THE DEVELOPMENT OF SCIENCE PROBLEMS FOR THE ANKENY HIGH SCHOOL GENERAL SCIENCE PROGRAM

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by
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THE DEVELOPMENT OF SCIENCE PROBLEMS FOR THE
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The study is conducted through the use of statistical methods on the basis of the collected data.
CHAPTER I

INTRODUCTION

I. THE PROBLEM

Statement of the problem. The purpose of this study was to develop science problems for a problems approach to the teaching of general science in the ninth grade at Ankeny High School. A science problem in this study was considered to be a question or statement pertaining to science that would provide a basis for a student investigation. The problems were prepared and used to teach one of the three general science classes at Ankeny High School during the 1960-1961 school year. Student class work during the school year consisted of a series of problem investigations. The students taught by this method represented the top third of the ninth grade selected on the basis of appraised mathematical ability.

The project was carried out during the 1960-1961 school year as one phase of the continuing development of the science program at Ankeny High School. The preparation and selection of problems involved consideration of the following factors:

1. Course objectives and content.

2. Unit organization of the course and the purposes of the units.

3. The nature of the students in the class in which the problems are to be used.
4. The facilities available for the study of problems.

The above considerations also operated as limitations of the study. For example, the special nature of the general science course as developed at Ankeny High School operated to determine the areas in science for which problems were developed.

The Ankeny High School. The Ankeny High School is a four-year high school. During the 1960-1961 school year the enrollment was 290.

The school had an eighteen member faculty. The science teaching assignments were handled by three teachers; one worked entirely in this area and the other two had half their assignment in science. Both the school and the community which it serves are growing rapidly, with each having approximately doubled in population in the past ten years. The school community includes the rural area surrounding the town of Ankeny, Iowa.

The Ankeny High School science program. The science program in the Ankeny High School system has received increased emphasis in the first six grades in recent years. Seventh and eighth grade students have studied science one period each day; so it is with a good science background that many of the students have entered high school. In high school, general science has been required as a ninth-grade subject, biology has been a tenth-grade elective, and physics and chemistry have been offered alternately for the eleventh and twelfth
grades. Half or more of the tenth-grade students have enrolled in biology each year. Approximately one third of the junior and senior classes have enrolled in physics or chemistry, depending upon the one being offered.

**Importance of the study.** The superior science background of students entering high school as compared to those entering a few years ago has offered an opportunity to enrich the science offerings for those of higher capability. There has also existed the challenge of providing materials for classes and individuals of varying ability.

New students have experienced many of the activities characteristic of the usual ninth-grade general science course. Their knowledge is, however, not so thorough as it needs to be in terms of understanding. They have encountered little in the way of quantitative thinking as applied to science. There has been great emphasis upon knowing about "things" of science and not so much upon science as a way of thinking.

It was therefore considered important to improve the program by (1) providing for differences in ability of classes and individuals, (2) introducing more quantitative thinking, (3) encouraging depth of understanding, (4) placing more emphasis upon science as a way of thinking, and (5) transferring the initiative for learning to the student. It was a basic assumption in this study that the problems approach would contribute to the improvement of the program in the above areas.
II. PROCEDURE

The major task in the study was the development of the problems. A number of preliminary steps were required to facilitate the development of the problems. The first of these was the establishment of course objectives. These were established by considering the needs of the Ankeny High School general science program and objectives common to science courses.

Another organizational step was the determination of the course content. This was accomplished by surveying several general science textbooks and considering the areas of information that had been covered in the science program below the ninth-grade level.

It was necessary next to organize the course content into units. The information in each unit was classified into these categories: (1) concepts, (2) quantitative relationships, (3) skills, and (4) vocabulary.

The types of problems that would be required to satisfy course objectives and types of learnings within the units were determined.

The class was organized in the use of room facilities, time, and method of problem reporting. A system of evaluating problems and grading was established. Unit tests were developed.

The problems were developed and selected in light of the foregoing organizational steps. The ideas for some of the problems were taken from textbooks and laboratory manuals.
Other problems were developed by the writer. The problems were used in class as the units were developed. If the problems were not adequate, they were modified or discarded.

Discussion of the development of the problems is presented in Chapter II of this study. The problems are presented in Chapter III.

Early in the course, it was decided that the teaching of problem solving should be an integral part of the science program. The writer was concerned with the development of greater understanding of problem-solving ability by students. He felt that problem-solving ability could be of great value in the teaching of problem solving. It was also felt that problem-solving ability could contribute to a more meaningful learning experience.

A survey of the literature was made to determine the following: (1) the effectiveness of the problems approach as a method of teaching science; (2) criteria for the design and selection of science problems.

Evaluation of the use of problems as a method of teaching science. The teaching of science involves more than the imparting of factual and conceptual information. Perhaps of greater importance is an understanding of science as a way of thinking that expresses itself in problem-solving ability by students. Heiss, Oburn, and Hoffman suggested that science can be of great value in the teaching of problem solving. They also indicated that content learned in reference to the solution of problems, where problem solving has been used, is more efficiently retained than when taught by traditional methods.¹

Slavson and Speer made these points concerning a problems approach to the teaching of science: (1) in general, the method is an improvement over other abstract-verbal plans such as the lecture, question and answer, and library methods;

(2) it sets problems and therefore gives purpose and direction; (3) some of the problems may be a challenge to some of the pupils; (4) it provides motivation for the acquiring of information. The teacher using the method finds that he has to combine with it the teaching of subject matter in order that the pupils may obtain the information necessary for solving problems; and (5) the plan increases in suitability as it is applied to higher grades with pupils more able to do reflective thinking. These authors cautioned that the pupil might be puzzled why he should solve the problem and thus lack a willingness to embark on the problem.¹

Burnett referred to a doctoral study by Barnard in discussing the merits of problem solving. Barnard worked with college students enrolled in two introductory courses in biology. In one course the conventional lecture-demonstration method was used, in the other the problem-solving method. Barnard found that the lecture-demonstration method was superior with respect to the development of problem-solving ability and the formation of attitudes.² Burnett suggested that the problems approach might show more favorably if the group were...


tested after a year, as it is recognized that the remembrance of related facts is more permanent.\textsuperscript{1}

Dawson made a study of elementary students that had been taught soil science in two groups, one by lecture and one by solving problems. He reached these conclusions: (1) lecture-recitation and problem-solving methods were virtually equal in test scores involving recall of specific information; (2) the problem-solving method has statistically significant advantages over the lecture-demonstration method with respect to achievement on tests covering problem-solving abilities; and (3) the students felt they had better accomplished the educational objectives when the problem approach was used.\textsuperscript{2}

Barr compared the achievement of groups of general science students taught by the problem method with the achievement of general science students in an equated group taught by a conventional testbook recitation and lecture demonstration. The problem method was found to realize better achievement in comprehension and interpretation of scientific problems.\textsuperscript{3}


\textsuperscript{2}Murray D. Dawson, "Lectures Versus Problem-Solving in the Teaching Elementary Soil Science," \textit{Science Education}, XL (December, 1956), 404.

