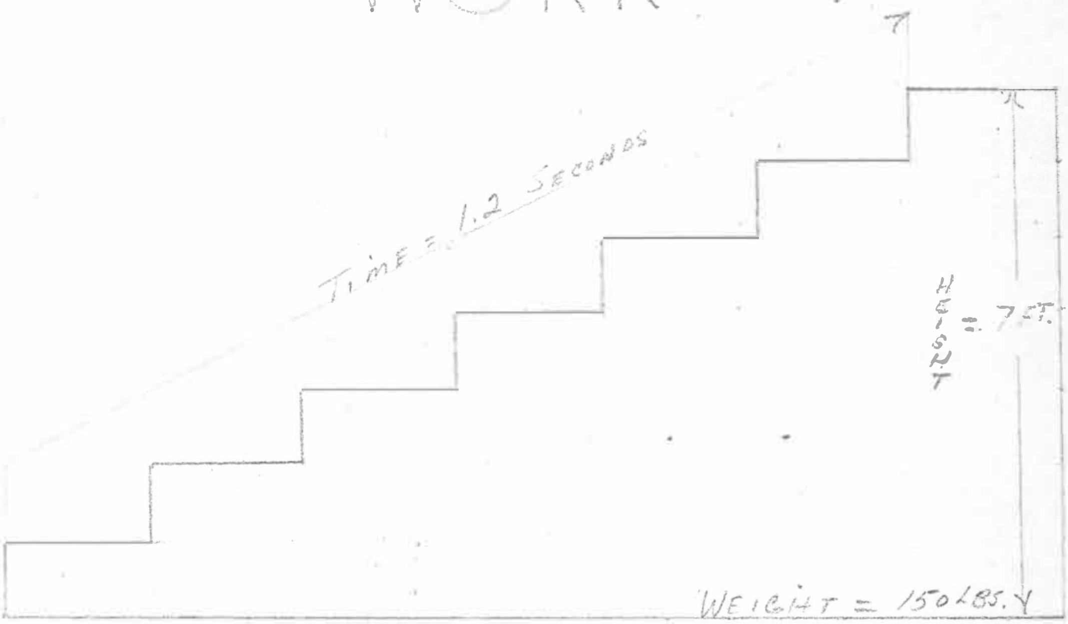


FIG. 9
STUDENT CLIMB TIMED

WEIGHT = 150 LBS.

DISTANCE = 7 FT.

TIME = 1.2 SEC.

POWER = 1050 FT. LBS ÷ 1.2 SEC. = 858.8 $\frac{\text{FT./LBS}}{\text{SEC.}}$

Uniform acceleration

The relationship between uniform change in speed and direction form the basis for understanding uniform acceleration. A variety of objects may be used for observation of acceleration relationships. If a bucket of water is swung overhead with sufficient acceleration--greater than gravity--the water will remain in the bucket. Before a student does this, the radius (the student's arm to the center of gravity of the bucket) is recorded by each person. As the bucket is swung, the time for one swing is recorded. From this the velocity is calculated and then the acceleration. A circular acceleration graph may be required of the student to make the concept more tangible. The mathematical procedure aids in organization of the experimental facts.

This principle enables students to understand our acceleration due to the earth's rotation and revolution as well as the planetary system in general.

Organization of uniform acceleration

Uniform Linear Acceleration

Acceleration	$A = 2D \div T^2$	Gravity (freely falling object)
Distance	$D = AT^2 \div 2$	Vertical ball throw
Time	$T = \sqrt{2D \div A}$	Freely falling object from a given height

Uniform Circular Acceleration

Acceleration	$A = V^2 \div R$	Small bucket of water swung vertically
Velocity	$V = \sqrt{A_c R}$	Maximum speed on circular student run
Radius	$R = V^2 \div A_c$	Minimum radius for circular student speed

ACCELERATION

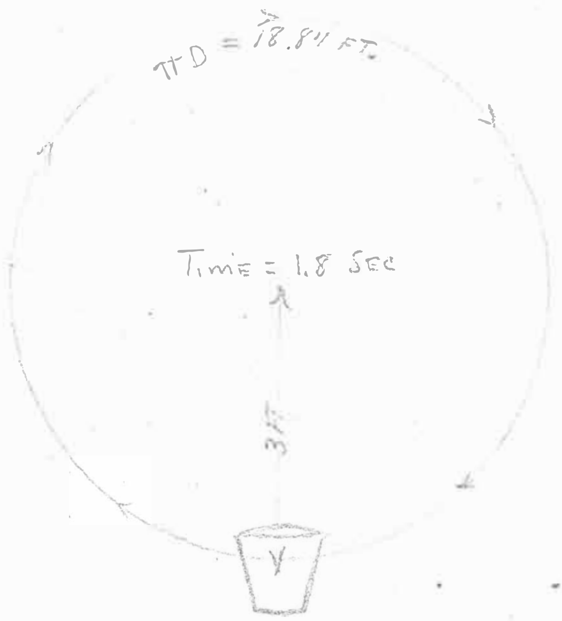


FIG. 10
STUDENT BUCKET SWING TIMED

$$\text{Velocity} = \frac{18.84 \text{ FT.}}{1.8 \text{ SEC.}}$$

$$\text{Velocity}^2 = 108.16 \frac{\text{FT}^2}{\text{SEC}^2}$$

$$\text{Radius} = 3 \text{ FT.}$$

$$\text{Acceleration} = 108.16 \frac{\text{FT}^2}{\text{SEC}^2} \div 3 \text{ FT} = 36 \text{ FT/SEC}^2$$

A Unit In Chemical Relationships of the Elements

The more common elements reveal chemical and physical relationships when grouped according to the number of electrons in the valence orbit of the atoms.

Observation of physical conditions and of chemical activity of the elements will be the basic experimentation. The student activity will be the geometric construction of an atom of an element from each chemical group. Valence is illustrated by the number of electrons in the outer orbit, atomic number by positive particles in the center, and atomic weight by the sum total of neutral and positive particles in the center circle of the diagram.

Application of the principles illustrated will enable the students to distinguish between the chemical and physical meaning of metal. The students also see that chemical activity is dependent on two things: the number of valence electrons and the affinity of the nucleus for those electrons. With these principles they can explain phenomena which they have observed, establishing a foundation to which they may relate their present knowledge of elements, and upon which further concepts may be built.

Organization of chemical relationships of the elements

1. Combining relationships
2. Ionic relationships
3. Weight relationships

Combining relationships

The ratio of combined atoms in compounds provides evidence of valence in atoms, and illustrates the law of combining proportions for molecules of compounds.

Decomposition of water by electrolysis into oxygen and hydrogen atoms in a ratio of one to two can be observed directly, since both products are gases and the number of atoms in each is directly proportional to the volume of each product. In addition to this, it can be observed that the oxygen atoms are liberated at the positive pole, thus having a negative valence and the hydrogen atoms are liberated at the negative pole, thus having a positive valence.

The valences of these two products are then related to the valence of elements in all the other chemical groups. This relationship is shown in the following outline.

<u>Organization of combining relationships</u>

Chemical Group	Combining Relationships	Experiment
I	$Na + H_2$	$Na + H_2O \rightarrow NaOH + H_2$
II	$Mg + O_2$	$2Mg + O_2 \rightarrow 2MgO$
III	$Al + O_2$	$4Al + 3O_2 \rightarrow 2Al_2O_3$
IV	$C + O_2$	$C + O_2 \rightarrow CO_2$
V	$P + O_2$	$P_4 + 5O_2 \rightarrow P_4O_{10}$
VI	$S + C_2$	$S + O_2 \rightarrow SO_2$
VII	$Cl + H_2$	$2Cl + 2H_2O \rightarrow 4HCl + O_2$
VIII	He + Ne	Inert