There is evidence that under conditions of teaching other than the problem method, pupils test higher in the acquisition of information. Hurd studied the relative value of the topical versus the problem method, using matched groups studying the subject of heat in high school physics, and found that his results supported this.¹

These references concerned with evaluation of a problems approach to science teaching suggested these generalizations:

1. Learning of information takes place as well or better in traditional methods of teaching as in a problems approach. However, the information learned is probably more efficiently retained by the pupil if problems are used.

2. Pupils who have worked on problems show increased problem-solving ability in science as compared to those taught by traditional methods.

3. The problems approach encourages, to a greater extent, favorable student attitudes and motivation.

Design of science problems. Thurber and Collett, in suggesting a problems approach to science, set forth the first of several criteria that have been considered in developing problems:

The science program can be built up almost completely on a problem-solving basis. To be most useful to the pupils the situations should be as realistic as possible. Many problems can be taken from real life. Other problems can be so similar to real life problems that transfer is easy.¹

Twiss established a second criterion, that of the importance of interest, in stating:

It follows, therefore, that the problems through which one expects to teach the facts, ideas, concepts, and principles of the various branches of science must be found among those that lie near the interests and experiences of the students and can be led up to in such an interesting way that they will appropriate them as their own.²

Another criterion was advanced by Twiss, that of the relationship between the complexity of the problems and student ability, when he said:

The problems presented to them must be within the range of their concept knowledge and of their powers of abstraction at the particular stage of their development at which the teacher finds them.³

Hunter suggested two ideas that must be considered, stating that problems should gradually increase in complexity and should together form a logical sequence which helps to unfold some larger ideas of science.⁴

³Ibid., p. 115.
Thurber and Collett stressed the importance of quantitative thinking as a part of science.

Pupils need a science program that is based upon mathematical concepts from the beginning. Only thus can they develop "number sense" and learn to appreciate the properties of numbers. This program must extend through such courses as physics and chemistry, with more pupils being brought into these courses to benefit from the important concepts in them.¹

From the foregoing, the criteria established for the design of problems were as follows:

1. Problems should be as realistic as possible.
2. They should be close to the interests and experiences of the students.
3. They should vary in complexity.
4. They should be related to help unfold larger ideas of science.
5. They should provide for the strengthening of quantitative thinking.

These criteria referred to the development of problems for this study. Where possible the home and community were used as sources of equipment or points of observation in an effort to associate science with student interest and experience. An excess of problems was provided. Problems varied in complexity and in type so that student ability was considered. All problems in the same unit were concerned with one general topic so that they contribute to the general understanding of

the unit. In each unit quantitative problems for which the data have been given and those in which the data were to be determined by the student were provided.

II. DEVELOPMENT AND USE OF MATERIALS

Prior to the development and use of the problems, it was necessary to clearly identify course objectives, subject matter content, and unit organization. Consideration of these matters is presented in this section.

Course objectives. Direction for the organization of the study has been established in the objectives of the course. These objectives were developed in light of needs present in the Ankeny High School program and objectives common to science teaching. They have been considered as directions of growth toward which the individual may be directed. They are as follows:

1. To acquaint students with the historical development of science and its influence on society.
2. To promote the acquisition of scientific information with the emphasis on conceptual understanding.
3. To develop quantitative thinking.
4. To develop a useful science vocabulary.
5. To become familiar with the correct and safe use of laboratory equipment and materials.
6. To become familiar with the "scientific method"
and to learn to apply it to both problems of the science class and to our daily environment.

7. To encourage avocational and vocational interests of a scientific nature.

8. To promote the understanding of applied science in our daily lives.

Selection of course content. With increased emphasis upon science in the grades, students know more about science in general when they reach ninth grade. They have been exposed to much of the subject matter of the usual general science course. It is therefore important that their study in ninth grade be one of increased depth. It is logical that the subject matter remain essentially the same, with some exceptions. The usual topics covering conservation and living things have been omitted. These topics have been studied in an earlier grade. The majority of Ankeny High School students elect biology for the tenth grade. Also, many of them study aspects of biology in home economics and agriculture courses. It was therefore felt that it was more important to study chemistry and aspects of chemistry relating to biology more thoroughly than to devote part of the school year to biological topics. This also would permit increased time to be spent on other topics.

The areas selected for unit development are largely in the physical sciences and were selected after comparing a
number of the current general science texts and selecting material common to them. Increased emphasis has been placed on the subjects of measurement and chemistry as compared to that found in a general science text. The topics selected were: (1) measurement; (2) matter and energy; (3) chemistry; (4) the atmosphere and air pressure; (5) fire, temperature, heat; (6) water and water pressure; (7) magnetism and electricity; (8) communication using electricity, magnetism, and electromagnetic waves; (9) sound; (10) light; (11) astronomy, the earth, and time; (12) simple machines and the steam and gas engines.

**Unit organization and problem development.** The material covered in the unit falls into the following categories: (1) concepts; (2) quantitative relationship; (3) skills; and (4) vocabulary. Concepts include laws of science, principles, and understandings. Quantitative relationships are those that involve numerical expression of and relationship between such aspects of science as mass, volume, distance, velocity, and time—in proper units. Under the heading of skills are included those learnings that involve the use of laboratory equipment. The vocabulary list for each unit involves those terms that are vital to the understanding in the other three categories and the unit topic in general.

The major portion of the material to be covered was selected by surveying a number of current general science texts
Additional material was included in several of the units as a result of the writer's experience in teaching high school physics and chemistry. This was particularly true in the units on measurement, matter and energy, and chemistry.

Several kinds of problems were required to enable coverage of the different kinds of learnings in a unit. They may be described as follows: (1) investigation requiring the use of the "scientific method"; (2) learning vocabulary terms; (3) written problems involving quantitative relationships; (4) learning a skill; (5) looking up information; and (6) making an explanation. In each unit varying numbers of each of these type problems are found.

An individual problem was placed in the unit to cover the items in the four types of learnings found in each unit. Additional problems were added in each unit to provide extra opportunities for students of varying ability. Many of the ideas for the problems have come from science texts and laboratory manuals; others were developed by the writer. It was found necessary to replace some problems and rewrite others as they were used in the class. It seems that good problems are evolved rather than created. The type of problem used and the material covered in the unit were major factors in the satisfaction of course objectives.

Each unit thus includes this organization:

1. A classification of material to be covered, organized as follows:
a) Concepts
b) Skills
c) Quantitative relationships
d) Vocabulary

2. A list of quantitative problems to provide practice in the quantitative relationships selected.

3. A list of problems for the development of concepts, skills, and vocabulary.

Description of participating class and science room which the class used. The class in which the problems approach was used had an average enrollment of thirty-two. The class represented the top one-third of the Ankeny High School freshmen on the basis of appraised mathematical ability. The criteria used in making this appraisal were: (1) student performance on the Iowa Algebra Test; (2) the Iowa Basic Skills arithmetic score; (3) arithmetic grades from the first semester of eighth grade, and (4) teacher judgment. The class devoted one fifty-five minute period each school day to science.