GROUP VIII

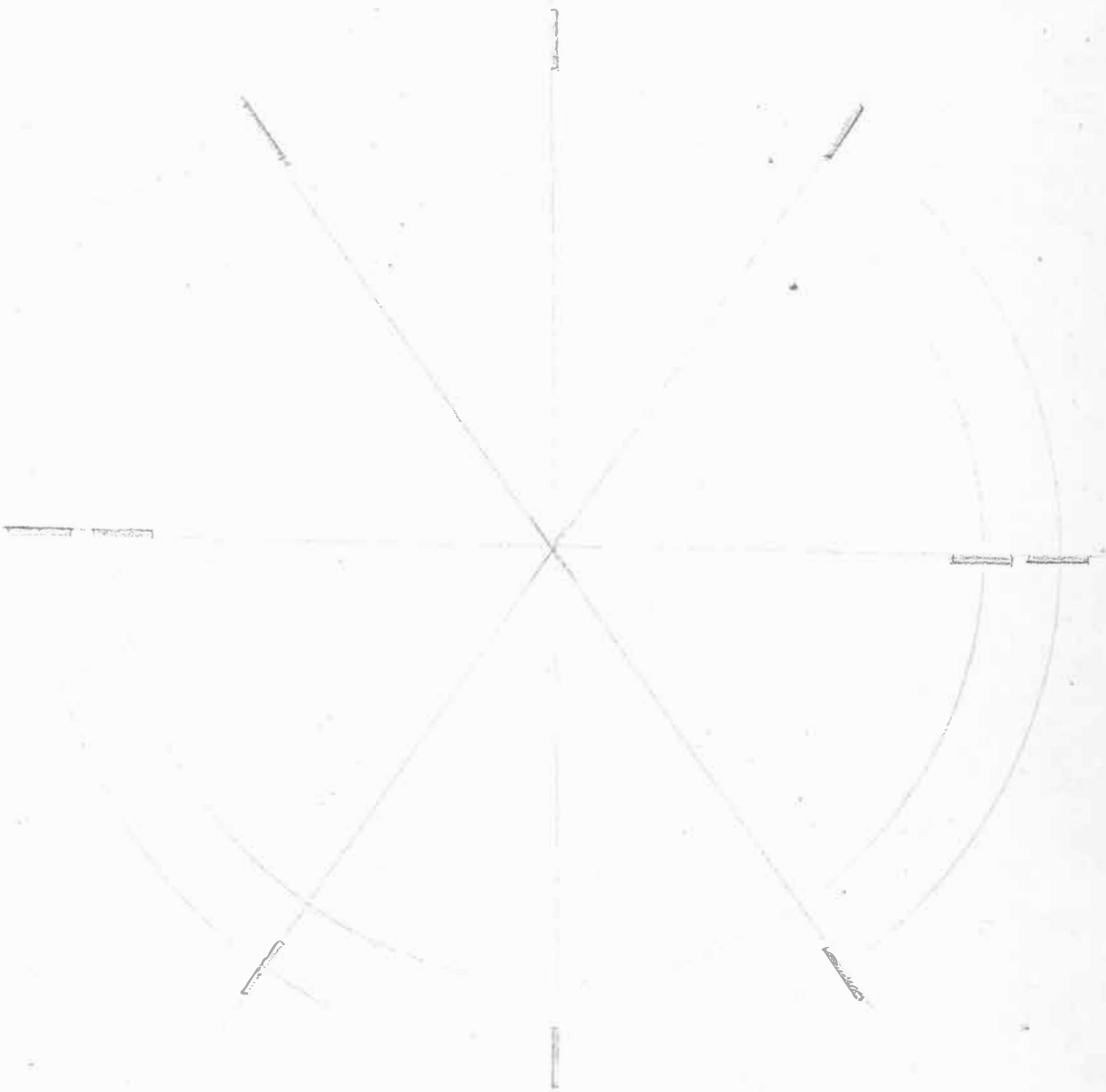


FIG. 11

NEON ATOM
(ELECTRONS)

Ionic relationships

The relationship of atoms to the gain or loss of electrons can be demonstrated by common chemical reactions. The experiment consists of common chemical reactions which are of economic importance and whose function depends upon ions from each chemical group.

The hypothesis of ionization would require the presence of positive particles, protons, in the atoms. These are geometrically constructed, equal in number to the number of electrons, in the nucleus of the representative atoms (I-VIII). The atom thus diagrammed corresponds to the ions formed in the experiment. Addition of the common inorganic radicals will complete an introduction to the common ions.

Application of this relationship will facilitate an understanding of compounds (combining proportions), solubility (ionization), and fundamental atomic structure (atomic number).

In the following outline a concise organization of ionic relationships is presented. Experiments have been chosen to illustrate the variations in electron gain and loss, introducing the concepts of atomic number and radicals.

Organization of ionic relationships

Group	Solution	Use	Experiment	Ion
I	NH_4Cl	Dry cell	$Zn \rightarrow Zn^{++} + 2e^-$	
			$2NH_4^+ + 2e \rightarrow 2NH_3 + H_2$	NH_4^+
II	$PbSO_4$	Auto battery	$Pb \rightarrow Pb^{++} + 2e^-$	
			$Pb^{++} + SO_4^= \rightarrow PbSO_4$	Pb^{++}
III	$Al(OH)_3$	Water purification	$2Al^{+++} + 3SO_4^= + 3Ca(OH)_2 \rightarrow$	
			$2Al(OH)_3 + 3CaSO_4$	Al^{+++}
IV			Non-ionic	
V	H_3PO_4	Fertilizer	$Ca_3(PO_4)_2 + 3H_2SO_4 \rightarrow$	
			$6H^+ + 2(PO_4)^{\equiv} + 3CaSO_4$	$PO_4^{\equiv}$
VI	$Ca(OH)_2$	Plaster	$Ca(OH)_2 + CO_2 \rightarrow$	
			$Ca^{++} + CO_3^= + H_2O$	$CO_3^=$
VII	HCl	Water oxygenator	$2Cl_2 + 2H_2O \rightarrow$	
			$4H^+ + 4Cl^- + O_2$	Cl^-
VIII	Neon gas	Neon light	Inert conductor	

GROUP VIII

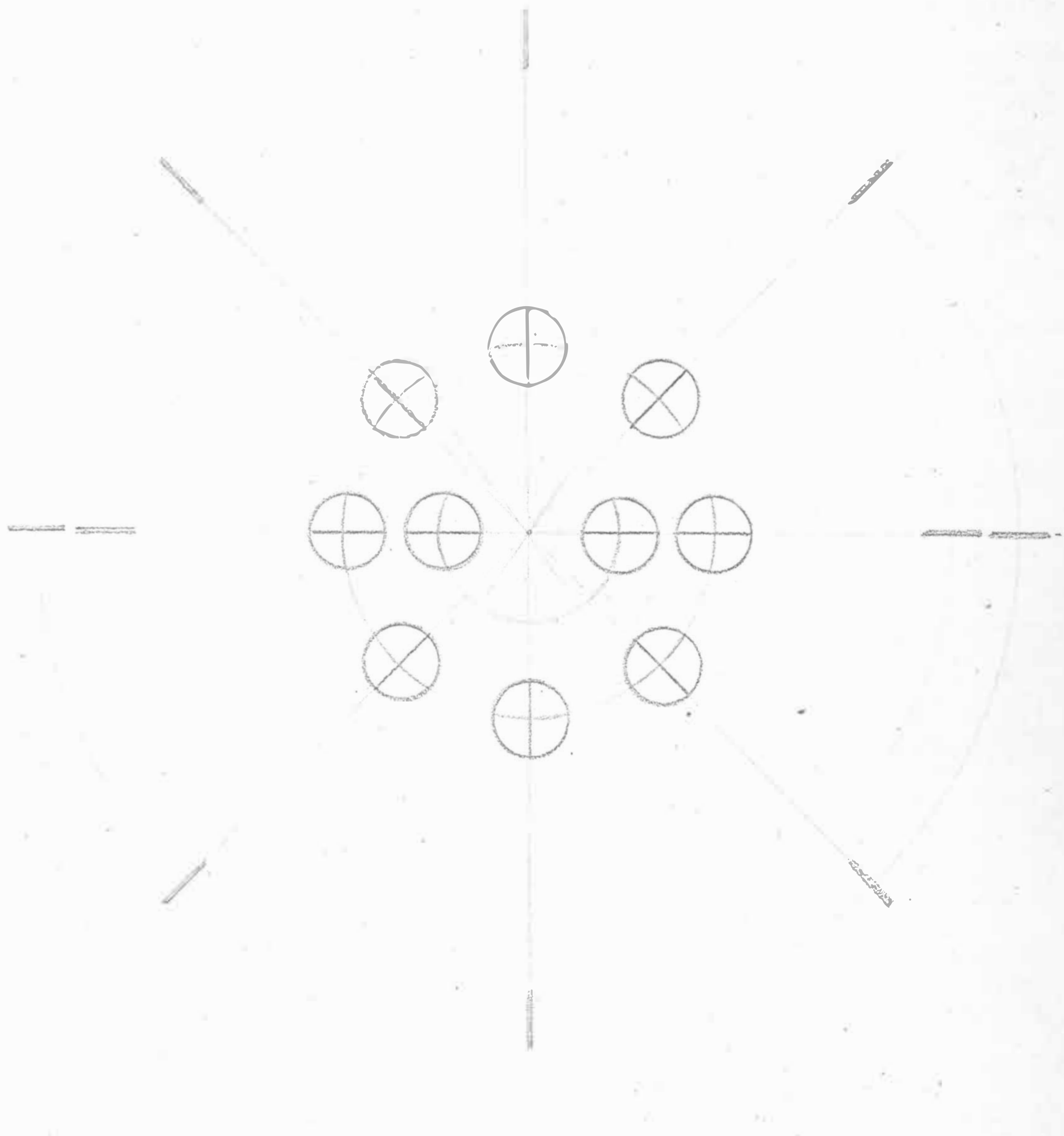


FIG. 12

NEON ATOM

(ELECTRONS AND PROTONS)

Weight relationships

A comparison in weight of atoms from the common elements will serve to introduce the relationship of relative weight to quantitative measurement. Comparing the weight of a golf ball (heavy atom) with ping pong balls (light atoms) serves to make this relationship tangible. The number of ping pong balls will correspond to the atomic weight of the golf ball. With this introduction the students understand Avagadro's Number as applied to gram atomic weights. Common elements may be used in measuring or weighing prescribed numbers of atoms.

The additional mass required by relative weights can now be added to the geometric diagram of each type atom. These particles (neutrons) are placed in the nucleus, equal in number to the difference between the atomic number and the atomic weight.

These principles introduce concepts that open an understanding of elementary quantitative analysis with interesting applications in pharmacy, medical prescriptions, and micro-techniques. Relationship between elements and gram atomic weights is shown in the following outline of this series of lessons.

Organization of weight relationships

Group	Element	Physical state	Gram atomic weight
I	Hydrogen	Gas	11.2 liters at S.T.P.
II	Mercury	Liquid	14.9 ccs.
III	Aluminum	Solid	26.98 grams
IV	Lead	Solid	207.21 grams
V	Nitrogen	Gas	11.2 liters at S.T.P.
VI	Sulfur	Amorphous	32 grams
VII	Iodine	Amorphous	126.9 grams
VIII	Neon	Gas	11.2 liters at S.T.P.

GROUP VIII

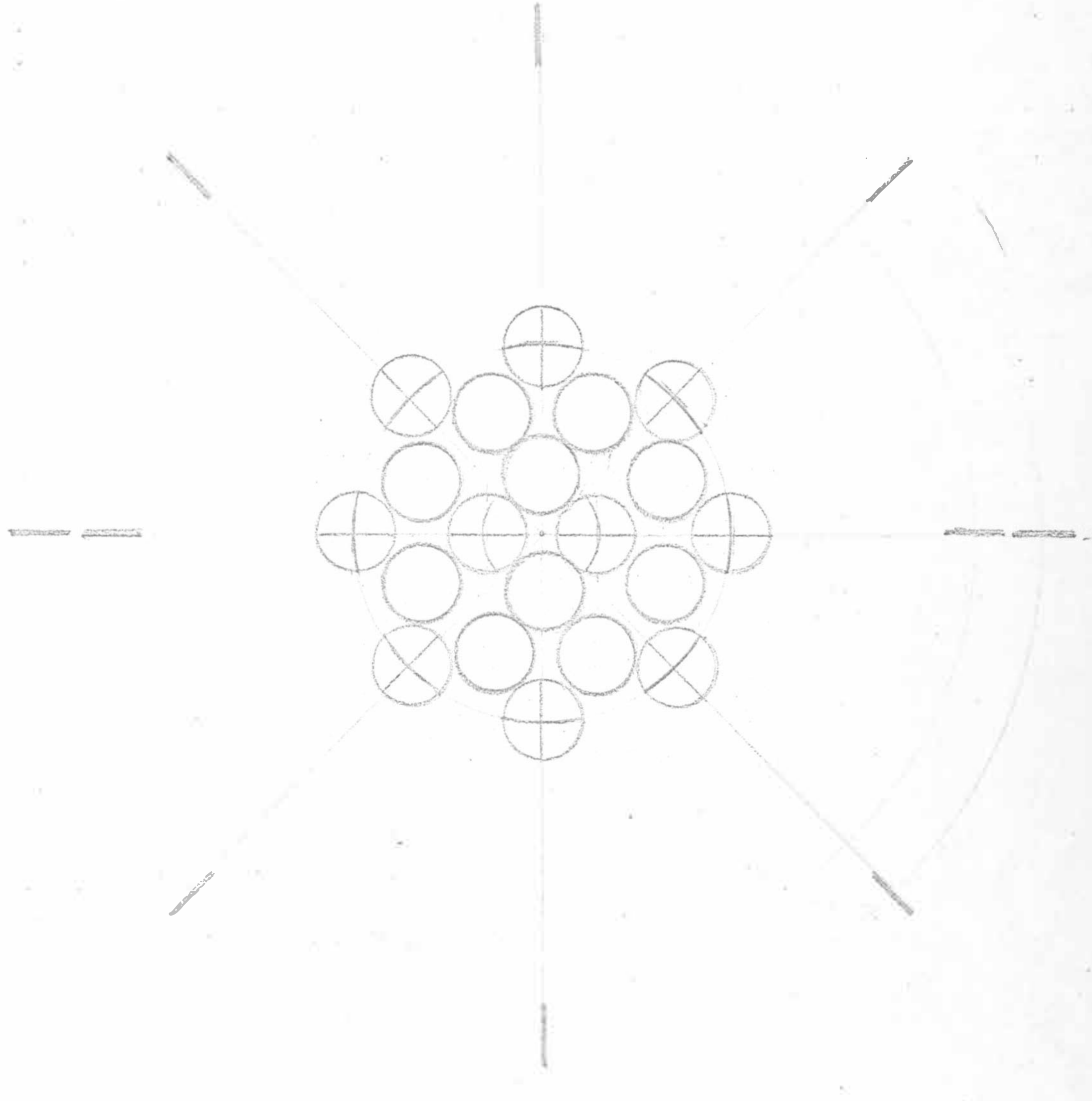


FIG. 13

NEON ATOM

ELECTRONS, PROTONS AND NEUTRONS

A Unit In Earth-Sun Relationships

The inclination of the earth's axis to the perpendicular rays of the sun is the basic concept involved in understanding earth-sun relationships.

The fact that the change in the earth's axis is only relative to the perpendicular rays of the sun can be demonstrated by mounting a globe on the free end of the horizontal demonstration bar at an angle of 24°, allowing it to revolve around the single vertical bar. The sun may be represented by a slide projector with a square field. Revolving the earth will demonstrate the earth's significant seasonal positions (solstice and equinox) as well as significant lines of latitude. Rotating the earth will demonstrate significant changes in length of our path in daylight and darkness as well as significant lines of longitude.

Students represent the earth's significant positions in relation to the sun by multi-stage diagrams of the earth as a circle, the sun's rays indicated by shading one vertical half of each.

With this background, the pupil can see the relationship between the change in seasons and change in length of day and night. In addition this principle is prerequisite to experimental determination of latitude and longitude.

Organization of a unit in earth-sun relationships

Seasons	Inclination of Earth's Axis
Winter	Winter solstice to spring equinox. 66°-90°
Spring	Spring equinox to summer solstice. 90°-114°
Summer	Summer solstice to fall equinox. .114°-90°
Fall	Fall equinox to winter solstice. . 90°-66°

Length of day and night

- Significant lengths
- Local lengths

Latitude

- Significant latitudes
- Local latitude

Longitude

- Significant longitude
- Local longitude

Experimental determination of length of a day

Variation in length of daylight and darkness can be shown to be a result of the earth's inclination to the perpendicular rays of the sun.

If one's local latitude is represented by a band of opaque tape on the mounted globe, the relative length of day and night can be observed as the earth is rotated while at the correct seasonal position.

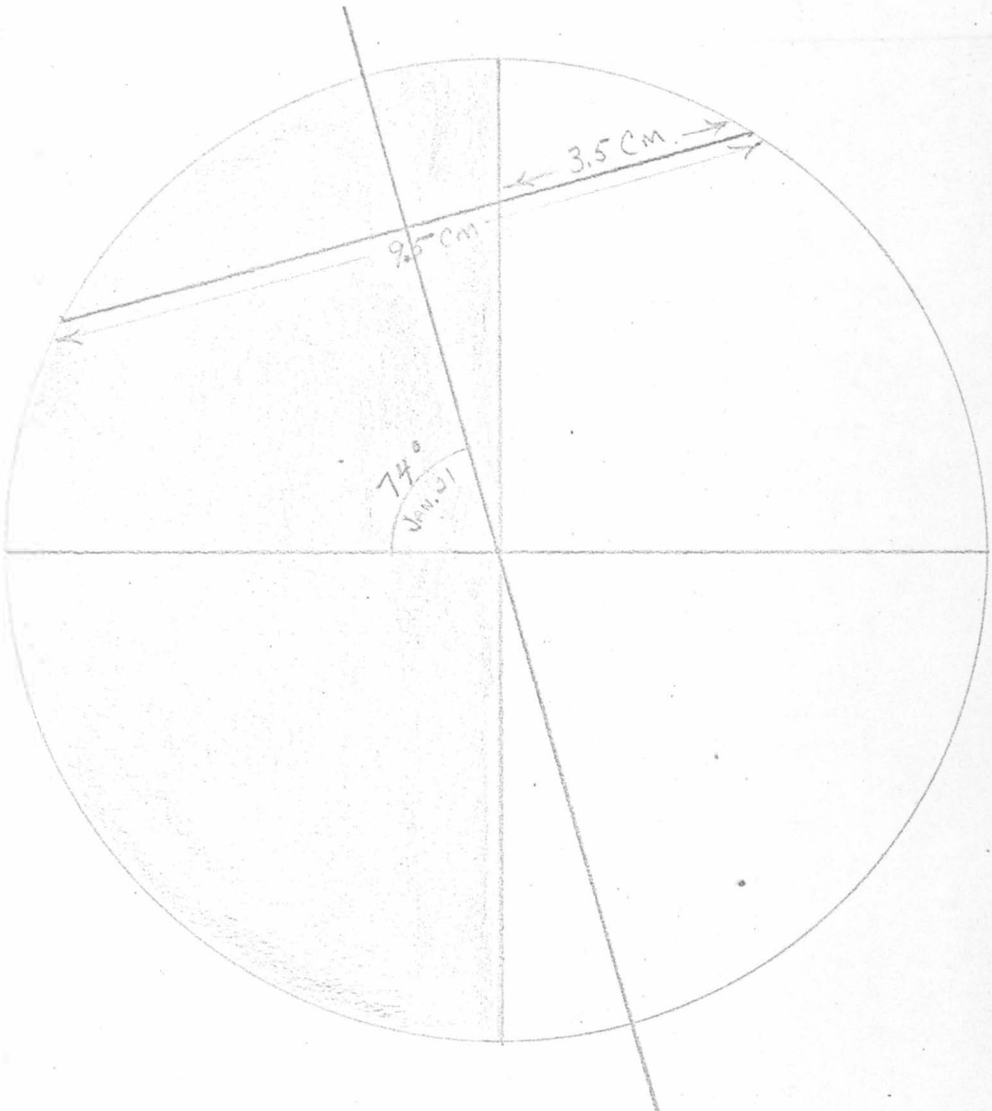
Given a piece of plain paper and protractor, the students can reconstruct the demonstration geometrically, representing the earth as a circle, the axis inclined according to the date and the path a chord to the circle perpendicular to the axis at the proper latitude. The circle is shaded through its vertical center line to represent daylight and darkness. The fractional part of the total path in daylight multiplied times twenty-four hours will be an estimate of the length of that day. The students may then check their estimate by comparing their computed length of that day with the actual length. Actual length may be found either by use of an almanac or by measurement.