This class met in the laboratory room used for physics and chemistry. The room has laboratory seating available for thirty students. The school physics and chemistry equipment was available to the general science class. The writer has been the physics and chemistry teacher at the school for the past six years.
Class use of problems. The pupils were given a duplicated copy of each unit as work on that unit began. (The materials provided the students are presented in Chapter III.) Orientation reading was then assigned in the reference texts. This was followed by a period of class discussion in which an overview of the unit was developed. The problems were then introduced and their use was explained. So that all students would encounter basic understandings central to the unit topic, a number of the problems in each unit were required. The problems dealing with vocabulary and quantitative relationships were among those required. The problems following the one concerned with vocabulary development in the problem list were usually used for extra credit investigations by the students. The students selected these extra credit problems according to their interest without restriction as to the work of other students or number of investigations that could be made.

The problems were investigated in different ways. Many were probed by individual students; on others small groups worked. Where equipment or background of the students were limiting factors, it was necessary for the class to work together. A number of the problems requiring explanation or information were completed by students as they worked in the school study hall or library. Many of the problems were approached in the student's home as the problem required observation, investigation, or use of home equipment.
After the introduction to the use of the problems, the class was organized for use of equipment and facilities. It was sometimes possible to organize for several days of work. A period of time was usually required for organization each day at the beginning of the period. It was the practice to require a written report for each problem. The different types of problems were reported according to the following instructions:

1. Learning of vocabulary terms. Concentrate on the correct spelling of the word as you write it five times. Follow with the definition or explanation of the word or term.

2. Solving quantitative relationship problems. Present the problem in organized form. Briefly state the reason for each mathematical step. Indicate the correct units for the answer with each carrying an

3. Learning a skill. Instructions will be given for each problem of this type.

4. Finding information or making an explanation. State the problem. Put the information or explanation in your own words. Indicate the source or sources of information.

5. Applying the scientific method. Use the following outline:

a) Statement of the problem

b) Tentative explanation (hypothesis)
c) Experimental design

d) Data (present in organized form)

e) Conclusion, summary, or answer to problem

Available to the students for sources of information, other than the writer, were the following: (1) a ninth-grade general science text; (2) a set of high school physics books and a set of high school chemistry books; (3) several miscellaneous high school science texts; (4) reference materials in the school library.

The problems were evaluated in several ways. Some of the problems were evaluated in each unit as they were completed; others were turned in at the completion of the unit. Occasionally the problems were used under test conditions. Extra credit problems were evaluated as they were completed. Grades were determined from problem evaluation and objective tests covering material common to the class with each carrying equal influence.

III. THE PROBLEMS AND COURSE AND UNIT OBJECTIVES

Problems analysis in light of course objectives and unit coverage. The problems for each unit were developed using the course objectives and the concepts, skills, quantitative relationships, and vocabulary for each unit as guides. An analysis of the problems in Units I, IV, and V was made to determine the adequacy of coverage of course objectives and unit information. Tables I, II, and III present this information.
The entries in Tables I, II, and III refer to course objectives or to information classified in a particular unit. More specifically, the entries are related to course objectives and unit organization as follows:

1. The number in the problem column in the table correspond to a problem number in the particular unit.

2. The numbers in the general objective column identified course objectives as listed in the discussion of course objectives.

3. The entries found in the concepts, quantitative problems, and skills column in the table referred to items under these headings within the organization for the individual unit.

4. Entries in the vocabulary column in the table were marked with an "x". An entry of this type indicated that a contribution had been made to the study of vocabulary by the problem in the left-hand column located on the same horizontal line.

5. The problem indicated in the left-hand column was evaluated according to whether it had made a major or minor contribution to the areas indicated in the vertical column. All numbers on a horizontal line were concerned with the same problem. For example, in Table II, concerned with Unit IV, problem one made a major contribution to the second course objective and a minor contribution to the fourth. It made a
major contribution to the understanding of concepts two and three, and a minor contribution to vocabulary study. In the same table, problem ten made an important contribution to the fourth course objective and a major contribution to the learning of the vocabulary words in the unit.

The coverage of course objectives and subject matter within the units appeared to be adequate for the units analyzed. It was assumed that these were representative of the coverage in the other units as they were designed under similar conditions.

IV. ADEQUACY OF APPROACH

The problems approach was evaluated in this study by a comparison of test scores and the writer's subjective judgment.

Comparison of test scores. At the end of the school year, the same final test was given to the class taught by the problem method that was used with a ninth-grade general science class in a previous year. The classes were similar in that they were both screened on the same basis. The previous class was taught using a traditional assignment-recitation approach. The test was objective in nature and had 115 questions. The control class had a median score of eighty-seven and an average score of eighty-six questions correct. The class taught using the problems had a median score of eighty-five and an
### TABLE I

**ANALYSIS OF UNIT I IN TERMS OF COURSE OBJECTIVES AND UNIT SUBJECT MATTER OBJECTIVES,**

**ANKENY HIGH SCHOOL GENERAL SCIENCE**

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<th>Problem No.</th>
<th>Course</th>
<th>Unit Coverage</th>
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### TABLE II

**ANALYSIS OF UNIT IV IN TERMS OF COURSE OBJECTIVES AND UNIT SUBJECT MATTER OBJECTIVES, ANKENY HIGH SCHOOL GENERAL SCIENCE**

<table>
<thead>
<tr>
<th>Problem No.</th>
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### TABLE III

**ANALYSIS OF UNIT V IN TERMS OF COURSE OBJECTIVES**

**AND UNIT SUBJECT MATTER OBJECTIVES,**

**ANKENY HIGH SCHOOL GENERAL SCIENCE**

<table>
<thead>
<tr>
<th>Problem No.</th>
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<th>Objective Reached</th>
<th>Concepts</th>
<th>Quantitative Problems</th>
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Problem teaching is very dependent on the teacher. More time was required to have competent workers in the student training program. The writer feels that any student teacher could benefit from receiving more training for improvements and the type of the teacher training would appear. Teacher growth in techniques and/or location skills...
average score of eighty-five. This suggested that the use of
problems as a method of teaching science compared favorably
with the assignment-recitation method of teaching in terms of
impacting information.

**Subjective evaluation.** It is the writer's opinion
that the problems and their use as developed in this study
helped meet the needs of the general science program at Ankeny
High School. This was particularly true in providing oppor-
tunity for increased application of science as a way of think-
ing, in increasing the depth of the course content, and in
providing students the opportunity to work according to their
ability. The definiteness of the problems and the fact that
they would be evaluated was a motivating factor in student
work.

Problem teaching is more demanding on the teacher.
More time was required in making equipment available to the
students and in evaluating student work. The teacher must
become adjusted to the class working on many problems at the
same time with the accompanying demands for equipment and
supervision.