A study of the significant lengths of day and night precedes this determination of the local length of a particular day. The series of lessons may be organized in the following manner.

Organization of lessons in length of day and night

1. Significant lengths of day and night
   a. Winter solstice
   b. Spring equinox
   c. Summer solstice
   d. Fall equinox
2. Local length of day and night

LENGTH OF TODAY



$$\frac{3.5\text{ Cm}}{9.5\text{ Cm}} \times \frac{24\text{ Hrs}}{\text{Day}} = 8.84\text{ Hrs.} = 8\text{ Hrs. } 51\text{ min.}$$

FIG. 14
LENGTH OF A DAY (JAN. 21)

Experimental determination of latitude

Correlation of the significant lines of latitude with the altitude of the sun during an equinox enables one to observe his own latitude. The basic experiment consists of "shooting the sun" with a protractor and straight edge to calculate the altitude of the sun.

The students represent the earth by a semicircle. The classroom floor is represented by a tangent drawn to the perimeter at an arbitrary point of the northern, daylight quadrangle formed by the axis and equator. From this diagram the pupil can see the complimentary relationship between the altitude and zenith angle and therefore of latitude.

This principle enables the student to locate his position north or south on the earth's surface, just as would be done in solar navigation.

Determination of local latitude is preceded by a study of significant lines of latitude, as shown in the outline of this series of lessons.

Organization of lessons in latitude

1. Significant lines of latitude

TIME (N. Hem.)		LATITUDE	POSITION OF SUN
Equinox	90°N	North pole	Horizontal
Winter solstice	66°N	Arctic circle	Horizontal
Summer solstice	24°N	Tropic of Cancer	Perpendicular
Equinox	0°	Equator	Perpendicular
Winter solstice	24°S	Tropic of Capricorn	Perpendicular
Summer solstice	66°S	Antarctic circle	Horizontal
Equinox	90°S	South pole	Horizontal

2. Local latitude

LATITUDE

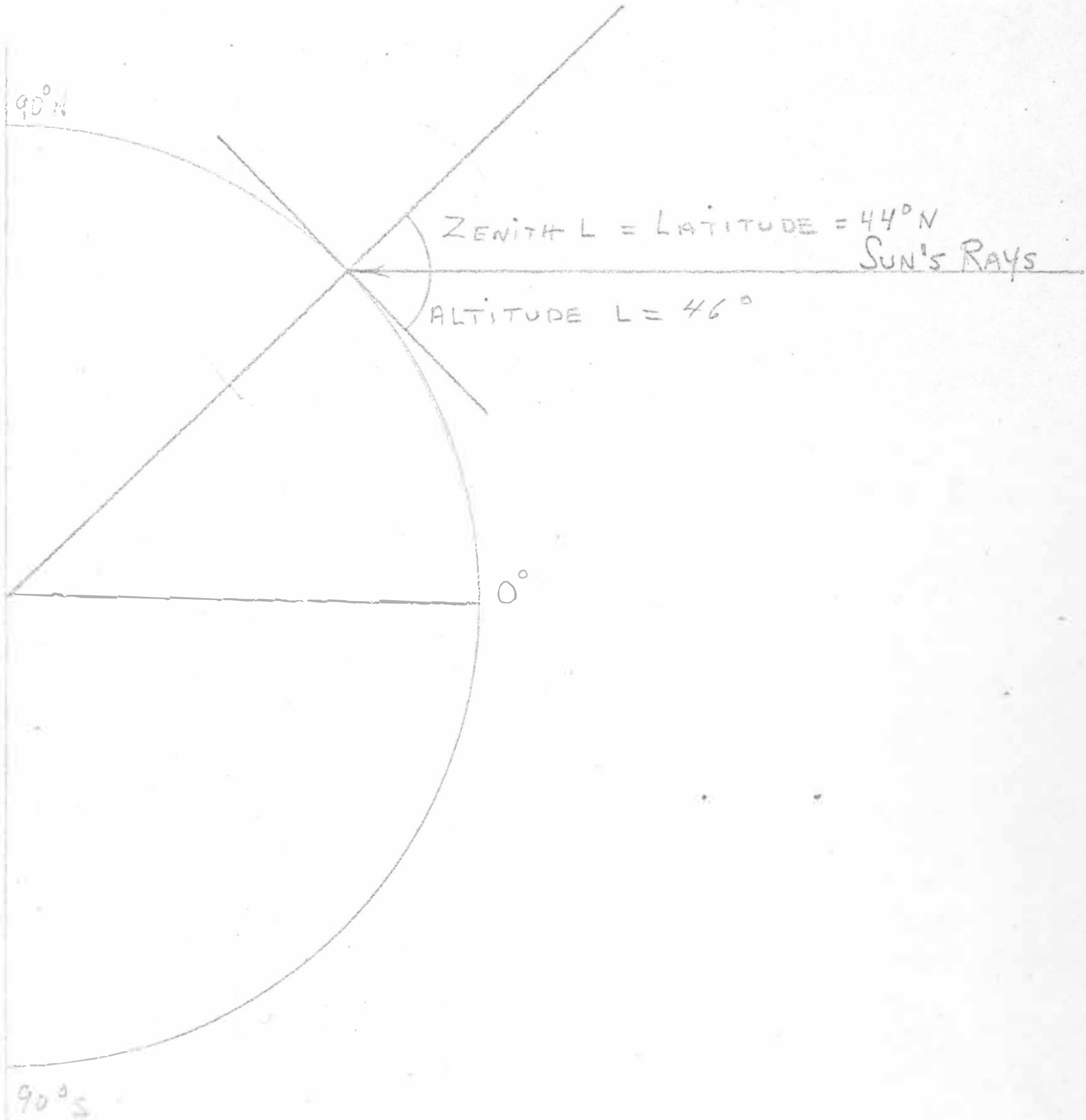


FIG. 15
LOCAL LATITUDE

Experimental determination of longitude

Correlation of significant lines of longitude with the position of the sun during an equinox enables one to determine his own longitude. To observe this experimentally we determine noon by the sun's apex. The difference between this time and noon, London time, is then computed. The number of hours difference multiplied by fifteen degrees per hour will indicate the number of degrees one is from the prime meridian.

Students record this observation by representing the earth with a circle, the north pole as its center. They then divide the circle into twenty-four equal arcs, each arc being fifteen degrees, the amount the earth rotates per hour. Thus a tangible view of the relationship between longitude and time is provided.

This principle makes simple the location of significant lines of longitude by the position of the sun related to the prime meridian. A study of the significant lines of longitude precedes this determination of local longitude.

Organization of lessons in longitude

1. Significant lines of longitude

TIME	LONGITUDE	POSITION OF SUN
12 noon	0° Prime meridian	Zenith
6 A.M.	90°E. East 90° meridian	Eastern horizon
6 P.M.	90°W. West 90° meridian	Western horizon
12 midnight	180° International date line	Opposed zenith

2. Local longitude

LONGITUDE

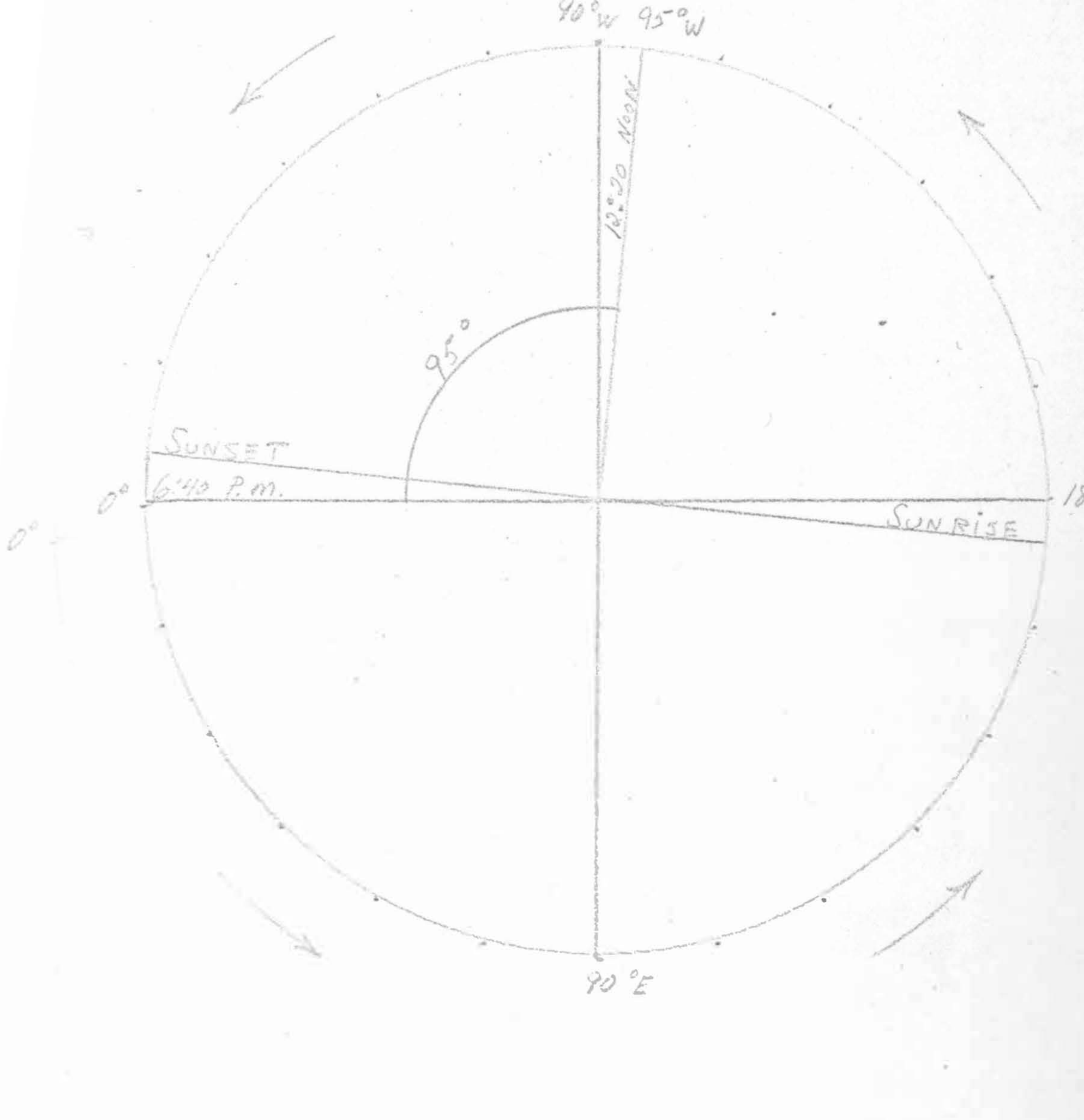


FIG. 16
LOCAL LONGITUDE

PART 9 — SCIENCE

This is a test of your understandings in science and your ability to work with problems in science. The test questions look like this:

> S_1. We use a thermometer to measure
>
> a) rain.
> b) snow.
> c) air pressure.
> d) time.
> e) temperature.

Mark your answer to question S_1 on your answer sheet.

A thermometer is used to measure temperature, and you should have marked the fifth answer space for problem S_1. Be sure you filled in the fifth answer space with a heavy black mark.

In this test you will find 60 problems like this one.

Please do not make any marks on this test booklet. Do your figuring on scratch paper; and then mark your answer for each problem on your answer sheet.

Your score will be the number of answers you get right. Be sure to mark one answer — the answer you think is right — for each problem.

— Important Facts and Principles —

1. Which of the following causes the greatest absence from school?
   a) colds
   b) scarlet fever
   c) mumps
   d) measles
   e) chicken pox

2. You will probably live longer than your grandparents because
   a) homes are better heated than in the past.
   b) people retire sooner than they used to.
   c) modern homes are air conditioned.
   d) people are stronger than they used to be.
   e) more is known about the causes of disease.

3. If water contains harmful bacteria, it can be made safe to drink by
   a) straining it through a clean cloth.
   b) boiling it for at least 10 minutes.
   c) mixing it with air.
   d) allowing it to stand in sunlight.
   e) adding a teaspoon of baking soda.

4. The most common cause of home injuries is
   a) fires.
   b) poisons.
   c) falls.
   d) electric wiring.
   e) careless use of guns.

5. Rock wool and fiber glass are good insulators because they
   a) absorb heat.
   b) contain dead air spaces.
   c) reflect heat.
   d) allow air to circulate.
   e) are good conductors.

6. Clothes dry fastest outside when the air is
   a) cold and moist.
   b) cold and dry.
   c) warm and moist.
   d) warm and dry.
   e) none of these.

7. Thunder is heard after a flash of lightning because
   a) the air is full of moisture.
   b) light travels faster than sound.
   c) sound travels only through air.
   d) sound travels in straight lines.
   e) sound travels faster than light.

8. The main difference between clouds and fog is that
   a) one is denser.
   b) one is heavier.
   c) one is closer to the ground.
   d) one contains more dust.
   e) one contains more water vapor.

9. Day and night are caused by the
   a) phases of the moon.
   b) revolution of the earth.
   c) revolution of the sun.
   d) tilt of the earth's axis.
   e) rotation of the earth.

10. The seasons change because the
    a) earth's axis is tilted.
    b) sun turns on its axis.
    c) moon travels around the earth.
    d) earth turns on its axis.
    e) earth's orbit is oval.

11. Moonlight is caused by
    a) gases on the moon.
    b) radioactivity on the moon.
    c) light reflected from the earth.
    d) light reflected from the sun.
    e) the moon's hot surface.

12. The star nearest to the earth is
    a) Vega.
    b) Alpha Centauri.
    c) the North Star.
    d) Orion.
    e) the sun.

Go right on to the next page.

CIENCE

. Volcanoes are found mainly in

a) desert regions.
b) mountainous regions.
c) offshore regions.
d) arctic regions.
e) deltas.

. Which chemical is added to drinking water to help reduce tooth decay?

a) bromine
b) chlorine
c) salt
d) iodine
e) fluorine

5. A carbon dioxide fire extinguisher puts out a fire by

a) forming water over the fire.
b) smothering it.
c) cooling it.
d) combining with the fuel.
e) combining with the oxygen.

6. Which of these is <u>not</u> a form of oxidation?

a) melting of ice
b) rotting of wood
c) burning of coal
d) rusting of iron
e) burning of fuel in a rocket

7. Soap suds are produced best with

a) ocean water.
b) lake water.
c) rainwater.
d) well water.
e) tap water.

8. Which of these is important in controlling insects?

a) early plowing
b) field mice
c) bees
d) birds
e) fertilizers

19. Bees are important to farmers chiefly because they

a) serve as food for birds.
b) make honey.
c) scare away harmful animals.
d) help spread pollen.
e) remove nectar from flowers.

20. Dogs, cats, humans, and cows are mammals because they have

a) four limbs.
b) teeth.
c) digestive systems.
d) milk glands.
e) backbones.

21. Recently typhoid fever broke out in one part of a city. Which of the following was probably most closely related to the outbreak of this disease?

a) garbage was not collected on schedule
b) the section with typhoid had new water mains
c) insects were found in the water supply
d) the drinking water did not contain fluorine
e) a broken sewer pipe was found in a food store

22. An ice cube tray was filled with water. It was placed in the freezer and allowed to freeze. When the tray was removed, it was noticed that the ice cubes had "bulged up." The reason is that

a) water is a liquid, but ice is a solid.
b) the freezer was too cold.
c) most things expand when they are cooled.
d) water expands when it freezes.
e) cold water freezes faster than warm water.

23. Many families use small ice chests on camping trips. If the ice in the chest is wrapped in heavy brown paper,

a) the ice will melt faster.
b) the ice will not cool the food so well.
c) the food will cool faster.
d) the ice will not melt.
e) the food will not spoil.

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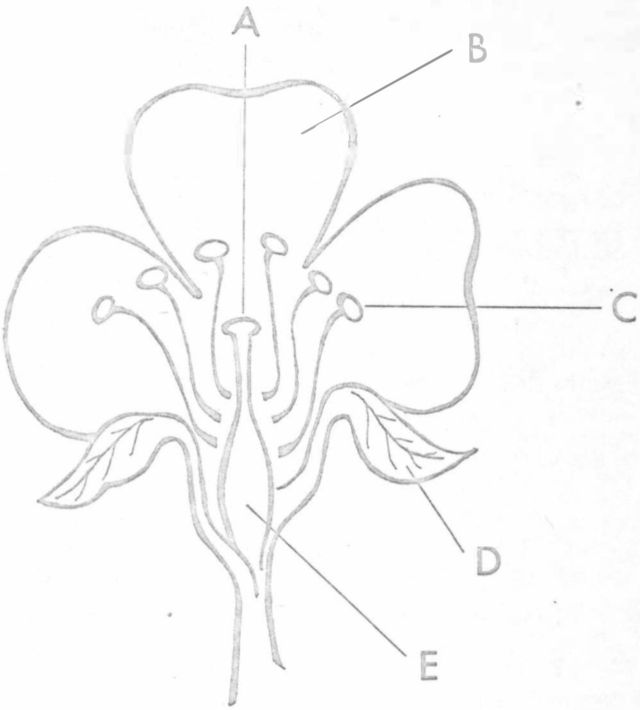
— A Study of the Parts of a Flower —

The diagram below shows the main parts of a flower. Use the letters in the diagram to answer the following questions.