On the basis of the development of this study over
the 1960-1961 school year as it was used in one class, the
writer feels that each year the material is used opportunity
for improvements and additions to the unit material would ap-
pear. Teacher growth in techniques and organization skills
needed to use the problems should evolve with experience. The problems should become more effective, as use and teacher experience increase, as a method of teaching ninth-grade general science.
CHAPTER III

PROBLEMS ORGANIZED BY UNITS

In this chapter are presented the problems prepared in terms of the purpose of this study. They are presented in the twelve units into which the course was divided. For each unit, the following is presented:

1. Outline of the unit
   a) Concepts
   b) Skills
   c) Quantitative problems
   d) Vocabulary

2. Problems for use in each unit

   I. UNIT I--MEASUREMENT

Concepts

1. Measurement in science
2. Limitation of human senses
3. The "scientific method"
4. Acceptance of scientific information
5. The metric system
6. Types of measuring instruments
7. Significant figures in measurement
8. Errors in measurement, parallax, meniscus reading
9. Writing large and small numbers in terms of ten
   (scientific notation of numbers)
10. Per cent error calculations

Quantitative Problems

1. Area
2. Volume
3. Conversion from one unit to another within the metric system
4. Conversions between the English and the metric system
5. Significant figures
6. Writing large and small numbers in terms of ten

Skills

1. Using the balance
2. Using the meter stick
3. Using the graduated cylinder
4. Using the pipette

Vocabulary

<table>
<thead>
<tr>
<th>Metric system terms</th>
<th>volume</th>
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<td>parallax</td>
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<tr>
<td>meniscus</td>
<td>control</td>
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<td>variable</td>
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<td>area</td>
<td>vernier caliper</td>
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<tr>
<td>cubic</td>
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</table>

Quantitative Problems

1. How many millimeters are there (a) in one centimeter? (b) in one meter? (c) in one kilometer?

2. How many centimeters are there in (a) one foot? (b) two meters? (c) How many inches are there in one meter?
3. How many milliliters are there in (a) two liters? 
   (b) ten liters? (c) How many liters are there in 
   one cubic meter? 
4. Calculate the number of milligrams in (a) 0.4 kilogram, 
   (b) one pound. (c) How many grams are there in two 
   kilograms? 
5. A boy is 5 feet 8 inches tall and weighs 130 pounds. 
   What is his height in meters and his weight in 
   kilograms? 
6. A flask has a volume of 250 milligrams. (a) What part 
   of a liter is this? (b) How many grams of water will 
   the flask hold? 
7. Express these numbers using the scientific notation of 
   numbers: 
   (a) 3500          (d) 0.036 
   (b) 93,000,000     (e) 0.0000059 
   (c) 295,000,000,000 (f) 0.0000000000634 
8. Express these numbers in regular form: 
   (a) $3.1 \times 10^6$          (c) $2.1 \times 10^{-5}$ 
   (b) $1.98 \times 10^3$          (d) $9.8 \times 10^{-2}$ 
9. The underlined figures are doubtful. Round off your 
   answers to the degree of accuracy you are justified 
   in keeping. Keep one doubtful figure. 
   (a) Add $37676.6 \quad$ (b) Multiply $3534.2 \quad$ 
   $3537.4$                         $22.1$ 
   (c) Divide 364 by 2.5321
10. How are the areas of the following determined? (a) a square, (b) a circle, (c) a triangle?

11. How are the volume of a (a) cube, (b) cylinder, (c) sphere determined?

Problems

1. Discuss the place of measurement in science. Consider the limitation of the human senses in view of the frontiers of today's science.

2. Determine how accurately you estimate distance with your eyes. Estimate the length of an object that is (a) about the size of a book, (b) the height of a man, (c) the length or width of a house. Then measure the length of the objects as accurately as you can. Calculate for each estimated distance the error and the per cent error of your estimate. What do you conclude concerning the eye as an instrument of determining distance?

3. The following terms indicate information that has varying degrees of acceptance in the scientific world:
(a) guess (c) theory
(b) hypothesis (d) law

Briefly describe the type of information to which these terms apply. Are they in the correct order to indicate increasing degree of acceptance?
4. Develop a chart of the metric system in which the prefixes and the units of length mass and weight are considered. Explain the relationship between the meter, the liter, and the gram.

5. Establish experimentally the relationship between the centimeter and the inch. (a) One centimeter is equal to what fraction of an inch? (b) One inch is equal to how many centimeters?

6. What is the surface area of one of the laboratory work areas? (Subtract the area lost due to the sink.) Report your answer in square meters, square centimeters, and square feet. Use significant figures.

7. Determine the volume of a beaker by (a) using a graduated cylinder, (b) calculation using width and height of a beaker as measured. Report the calculated volume in milliliters, cubic centimeters, liters, and cubic inches. Use significant figures.

8. Report in organized form the weights of the indicated objects as determined on both the double platform and the triple beam balance. Report your answers on the double platform balance in terms of the nearest tenth of a gram, on the triple beam balance to the nearest hundredth of a gram.

9. Represent by diagram how an error of parallax may be avoided and how the level of a liquid in a narrow tube is determined when a meniscus is present.
10. Complete the quantitative problems.

11. Define the vocabulary terms.

12. How was the metric system developed?


14. Report on different types of measurements that are referred to in the Bible. Compare them to English or metric system measurements.

15. Interview five people as to whether or not they would prefer the metric system to the English system of measurement. Explain to them first what the metric system is and its advantages. Record their comments as carefully as you can.

16. Interview an engineer and discuss with him the problems that would be involved in industry in changing to the metric system. Report your findings.

17. What kind of measurements are made and what kind of instruments are used to make measurements at the John Deere Plant?

18. Can you express in metric units the amount of substance in several common grocery store items? Include in your items those which involve examples of linear, weight, and volume units.

19. Using three significant figures, express the distance from the sun to the planets in the solar system using the scientific notation of numbers. Give the distances as normally expressed first.
20. Show mathematically that the meter is approximately one ten-millionth of the distance from the equator to the North geographic Pole.

21. Look up in a physics book the coefficients of linear expansion of five metals and give the coefficients as normally expressed and as expressed using the scientific notation of numbers.

22. What percentage of our vertical wall surface is composed of glass window in the science room?

23. How many cubic feet of air do we have per student in this classroom? Consider twenty-five people in attendance in the classroom. Report your answer also in terms of cubic meters of air per student.

24. How thick is a piece of paper? How do different kinds of paper compare in thickness?

25. How much air is inhaled or exhaled under various conditions?

26. Make a spring balance out of a spring, calibrate it and determine the weight of several objects.

27. What is the size of a drop of water? Do further work with other liquids as to the size of drop that they form.

28. Determine the distance that it is no longer possible to hear a reproducible sound. Test more than one person.

29. At what concentration of salt in water is it impossible to recognize the taste of salt in the water?
30. Calculate the volume of a round-bottomed flask. Include the neck in the calculations. Check your work by using a graduated cylinder.

31. Make a double platform balance. Make a set of weights and weigh several objects.

32. Develop a method of determining the height of an object from a distance. Verify your method by making an actual height determination of a couple of objects so the two methods may be compared.

33. Using one linear measuring device as a standard, compare several other devices such as a yard stick, a metallic tape, a one-foot ruler, a sewing tape. Determine the difference and the per cent difference for a unit of length as you compare the measuring devices to the one you have accepted as a standard.

34. Determine the rate of flow of H₂O from several water faucets in a building. Does the height of the water faucet seem to make any difference?

35. Determine the elasticity (amount of bounce as compared to height from which dropped) for several different type balls. Include balls made of different materials such as rubber, glass, wood, inflated balls, etc.

36. How do the turning radii of different automobiles compare?
37. Calculate the revolutions per minute of an automobile wheel when it is traveling at two different speeds. Determine what the revolutions per minute will be at the same speed when the tread is completely worn from the tire.

38. How much does a cake change in volume when baked as compared to the volume occupied by the mixed ingredients?

39. Compare scales in several Ankeny stores by weighing the same object on several of them.

40. How does the volume of popped and unpopped popcorn compare?

41. What is the weight loss in a baked item if it is allowed to dry out over a period of days?

42. Demonstrate the relationship that exists between the ml, the cubic cm, and the gram of H₂O.

43. Make a time analysis of your day over several days time. List the type of activity and the amount of time there spent.

II. UNIT II--MATTER AND ENERGY

**Concepts**

1. Historical development
2. Matter and energy
3. Properties of matter
4. Forms of energy
5. Atomic theory and energy. What was Albert Einstein's theory of relativity?
6. Atomic particles and their arrangement in the atoms.
7. Atomic weight and number of the elements.
9. Gravity and its relation to the forces of attraction. Why do objects fall to the earth?
11. Physical and chemical changes.

Vocabulary

- matter
- energy
- organic matter
- inorganic matter
- kinetic energy
- potential energy
- chemical energy
- atomic energy
- mass
- inertia
- gravity
- atom
- element
- physical change
- force
- proton
- neutron
- electron
- nucleus
- molecule
- isotope
- electromagnetic energy
- electrical energy
- heat energy
- sound energy
- chemical change
- weight
- mixture
- solution

Problems


2. What is the law of the conservation of matter and energy? What is the reason the law is stated differently today?
than it was a few years ago? What part did Albert Einstein play in developing our present concept of
the relationship between matter and energy?

3. Represent by diagram the arrangement of electrons, pro-
tons, and neutrons in the nucleus and energy levels
in an atom of each of the elements in the first three
periods of the atomic chart. Label each diagram with
the proper atomic name and symbol.

4. Using three diagrams, represent the relative space be-
tween atoms and molecules and the type of motion
that is characteristic of atoms and molecules in
solids, liquids, and gases.

5. What are Newton's three laws of motion? Demonstrate
or cite an example as evidence which would verify
these understandings.

6. Does a gas have weight?

7. Discuss briefly each of these conceptions of matter:
   (a) Matter is composed of molecules; (b) Matter has
   mass; (c) Matter has weight; (d) Matter is impene-
   trable; and (e) Matter is porous.

8. Design and perform experiments which will demonstrate
   (a) a chemical change; (b) a physical change. Explain
   why your experiments demonstrate these.

9. What is the nature of atomic energy? What are radio
   active substances? Of what is radioactivity composed?
   What eventually happens to radioactive substances?
10. Complete the study of the vocabulary terms.
13. Make a book report on one of the men that were prominent in the development of man's knowledge concerning the atom.
14. Collect five or more compounds that you find in common usage. List their common name, their chemical name, and the chemical formula. Collect actual samples. (You could use small jars for your display.)
15. Make a model of one or more chemical compounds.
16. Collect five or more mixtures. Collect them in jars.
17. Compare the mass and weight of an object on the earth with the mass and weight that it would have on the moon.
18. Make a model of an atom of one or more elements.
19. Represent by diagram the structure of elements 92 to 100, using the information on the periodic chart to make your diagrams.
20. Find out from the chemistry book what elements are in the halogen family. Diagram the structure of this family of elements.
21. Find out from the chemistry book which elements are known as inert gases. Diagram their structure.
if you can find out why they are called inert gases and why they are inert in terms of their structure.

22. How much would you weigh if you were 4,000, 8,000, and 12,000 miles from the earth? (Consult a physics book.) What mathematical relationship expresses the way weight changes as an object leaves the earth?

23. Demonstrate that a substance may exist as a solid, a liquid, or a gas depending on temperature or pressure changes. (It would be easier to make only temperature changes and keep the pressure constant. Be sure to show that the substance is not changed into another substance when it becomes a gas.)

24. What distance is required to overcome the inertia of a bicycle traveling at ten miles per hour.

25. What distance is required to overcome the inertia of a car traveling at ten miles per hour.

26. Investigate the statement: heavy objects fall faster than light ones. Is the atmosphere a factor?

27. Design and follow a procedure in which you separate a mixture of sand, salt, and water into these three substances.

28. Determine the per cent of salt by weight in a salt water solution containing an unknown amount of salt.

29. If you add equal amounts of water and alcohol to each other, does the volume of the two added together equal the sum of the initial volumes of the water
and alcohol? Can you explain what has happened?
(You will have to measure very carefully.)

III. UNIT III--CHEMISTRY

**Concepts**

1. Symbols
2. Atoms are held together in molecules and in crystals
3. Valence
4. Formulas
5. Naming compounds
6. The chemical equation
7. Metals and non-metals
8. Acids, bases, salts
9. Neutralization—use of indicators
10. Activity of metals and replacement
11. Weight relations in an equation
12. Oxidation
13. Carbon compounds
14. Plastics
15. Roasting and reduction of ores
16. Photosynthesis
17. Fermentation
18. Respiration

**Skills**

1. Learning the names of equipment
2. The bending and fire polishing of glass tubing
3. Assembling glass tubing safely

4. Using the blow pipe

5. Using the Bunsen burner

Vocabulary

- molecule
- compound
- acid
- base
- salt
- litmus paper
- ion
- chemical bond
- radical
- oxidation
- photosynthesis
- fermentation
- metal
- non-metal

Problems

1. Learn the symbols for the following atoms or radicals:

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<th>Metals</th>
<th>Non-Metals</th>
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<td>Sodium</td>
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<tr>
<td>Mercury</td>
<td>Phosphorous</td>
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<tr>
<td>Aluminum</td>
<td>Nitrogen</td>
<td>Inert elements</td>
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<td>Hydroxide</td>
<td>Helium</td>
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<td>Sulfate</td>
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<td>Carbonate</td>
<td>Argon</td>
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<td></td>
<td>Bicarbonate</td>
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</table>

2. Record in organized form the class discussion on the bonding of atoms in compounds.

3. Name the following compounds or give the formula:

- NaOH: Silicon dioxide
- Calcium oxide: CO₂
- Potassium flouride: Carbon tetrachloride
- ZnO: Al₃(SO₄)₃
- AlCl₃: FeO
- NaHCO₃: H₂O
- Zinc sulfide: Calcium sulfate
- Carbon monoxide: CaCO₃

4. Make a 90 bend out of glass tubing and fire-polish the ends.
5. As the different items of chemical equipment are presented, make a simple diagram of each. Name each article and indicate its use.

6. Observe the demonstration table containing several metals and several non-metals. List general characteristics you observe for each group as you observe them at room temperature. Look up the terms metal and non-metal in the chemistry book and determine if you can how these two groups of elements differ from each other in atomic structure.

7. Starting with hydrochloric acid and sodium hydroxide, design and carry out a process that will enable you to produce table salt. Give the general equation for the reaction between an acid and a base. Give the equation using chemical formulas for this chemical reaction.