24. The sepals of a flower protect the bud before the flower opens. Where are the sepals?

    a) A b) B c) C d) D e) E

25. If this is an apple blossom, which part will develop into the apple?

    a) A b) B c) C d) D e) E

26. Where are the seeds formed?

    a) A b) B c) C d) D e) E

27. Where are the pollen grains formed?

    a) A b) B c) C d) D e) E

28. By holding a plant upright, the stem helps the plant to get

    a) chlorophyll.
    b) air and sunshine.
    c) water.
    d) nitrogen.
    e) minerals.

29. The main activity of a leaf on a green plant is to

    a) absorb rainwater.
    b) make food.
    c) protect the plant.
    d) protect the flower.
    e) shade the stem.

30. Green plants make their own food using sunlight and

    a) chlorophyll.
    b) nitrogen.
    c) oxygen.
    d) carbon monoxide.
    e) proteins.

31. Which statement best describes the main job of a flower?

    a) To produce seeds
    b) To make food
    c) To store food
    d) To attract bees
    e) To carry on photosynthesis

Go right on to the next page.

— A Study of Simple Machines —

Simple machines are used to do work. Here is a list of five simple machines:

A — Lever
B — Wedge
C — Wheel-and-Axle
D — Pulley
E — Inclined Plane

Decide which simple machine would be most useful to do each of the jobs listed below.

. A man wants to raise a box to the top of a tall building.

a) A b) B c) C d) D e) E

. A man is pushing a baggage cart up an airport ramp.

a) A b) B c) C d) D e) E

. A boy scout is chopping wood for a campfire.

a) A b) B c) C d) D e) E

. A man is jacking up his automobile.

a) A b) B c) C d) D e) E

. A girl is twisting a doorknob.

a) A b) B c) C d) D e) E

. A woman is digging up dirt with a spade.

a) A b) B c) C d) D e) E

3. A boy is pushing the pedals of his bicycle to make it go faster.

a) A b) B c) C d) D e) E

— Birds That Stand While They Sleep —

Some birds sleep while perched on a tree-limb or a wire. Other birds, like storks or herons, sleep while standing on one leg.

Birds that stand on a limb or wire have a tendon in their feet and legs that draws tight when the birds' toes are curled around an object. As the toes curl around a tree-limb or wire, the tendon is locked in place with a "special locking device."

With birds that stand on one leg, the leg "locks" in position, much like the blade of a jacknife snaps into the open position.

Answer the following questions, using these marks:

T — if the statement is all true.
t — if the statement is likely true.
? — if you cannot tell from this study whether the statement is true or false.
f — if the statement is likely false.
F — if the statement is completely false.

39. All birds sleep while standing on one leg. (T — t — ? — f — F)

40. Some animals sleep while standing on all four legs. (T — t — ? — f — F)

41. Most birds sleep about eight hours a night. (T — t — ? — f — F)

42. All birds that sleep while standing on one leg are water birds. (T — t — ? — f — F)

43. Canaries have locking tendons in their feet and legs. (T — t — ? — f — F)

44. Woodpeckers sleep with their feet hooked into the bark of a tree. (T — t — ? — f — F)

45. Perching birds can sleep on wires because they have special locking devices in their feet and legs. (T — t — ? — f — F)

46. Many birds prefer to live in birdhouses, rather than sleeping outside. (T — t — ? — f — F)

Go right on to the next page.

— An Experiment with Green Ink —

Tom wrote these notes in his science notebook:

"We filled a small medicine dropper with green ink. Then Mary put the dropper in a glass of water without squeezing out any ink. The teacher left the glass on her desk without letting anyone touch it. When we came to school the next day, all the water in the glass was green."

47. Which statement best explains what happened?
   a) A liquid takes the shape of its container.
   b) Heating a liquid makes the molecules move faster.
   c) The molecules of a gas move faster than those of a liquid.
   d) The molecules in a liquid are always moving.
   e) Air pressure was pushing on the water in the glass.

48. Which statement best explains why Mary was able to fill the dropper with green ink and keep it from running out while she placed it in the water?
   a) Air pressure pushes in all directions.
   b) Air molecules are always moving.
   c) Air molecules move faster than ink molecules.
   d) Green ink is denser than water.
   e) The rubber bulb on the dropper sucks in the ink.

49. Four of the following observations are similar to the observation with the green ink. Which is not similar?
   a) If a large balloon is placed in a refrigerator, it soon becomes smaller.
   b) If a lady is cooking onions, you can soon smell them all over the house.
   c) If a tablet of food coloring is placed in a cup of water, soon all of the water is colored.
   d) If an open bottle of perfume is placed in a room, it can soon be smelled all over the room.
   e) If sugar is placed in a glass of lemonade without stirring it, the whole glass of lemonade soon tastes sweet.

50. Suppose the water in the glass was hot, rather than at room temperature. How would this affect the experiment?
   a) There would be no difference.
   b) The water would evaporate quickly.
   c) The green color would stay in the dropper.
   d) The green color would spread more slowly.
   e) The green color would spread faster.

— An Experiment with Geranium Leaves —

As an experiment, some fifth-graders took a healthy geranium plant and spread vaseline on the backs of two leaves. They let the rest of the leaves grow normally. After a few days, the two leaves covered with vaseline turned yellow and died.

51. The vaseline was harmful to the leaves because it
   a) prevented the plant from producing seeds.
   b) prevented water from entering the leaves.
   c) prevented sunlight from entering the leaves.
   d) prevented air from entering the leaves.
   e) prevented the flowers from blooming.

52. If the vaseline had been spread on the tops of the leaves,
   a) the results would have been the same.
   b) the leaves would have curled and died, but would not have turned yellow.
   c) the leaves would have turned yellow faster.
   d) the leaves would have turned yellow, but more slowly.
   e) the leaves probably would have continued to grow normally.

53. In this experiment, the vaseline covered small openings on the leaves called
   a) chlorophyll.
   b) stomata.
   c) palisade cells.
   d) chlorplasts.
   e) vascular bundles.

Go right on to the next page.

—— A Study of Sounds ——

All sounds are caused by the vibration, or back-and-forth movement, of the molecules of some material. Differences in sounds are caused by differences in the way objects vibrate.

For example, if objects vibrate slowly, the sounds produced are usually low. If objects vibrate rapidly, the sounds are higher. Some objects vibrate so fast that the sound cannot be hear by human ears.

A man's voice is deeper than your voice because

a) his vocal cords vibrate more slowly than yours.
b) his vocal cords vibrate more rapidly than yours.
c) he talks louder than you do.
d) he has larger lungs than you have.
e) his vocal cords have a back-and-forth movement.

In a piano, long heavy strings produce low notes, and short thin strings produce high notes. The reason for the differences is that

a) thin strings vibrate too rapidly to he heard by humans.
b) long heavy strings are used the most and will last longer.
c) long heavy strings vibrate faster than short thin strings.
d) long heavy strings vibrate more slowly than short thin strings.
e) long heavy strings stay in tune better.

There are special dog whistles that can be used to call dogs. The dogs can hear the whistle, but most people cannot. The reason is that

a) dogs have longer ears than humans.
b) dogs are trained to hear the whistle.
c) dogs have better ears than humans.
d) the whistle vibrates very rapidly.
e) the whistle vibrates very slowly.

Scientists know that no sounds can be heard in outer space. The reason is that

a) light travels faster than sound.
b) there are no molecules in outer space.
c) cosmic rays in outer space destroy sound.
d) it is too dark in outer space.
e) it is too cold in outer space.

—— A Study of Colors ——

Some fourth-grade boys and girls decided to make a "stained glass window" for use in a class play. First they planned the design, and then they painted the design on a large sheet of tissue paper.

Later, they put the tissue-paper "window" on one of the real windows in their room. When the sun shone on the window, John saw that the design appeared on one of the desks in the room. John also noticed that this desk was cooler than other desks on which the direct sunlight was shining.

58. People who passed the school could see the design that the children painted. From the outside, the red section of the design looked red because it

a) reflected red light.
b) reflected a mixture of yellow and orange light.
c) reflected all the sunlight.
d) absorbed all the sunlight.
e) absorbed all the red light from the sun.

59. The students used black, white, red, green, and blue paint to make the design. Which color absorbed <u>all</u> the light from the sun?

a) blue
b) green
c) red
d) white
e) black

60. The desk under the window was cooler than the other desks because the "stained glass window"

a) absorbed none of the sunlight.
b) reflected all the sunlight.
c) absorbed some of the sunlight.
d) transmitted all the sunlight.
e) refracted the sunlight.

STOP

PART 9 — SCIENCE

This is a test of your understandings in science and your ability to work with problems in science. The test questions look like this:

> S_1. The earth revolves around the sun about once every
>
> a) 12 hours.
> b) 24 hours.
> c) 7 days.
> d) 28 days.
> e) $365\frac{1}{4}$ days.

Mark your answer to question S_1 on your answer sheet.