8. Using a Florence flask, a rubber stopper, a 90 glass bend, and rubber hose set up a distillation. Distill a solution containing one crystal of potassium permanganate in 50 ml of water. Results? (1) How do you account for the color of the condensate? (2) What safety rules did you follow in assembling the apparatus? (3) Include a labeled diagram of your distillation arrangement in your report.

9. Write the equation for the formation of water from hydrogen and oxygen. Below the left-hand side of the
equation, make an atomic diagram showing number of nuclear particles and electron arrangement for each atom represented and each time it is represented.

(1) What relationship exists between the number of hydrogen and oxygen atoms required in making water?
(2) What relationship in atomic weights exists between hydrogen and oxygen in forming water? (3) What weight of hydrogen would be required to reach with eight pounds of oxygen and what would be the weight of water formed?

10. Demonstrate the oxidation of hydrogen, iron, and magnesium. Describe what occurs for each reaction. Write the chemical equations for the reactions. How do the products of the reactions compare physically and chemically? Has energy been released in each reaction? Discuss. In general, is energy released during oxidation?

11. By means of a diagram show why it is possible for carbon to form so many different molecules. Make molecular diagrams of the following common substances that are carbon compounds: (refer to a chemistry text)
(a) methane
(b) carbon tetrachloride
(c) an alcohol molecule
(d) a soap molecule
(e) a molecule of a plastic

12. Using a blow pipe, a charcoal block, and some lead oxide, produce some metallic lead. Explain what has
taken place chemically. What do the terms "roasting" and "reduction" refer to in the processing of ores?

13. It has been proposed that plants and man in the right proportion might be of mutual benefit to each other on a space flight. Explain why this is true in terms of photosynthesis and respiration. Use word equations for the reactions.

14. Set up as a class demonstration a fermentation reaction. Diagram and explain how the demonstration apparatus works. Identify the products of the reaction. What is the word equation for the reaction? How is fermentation involved in making bread rise?

15. Complete the vocabulary definitions.

16. New uses are being found for some of the less common elements. Find the uses which are now made of such elements as selenium, titanium, zirconium, iridium, gallium, and indium.

17. Diamonds and graphite are pure carbon compounds. What are physical characteristics of each? Why do they have different physical characteristics?

18. Compare the labels on several baking powders to determine if they are composed of the same ingredients.

19. Using a circle or bar graph, represent in terms of weight the ten most abundant elements in the earth's crust.
20. Secure from a chemistry book the chemical formulas for a number of plastics. Make structural diagrams of the molecules if you can. What are thermosetting and thermoplastic plastics?


22. Add vinegar to a teaspoon of baking soda in a glass. After the reaction has stopped, lower a burning match in the glass. Lower a match also into an empty glass. Compare your observations of what happens in the two glasses. Look up the reaction between the baking soda and the vinegar in a chemistry book and explain your observations as thoroughly as you can.

23. Are some elements chemically more active than others? Place several nails in a solution of copper sulfate.

(a) What is the appearance of the nail after a few minutes? (b) What happens to the color of the solution after a few hours? Investigate in a chemistry book the replacement of metals and explain what has happened. Use your observations as evidence. Write an equation for the reaction if you can.

24. Bicarbonate of soda, NaHCO₃, is sometimes used to settle stomach distress. (a) Why is this effective for some stomach conditions? (b) Can you write the chemical equation for the action of the baking soda?
25. Laundry bleach makes clothes "whiter." Find out from a chemistry book how a bleach works.

26. Find a chemical test for limestone. Describe what occurs as you perform the test on a piece of limestone. Try the test on unidentified rocks. Results? Write the chemical equation for the reaction that occurs with the limestone.

27. Copper roofs and statues containing copper turn a green color on standing for long periods of time exposed to the atmosphere. Explain what happens to the copper. Include a chemical equation for the reaction if you can. (This could be demonstrated by putting copper in a moist carbon dioxide rich environment.)

28. What happens when water is added to baking powder? How does this cause a cake to rise? Explain what happens using chemical terms if you can.

29. Aluminum does not become "rusty" and deteriorate when exposed to the atmosphere as iron does. Why is this so?

30. Using litmus paper or solution, test several substances you have at home to see if they give an acid, a neutral, or a basic reaction. The solids may be tested by putting them in water and testing the water if you use litmus paper. Record your observations in organized form.

31. Make a study of the effect of bleach on various kinds and colors of cloth.
32. Set up an experiment which investigates the relationship between moisture conditions and the rusting of nails. Remember to use a control.

33. Why are some elements referred to as the rare earth elements? Why have these become important in recent years?

IV. UNIT IV--THE ATMOSPHERE AND AIR PRESSURE

Concepts

1. Historical development
2. The gases of the atmosphere
3. The layers of the atmosphere
4. The atmosphere and gravity
5. Air pressure
6. The barometer and elevation
7. The compression pump
8. The vacuum pump
9. The lift pump
10. The siphon
11. The atomizer
12. The airplane and the atmosphere
13. Jet propulsion
14. Elasticity of the air
15. Temperature and pressure effects on a volume of a gas
16. The barometer and weather
Quantitative Problems

1. Air pressure

2. Air pressure and elevation

3. Lift on a balloon

4. Wing lift on an airplane in flight

5. Total force from air pressure

Vocabulary

pressure
buoyancy of air
forces on an airplane: drag, lift, thrust, gravity
vacuum
pneumatic
siphon

Quantitative Problems

1. The weight of a cubic foot of air near sea level is ___.

2. Sea level air pressure may be stated in terms of the following: (a) __ lb/in², (b) ____ in. of Hg, (c) ____ millibars, (d) ____ ft. of water, (e) ____ mm of Hg.

3. A one inch hollow cube has what total force pressing in on its entire surface?

4. The barometer reading drops approximately one inch with each rise of elevation of 900 ft. over a particular point. When the mercury barometer reads 29 in. in Ankeny the reading at 5,000 ft. elevation over Ankeny would be what?

5. A balloon 30 ft³ capacity weighs 8 oz. It is filled with helium gas which weighs approximately 0.14 oz/ft³
at sea level pressure. Air near sea level weighs approximately 1.3 oz/ft³. What is the left-over lifting force that this balloon would have?

6. The air pressure in a house is 14 lb/in². A tornado moves over the house and the outside air pressure above the house is lowered to 12 lb/in². The roof area of the house is 900 ft². What is the total force tending to lift the roof off the house?

7. The motion of an airplane through the air causes the air pressure to build up to 15 lb/in² under the wing of an airplane, and lowers the pressure above the wing to 14 lb/in². What is the lifting force tending to keep the airplane in the air for each square foot of wing surface?

8. A suction cup three inches in diameter is forced against a smooth surface. Assuming that all the air has been forced from beneath the suction cup, what force would be required to pull it loose?

Problems

1. (a) Find out the names of the layers of the atmosphere and describe their nature as thoroughly as you can. (b) Find out what the percentage composition of the air by volume is in terms of the gases of which it is composed.

2. Perform and write up one experiment that demonstrates that air exerts pressure.
3. Submit diagrams with explanations of how the following operate: (a) a vacuum pump, (b) a compression pump, (c) a lift or "suction" type well pump, (d) a drinking straw, (e) an atomizer.

4. Perform and write up an experiment which demonstrates the part of the atmosphere by volume that is oxygen. Use measurements to support your conclusion.

5. Design and perform an experiment which illustrates the effect of temperature and pressure changes on a volume of a gas that is in an elastic container. Can you explain the results of your experiment in terms of what you know about the movement of molecules in gases.

6. Briefly describe the contributions of Torricelli, Galileo, Pascal, and Von Guericke to man's knowledge of the atmosphere or air pressure.

7. Discuss the four forces that are acting on an airplane in flight; indicate the direction in which they are acting and if possible how they may be increased or decreased.

8. What is wrong with the word "suction" as a term to describe phenomena associated with air pressure?

9. Explain with the aid of a diagram the principle of the mercury barometer. Explain why the barometer reading changes as the elevation increases.

10. Complete the vocabulary definitions.

11. Complete the quantitative problems.
12. A car weighs 4,000 pounds; its tires have been adjusted to a pressure of twenty-five pounds per square inch. Assuming that the car's weight is equally distributed, how many square inches of each tire's surface will be flat on the ground? What reasoning is behind your solution to the problem?

13. A spherical balloon weighing one pound empty is three feet in diameter when filled with helium. It would have what lifting power? (Weight of helium per ft$^3$ may be found in a physics book.)

14. Present a diagram and explanation of the Westinghouse Air Brake. (This brake is used on trains.)

15. Explain the functioning of a "jack-hammer."

16. Explain the functioning of an air pressure paint sprayer.

17. Place a moistened piece of water-resistant cardboard over a half-filled glass of water. Press in on the center of the cardboard and invert the glass. Release your hold on the cardboard with the glass inverted. Result. Turn the glass sideways. Result. Submit an explanation.

18. Place a thumb tack through the center of a playing card or card of similar size. Hold the playing card against the bottom of a wooden thread spool with the tack centered in the opening. Blow vigorously down through the opening in the spool and release the card as you do. Result? What is the explanation? (Look up Bernoulli's principle.)
19. How much air pressure can you exert above normal air pressure by blowing with your mouth? You will need to make a manometer to measure this.

20. Record barometer readings over a several-days period. Make observations of weather conditions at the time you make the readings. What relationships exist between your barometric readings and observed weather conditions?

21. What happens when a toy balloon that has been filled with air is released? Explain in terms of unbalanced forces due to air pressure and design of the balloon. Use a diagram. How is this similar to rocket and jet propulsion? Why does rocket propulsion work best in space?

22. Why does an inflated basketball bounce when dropped on a hard surface?

V. UNIT V--FIRE, TEMPERATURE, HEAT

Concepts

1. Oxidation, combustion, and products of combustion
2. Conditions necessary for combustion
3. Heat and molecular motion, change of state
4. Kindling temperature
5. Spontaneous combustion
6. Fahrenheit and centigrade temperature scales
7. Temperature and heat content
8. Convection
9. Conduction
10. Radiation
11. Heat and expansion
12. The thermostat
13. Refrigeration
14. Methods of determining temperature
15. Fire safety
16. Color and absorption and radiation of heat energy

**Quantitative Problems**

1. Quantity of heat lost or gained

2. Fahrenheit and centigrade comparison

**Vocabulary**

- combustion
- oxidation
- kindling temperature
- soot
- calorie
- British thermal unit
- conduction
- convection
- radiation
- temperature
- heat

**Quantitative Problems**

1. Make an accurate drawing of the Fahrenheit and centigrade scale, placing them side by side with equal vertical space between those points on the two scales that represent the freezing and boiling point of water.

2. Converting centigrade to Fahrenheit temperatures:
(a) How does the centigrade degree compare with the Fahrenheit degree as an indication of temperature change?

(b) How may a temperature change of several centigrade degrees be stated in its Fahrenheit equivalent?

(c) Because the Fahrenheit scale does not have its zero reading at the freezing point of ice, what number of degrees must be added after converting the number of centigrade degrees to Fahrenheit degrees?

(d) Apply the information developed and state a relationship whereby centigrade may be converted to Fahrenheit temperatures.

3. Convert Fahrenheit to centigrade temperatures:

(a) How does the Fahrenheit degree compare with the centigrade degree?

(b) How may a temperature change represented by several centigrade degrees be represented in Fahrenheit degrees?

(c) How must the Fahrenheit reading be adjusted before converting? Its zero and that of the centigrade do not represent the same temperature?

(d) State a relationship whereby Fahrenheit may be converted to centigrade readings.

4. Convert these temperatures to the other temperature scale by first interpreting the drawing made for problem one and then by mathematical means:
5. A bucket containing ten pounds of water warms up during the day from 40°F to 55°F. How much heat has been absorbed by the water?

6. A beaker of boiling water cools to room temperature of 22°C. It contains 90 g of water. It has lost how much heat in cooling?

7. Fifty grams of water at 100°C are mixed with 30 g of water at 80°C. What will be the final temperature of the mixture?

8. Solve algebraically for the temperature at which the centigrade and Fahrenheit scales are equal numerically.

Problems

1. Distinguish between oxidation and combustion. Using a Bunsen burner, beakers and limewater identify three products of combustion of the gaseous fuel. What evidence indicates the presence of each product? Account for the products in terms of the chemical formula of the fuel.

2. Using a Bunsen burner and a wire gauze, demonstrate the conditions necessary for combustion.

3. Compare several substances as to their relative kindling temperature. Investigate the state of subdivision as a factor in the kindling temperature of a substance.
4. Set up a condition which demonstrates the conditions leading to spontaneous combustion. Represent the time and temperature change relationship with a graph. What causes the change in temperature? What condition must be met before combustion takes place?

5. Set up an experiment that will demonstrate the difference between temperature and heat content.

6. Determine the amount of heat given up by a hot quantity of water and the amount taken on by a cold quantity of water when they are mixed together.

7. Perform and report in writing the results of demonstrations which illustrate the transfer of heat by:
   - (a) conduction, (b) convection, and (c) radiation.

8. Perform and write up demonstrations which investigate the effect of heat upon a solid, a liquid, and a gas in terms of expansion.

9. Subject the bimetallic strip to temperature change. Results. Why does the strip respond in this fashion? With the aid of a diagram, explain how a bimetallic strip is used in a thermostat.

10. Diagram the refrigeration cycle. Explain what is happening in terms of kinetic energy of molecules in each phase of the cycle.

11. Describe three methods of measuring temperature other than the expansion of a liquid.

12. Make a list of all the fire hazards you recognize that are in the picture on the bulletin board. Set up
a rating scale and inspect your home for these hazards.
13. Explain as thoroughly as you can how your home is heated. Include diagrams of the heating equipment. Indicate where conduction, convection, and radiation are taking place.
14. Explain how the thermos bottle is made to prevent heat transfer by conduction, convection, and radiation.
15. Experimentally investigate this problem. How does the color of an object affect its ability to absorb and radiate heat energy?
16. Work the quantitative problems.
17. Complete the vocabulary list.
18. Using diagrams, explain how a hot water or steam heating system functions. What is the main difference between the systems?
19. Discuss the heat problems that would be involved in sending a man to the moon and in his exploration of the moon.
20. How much heat do different size light bulbs produce when they "burn" for a period of time?
21. Design a piece of equipment that will trap the radiant energy from the sun.
22. Experimentally develop the relationship between surface pressure and boiling point of a liquid.
23. Make a thermometer similar to the one that Galileo made using air as the expanding and contracting medium.
Explain its operation. What shortcomings does it have?