The earth revolves around the sun once a year — once every $365\frac{1}{4}$ days. The answer is $365\frac{1}{4}$ days, and you should have marked the fifth answer space for problem S_1. Be sure that you filled in the fifth answer space with a heavy black mark.

In this test you will find 75 problems like this one.

Please do not make any marks on this test booklet. Do your figuring on scratch paper; and then mark your answer for each problem on your answer sheet.

Your score will be the number of answers you get right. Be sure to mark one answer — the answer you think is right — for each problem.

STOP

ENCE

— Important Facts and Principles —

The most frequent cause of death of children between 5 and 14 years of age is

a) accidents.
b) influenza.
c) leukemia.
d) pneumonia.
e) polio.

What has probably been the most important reason for the great increase in the average length of life since the 18th century?

a) change in eating habits
b) conquest of cancer and heart disease
c) general improvement in housing
d) improvement in methods of food production
e) reduction of deaths from infectious diseases

Probably the most likely reason why dinosaurs became extinct was that they

a) could not find food.
b) failed to adapt to a changing environment.
c) killed each other in combat.
d) were eaten by the more complex animals.
e) were killed by erupting volcanoes.

In plants, the term <u>photosynthesis</u> refers to the

a) assimilation of carbon dioxide.
b) green coloring matter.
c) manufacture of food.
d) release of excess water.
e) release of oxygen.

Plant cells differ from animal cells in that plant cells have

a) a cell membrane.
b) a cell wall.
c) a nucleus.
d) cytoplasm.
e) protoplasm.

The air immediately over a large forest on a bright summer day is different from the air over a large city. The most obvious difference is that the air over a forest, compared with the air over a city, contains

a) less oxygen and less moisture.
b) less oxygen and more carbon dioxide.
c) less oxygen and more moisture.
d) more oxygen and less carbon dioxide.
e) more oxygen and less moisture.

7. A plant that was placed in a totally dark box for 24 hours grew upright. A second plant was placed for 24 hours in a dark box with a hole which allowed light to enter on one side. The second plant grew toward the hole. The most correct conclusion that may be drawn from this experiment is that

a) a plant needs light for photosynthesis.
b) a plant responds positively to light.
c) auxins are necessary for plant tropisms to occur.
d) plant leaves reach for the light.
e) sunlight encourages plant growth.

8. Why do the largest number of ocean organisms live near the surface of the ocean?

a) Salt water has more minerals than fresh water.
b) The ocean bottom contains radioactive materials.
c) The intensity of light that reaches ocean organisms decreases as depth increases.
d) The ocean water is colder near the bottom.
e) The surface water is less polluted.

9. All the planets in the solar system

a) are the same size.
b) have natural satellites.
c) have the same density.
d) have the same gravity.
e) revolve around the sun.

10. A suggested procedure for providing both food and oxygen on long-distance space flights is to maintain, on the rocket ship, cultures of

a) algae.
b) amoebae.
c) bacteria.
d) molds.
e) yeasts.

11. Which of the following statements about bacteria is most correct?

a) All bacteria are harmful.
b) All bacteria are useful.
c) Bacteria are microscopic animals.
d) Some bacteria are harmful, some are useful.
e) Some bacteria make their own food.

Go right on to the next page.

Bacteria in the blood stream may be destroyed by

a) blood platelets.
b) plasma.
c) red corpuscles.
d) toxins.
e) white corpuscles.

Material for growth and repair of body tissues comes mainly from

a) fats.
b) proteins.
c) starches.
d) sugars.
e) vitamins.

Fossils are most likely to be found in

a) granite.
b) lava.
c) marble.
d) obsidian.
e) shale.

The metal obtained from hematite ore is

a) copper.
b) iron.
c) lead.
d) uranium.
e) zinc.

Soil erosion can be reduced by

a) crop rotation.
b) contour plowing.
c) dry farming.
d) grass burning.
e) intensive cultivation.

Project Mohole is an effort to

a) measure the cosmic rays in outer space.
b) reach the deepest part of the ocean.
c) reach the mantle of the earth.
d) send a manned satellite to the moon.
e) send television signals around the world.

Tides are chiefly the result of the action of

a) earthquakes.
b) hurricanes.
c) solar storms.
d) the moon.
e) the sun.

19. The principle of buoyancy is not primarily involved in the operation of

a) a balloon.
b) a sailboat.
c) a submarine.
d) an airplane.
e) an ocean liner.

20. The source of energy that we use least efficiently is

a) coal.
b) natural gas.
c) oil.
d) sunlight.
e) water power.

21. A physical property of a substance may be identified by

a) analyzing it under a spectroscope.
b) burning it.
c) reducing it to a powder.
d) testing it with acid.
e) weighing it.

22. Chemical compounds are always formed when

a) a gas is changed into a liquid.
b) a solid is melted.
c) a substance is changed into a gas.
d) two or more substances unite.
e) two substances are mixed.

23. Water flowing from artesian wells illustrates the principle that

a) certain minerals, such as limestone, are soluble in water.
b) water flows from regions of high pressure to those of low pressure.
c) the atmosphere exerts a pressure of 15 pounds per square inch.
d) water settles in the ground until it reaches the water table.
e) the pressure within a moving liquid is greater than the pressure in a non-moving liquid.

24. White light may be dispersed by a

a) lens.
b) mirror.
c) polarizing glass.
d) prism.
e) quartz glass.

Go right on to the next page

5. The best type of wire to use for the heating element of an electric toaster is

   a) aluminum.
   b) copper.
   c) nichrome.
   d) silver.
   e) tungsten.

6. When coal is burned,

   a) all the coal is reduced to ashes.
   b) all the matter is converted to energy.
   c) the coal is changed to other chemical substances.
   d) the elements in the coal are destroyed.
   e) the matter in the coal disappears.

7. Large bodies of water

   a) heat and cool at the same rate as land.
   b) heat more rapidly and cool more slowly than land.
   c) heat and cool more rapidly than land.
   d) heat more slowly and cool more rapidly than land.
   e) heat and cool more slowly than land.

8. The large-scale movements of air masses are regulated chiefly by

   a) barometric pressure.
   b) jet streams.
   c) the phases of the moon.
   d) the humidity of the mass.
   e) the temperature of the mass.

9. A cold front is most generally followed by weather that is

   a) calm.
   b) clear and cool.
   c) extremely windy.
   d) warm and cloudy.
   e) warm and humid.

0. Human control over the movement of large air masses

   a) is probably impossible.
   b) will require vast quantities of fuel.
   c) will depend largely on knowledge gained from Arctic explorations.
   d) will depend on further analysis of IGY information.
   e) will depend on information gained from lunar probes.

—— A Study of Nutrients in Corn ——

One day the students in South Junior High School were testing food to find out what nutrients are present in corn. The following statements are notes that were written in the notebook of one of the students:

A. "We crushed a dry corn seed and tested it with iodine. It turned black."
B. "We crushed a dry corn seed and tested it with Benedict's Solution. It did not change color."
C. "We added moisture to dry corn seeds to make them sprout."
D. "We crushed a corn seed that had started to sprout and tested it with Benedict's Solution. The solution turned red."
E. "We added limewater to a jar containing sprouting corn seeds. The limewater turned milky."

Indicate which of these notes is most closely related to each of the following statements:

31. Corn seeds contain starch.

   a) A
   b) B
   c) C
   d) D
   e) E

32. Corn seedlings change starch into sugar.

   a) A
   b) B
   c) C
   d) D
   e) E

33. A growing corn seedling oxidizes food.

   a) A
   b) B
   c) C
   d) D
   e) E

34. Dry corn seeds contain little or no sugar.

   a) A
   b) B
   c) C
   d) D
   e) E

Go right on to the next page.

A Study of DDT

n this part of the test you will find the description of an experiment, followed by a series of statements. Read the description of the experiment and then classify each of the statements under one of the following categories:

- T — Definitely True, proven by the study.
- t — Probably true in light of the study.
- ? — Not relevant to the study.
- f — Probably false in light of the study.
- F — Definitely False, proven by the study.

When wild houseflies were collected from an area where no insecticide containing DDT had been used, about 99 percent of these flies were killed by an ordinary exposure to DDT. The remaining 1 percent of surviving flies, when allowed to mate and reproduce, produced offspring which were resistant to DDT. A greater amount of DDT than that used on the first generation was required in order to kill 99 percent of these offspring.

5. A very small percentage of the first-generation flies survived exposure to DDT. (T — t — ? — f — F)

6. All houseflies are now resistant to DDT. (T — t — ? — f — F)

7. DDT should no longer be used as an insecticide. (T — t — ? — f — F)

8. DDT and lead arsenate are both insecticides. (T — t — ? — f — F)

9. There is evidence that mosquitoes develop resistance to DDT. (T — t — ? — f — F)

0. A large proportion of second-generation houseflies remained alive when exposed to an ordinary amount of DDT. (T — t — ? — f — F)

1. Resistance to DDT has created a problem with respect to control of houseflies. (T — t — ? — f — F)

2. Many fly sprays contain DDT. (T — t — ? — f — F)

3. A greater amount of DDT is required to kill DDT-resistant houseflies than to kill ordinary houseflies. (T — t — ? — f — F)

4. Other species of insects have developed resistance to DDT. (T — t — ? — f — F)

45. DDT is effective for the control of many insects. (T — t — ? — f — F)

46. An ordinary exposure of houseflies to DDT kills 99 percent of the flies when they or their ancestors have never been exposed to DDT. (T — t — ? — f — F)

A Study of the Planet Mars

For many years interest has been expressed as to whether life exists on the planet Mars. Observations at Lowell Observatory show that seasonal dark markings in each hemisphere of Mars become greener and more prominent in the late spring and early summer of that hemisphere. This color fades to a chocolate brown in the autumn.

47. The fact that there are seasons on Mars indicate:
    a) Mars' equator is inclined to its orbit.
    b) Mars must have the same crustal composition as the earth.
    c) Mars must have some form of vegetation.
    d) Mars is rotating on its axis.
    e) Mars must have an elliptical orbit.

48. Observation has definitely shown that there is no chlorophyl on Mars. This fact
    a) excludes all life on Mars.
    b) excludes all plants but not animals.
    c) excludes life as we know it on earth.
    d) is not important in considering the possibilities of life on Mars.
    e) proves that there are some simple plants on Mars.

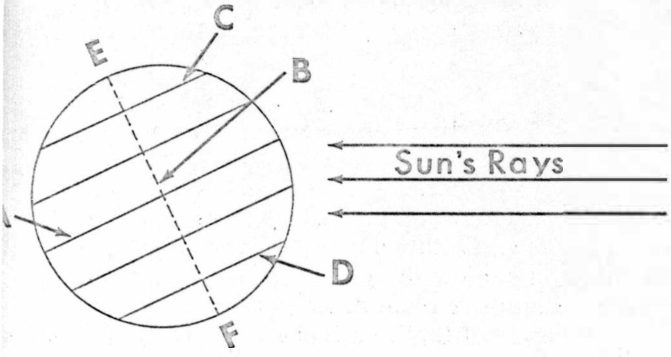
49. The atmosphere of Mars is thinner than that of the earth. There is less than 5 percent of the water vapor and less than 1 percent of the free oxygen as compared with the earth's atmosphere. These facts
    a) exclude all life on Mars.
    b) exclude animals but not plants.
    c) exclude plants but not animals.
    d) exclude life as we know it on earth.
    e) are not important in considering the possibilities of life on Mars.

50. Because of the thin atmosphere of Mars, it can be concluded that the
    a) escape velocity is very high.
    b) planet has a core of iron and nickel.
    c) planet is large.
    d) planet is very dense.
    e) surface gravity is small.

Go right on to the next page.

— A Study of a Diagram of the Earth —

The diagram below indicates the position of the earth on a certain day of the year. Use this diagram in answering questions 51-55.



51. The earth's axis is represented by letter
    a) A.
    b) B.
    c) C.
    d) D.
    e) E.

52. Line A represents the
    a) Antarctic Circle.
    b) Arctic Circle.
    c) earth's axis.
    d) Equator.
    e) Prime Meridian.

53. In the Northern Hemisphere, the season of the year is
    a) spring.
    b) summer.
    c) fall.
    d) winter.
    e) impossible to say.

54. At this time of the year, the distance between the earth and the sun is
    a) less than 93,000,000 miles.
    b) more than 93,000,000 miles.
    c) exactly 93,000,000 miles.
    d) approximately one light year.
    e) approximately 186,000 miles.

55. The diameter of the earth can be measured in two directions — by the line labelled A, or by a line from E to F. Which of the following best describes these two distances?
    a) The lengths of these two lines are not known.
    b) The two lines are equal.
    c) The lengths of the two lines vary.
    d) The line from E to F is the longer.
    e) The line through A is the longer.

— A Study of Iron Ore Production —

Suppose that in 1950 all of the Minnesota iron-ore producing areas experienced an increase in the tons of iron ore mined. The following percents of increases are to be compared with the year 1949:

Mesabi Range	10%
Cuyuna Range	20%
Vermilion Range	20%
Spring Valley Area	60%

Answer each of the following statements, using the following key:

T — Definitely True, indicated in the table.
t — Probably true, in light of the data in the table.
? — Not enough information given to decide.
f — Probably false, in light of the data in the table.
F — Definitely False, indicated in the table.

56. The Spring Valley Area has the richest ore. (T — t — ? — f — F)

57. The Mesabi produced only one tenth of the total amount of iron ore mined in 1950. (T — t — ? — f — F)

58. The yield of iron ore decreased in 1950 in Minnesota. (T — t — ? — f — F)

59. The Spring Valley Area has the greatest tonnage of ore available. (T — t — ? — f — F)

60. The Cuyuna and the Vermilion had the same per cent of increase. (T — t — ? — f — F)

61. The Cuyuna produced the same number of tons of ore as did the Vermilion. (T — t — ? — f — F)

62. Production of iron ore was greater in Sweden than in Minnesota in 1950. (T — t — ? — f — F)

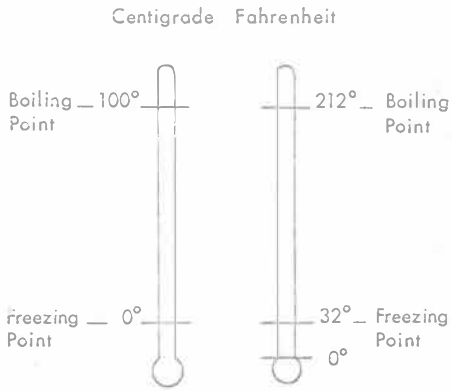
63. Considering all four deposits, Minnesota more than doubled its output of iron ore in 1950. (T — t — ? — f — F)

Go right on to the next pa

— A Study of Two Kinds of Thermometers —

We are concerned here with a comparison of two kinds of thermometers. One of these, known as the Centigrade thermometer, is shown on the left below; the other, known as the Fahrenheit thermometer, is shown on the right.

Answer the items that follow by referring to the two thermometers shown.



64. How many degrees are there between the freezing point and the boiling point on the Centigrade thermometer?
    a) 32
    b) 100
    c) 180
    d) 200
    e) 212

65. How many degrees are there between the freezing point and the boiling point on the Fahrenheit thermometer?
    a) 32
    b) 100
    c) 180
    d) 200
    e) 212

66. How does a Fahrenheit degree compare with a Centigrade degree?
    a) The Centigrade degree is larger.
    b) They are the same size.
    c) The Centigrade degree is smaller.
    d) The Fahrenheit degree is larger.
    e) They vary with the thermometer used.

67. If a Centigrade thermometer reads 10 degrees above the freezing point, how many degrees above the freezing point would the Fahrenheit thermometer read?
    a) 5 degrees
    b) 10 degrees
    c) 18 degrees
    d) 25 degrees
    e) 48 degrees

68. If the freezing point on a Fahrenheit thermometer is 32 degrees above zero, then how many degrees Fahrenheit above zero would a temperature of 10 degrees on the Centigrade thermometer be equal to?
    a) 5 degrees
    b) 10 degrees
    c) 18 degrees
    d) 25 degrees
    e) 50 degrees

Go right on to the next pa

— A Study of Vision Through Water —

Jack placed a penny on the bottom of a pan. He then stepped back so he just missed seeing the penny over the rim of the pan (as in A). He remained standing in position, and continued to look at the bottom of the pan while another student poured water slowly into the pan so as not to move the penny. As the water rose in the pan, the penny gradually came into Jack's view (as in B).

PROBLEM: Why could Jack see the penny after water was poured into the pan?

The statements that follow relate to the problem. Classify each of the statements according to the following:

T — Definitely True, proven by the study.
t — Probably true in light of the study.
? — Not relevant to the study.
f — Probably false in light of the study.
F — Definitely False, proven by the study.

69. Jack remained standing in the same spot while the water was being poured into the pan. (T — t — ? — f — F)

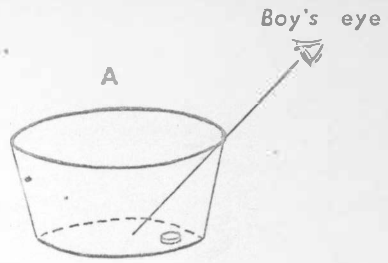
70. When a beam of light strikes water on an angle, it bends upward. (T — t — ? — f — F)

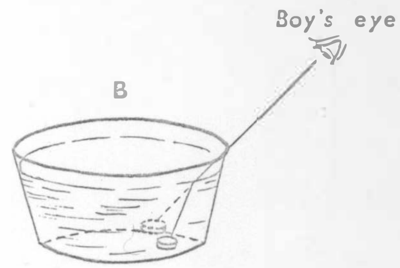
71. Jack began to see the penny because the water acted as a lens. (T — t — ? — f — F)

72. As the water was being poured, the penny did not move. (T — t — ? — f — F)

73. On leaving the water, the light reflected from the penny bent toward the boy. (T — t — ? — f — F)

74. Since the penny appeared to be higher up than it really was, Jack could see it through the water over the rim of the pan. (T — t — ? — f — F)





Apply the information from the above statements in answering the following question:

75. Bill is holding a fish spear in his hands. Looking into the water on an angle, he sees a very large fish that seems to be stationary about two feet below the surface of the water. Where should Bill aim the spear if he expects to strike the fish?

a) far "above" the fish
b) somewhat "above" the fish
c) "at" the fish
d) somewhat "below" the fish
e) far "below" the fish

STOP