24. Starting with water at the freezing point, make a study of the effect of heat upon its volume as it is warmed to the boiling point.

25. Determine experimentally the number of calories that are required to melt a gram of ice.

26. What is the Kelvin temperature scale? What is the relationship between 0°C Kelvin temperature and molecular motion in a substance? How do the centigrade and Kelvin temperature scales compare?

27. Explain one method of determining the temperature of a star.

28. Count Rumford and James Prescott Joule each stated important generalizations concerning heat. What important conclusion did each reach and what observation or experiment led them to this?

VI. UNIT VI--WATER AND WATER PRESSURE

Concepts

1. The water cycle
2. Dissolved gases in water
3. Taste in water
4. Water level
5. Pressure and depth
6. Ways to destroy bacteria in water
7. Separating water from dissolved matter
8. Removing sediment from water
9. Removing odors and color from water
10. Action of soap
11. Hard water, soft water
12. Plumbing system of a house
13. The water meter, how to read it, cost of water
14. Water pressure is equal in all directions from a point
15. Buoyancy of water
16. Hydraulic machines (Pascal's principle)
17. Water power

Quantitative Problems
1. Pressure in water
2. Buoyant force
3. Hydraulic cylinder relationships

Vocabulary
cesspool
septic tank
organic waste
aeration
precipitate
filtration
distillation

Quantitative Problems
1. A water tank six feet deep and ten feet square is filled with water. (a) What is the pressure at the bottom of the pool in lbs/in²? (b) What is the pressure at the bottom of the pool in lbs/ft²? (c) What is the total force on the bottom of the pool?
2. A one cubic foot object weighing sixty-five pounds in air is placed in a lake. (a) Will it sink or float? Why? (b) What buoyant force is acting upon it? (c) If it goes to the bottom, what force would be required to lift it?

3. A one cubic foot object weighing 15.6 pounds in air is placed in a lake. (a) Will it sink or float? Why? (b) What buoyant force is acting upon it? (c) If it floats, what fractional part of it will be sticking out of the water?

4. One cubic centimeter of iron weighs seven grams in air. It is dropped into water several centimeters deep. What force would be required to lift the iron off the bottom?

5. A city water tower is one hundred feet high. It is full of water. In a nearby building a water faucet at a height of sixty feet would have what water pressure available?

6. A hydraulic press has a large piston with a crosssectional area of 100 in² and a small piston with a crosssectional area of 2 in². A force of one pound is applied to the small piston. (a) Neglecting friction, what force would the large piston exert? (b) If the small piston moves one inch, how far will the large piston move?
7. Show mathematically that the buoyant force on a one foot cube is equal to the weight of the water displaced. Assume that the top of the cube is one foot below the surface of the water.

Problems

1. What is the water cycle? How are certain aspects of world rainfall patterns related to the water cycle?

2. With the aid of a vacuum pump and various temperatures of water, investigate the effect of temperature and pressure as factors influencing the amount of dissolved gas in water. Can you account for the appearance of stale water?

3. Water varies in taste in different localities. Explain why this is true and where and how the water acquires its taste.

4. What happens when water is put into connected tubes that are open at the top? What generalization can you make concerning what happens to liquids when placed in such containers? What is a practical application of this?

5. Using a Pascali's vase, apparatus, study the effect upon pressure of depth and shape of a container for liquids.

6. How may water become impure for drinking? List several diseases that may be transferred by impure water. Explain three ways in which bacteria in water may be destroyed.
7. Water entering a city water system is found to be "hard," contain sediment, have too high a bacterial count, and an undesirable odor and color. How could these conditions be remedied so that a large supply of water could be made available to the city?

8. What does soap do to make the cleaning action of water more effective?

9. What is meant by the terms "hard water" and "soft water"?

Using hard and soft water, compare the amount of soap suds that may be produced by equal amounts of a soap. Why does hard water require a greater amount of soap to be equally effective?

10. How does a trap function in a drain line of a plumbing system? Why must there be an air vent in the drain line between a sink trap and the soil pipe? Use diagrams in your explanation.

11. Make a drawing of the plumbing system in your home. Include both water and removal systems. Explain how both systems operate.

12. How much does the water used in your home cost each day? Read your water meter once a day at the same time for five days. Determine the amount of water used each day for the four-day period and determine its cost. On the basis of a four-day period, what will water cost your family for the year?
13. Is pressure equal in all directions in a liquid? Explain the functioning of any equipment used in the investigation of the question.

14. Determine the buoyant force that will be acting on an object that sinks in water by (a) calculation, and (b) experimentation.

15. Calculate how far a wooden block would sink were it to be placed in water.

16. What is the explanation for the Cartesian diver? Include a diagram.

17. Using Pascal's principle and a diagram, explain the relationship that exists in a hydraulic press.

18. How is water used to produce mechanical energy? Explain.

19. Complete the quantitative problems.

20. Complete the vocabulary definitions.

21. What is the nature of the Ankeny water system? Discuss the following: (a) source of water, (b) purification, (c) water softening, (d) distribution system.

22. What is the nature of the Ankeny sanitary disposal system?

23. What is the nature of the Des Moines water system?

24. How is the cost of water determined in Ankeny?

25. How does a hydraulic hoist similar to one that would be found at a gas station work? Include a diagram in your explanation.
26. Test powdered charcoal or boneblack for its effectiveness in removing various coloring materials or odors from water.

27. New York City and Chicago have interesting water systems. Report on one of these considering such aspects as supply, distribution, and treatment.

VII. UNIT VII—MAGNETISM AND ELECTRICITY

Concepts

1. Historical development
2. The nature of electricity and the electron
3. Static electricity and friction
4. Electricity through chemical action
5. Magnetism and the atoms structure
6. The magnetic field around a magnet
7. The magnetic field around a conductor and the electromagnet
8. The generator
9. Electrolysis
10. Electroplating
11. Heating effect of electricity
12. How a wire conducts an electric current
13. Series and parallel circuits
14. Ohm's Law
15. Cost of electricity
16. The doorbell
17. The electric motor
18. Home wiring
19. Alternating and direct current

Quantitative Problems
1. Using Ohm's Law
2. The cost of electrical power

Vocabulary

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<td>volt</td>
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<td>galvanometer</td>
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Quantitative Problems
1. How many amperes will flow through a circuit having three ohms resistance if the pressure is six volts?
2. What is the resistance in a circuit if one ampere flows under a pressure of 120 volts?
3. A circuit has fifteen ohms of resistance and eight amperes of current are flowing through it. What is the electrical pressure in the circuit?
4. How many amperes does a 220 watt appliance draw on a 110 volt circuit?
5. How many kilowatt hours of electrical energy are consumed by six seventy-five watt light bulbs if they are used ten hours?

6. What is the cost of operating a seven-hundred watt electric iron for five hours at three cents per kilowatt hour?

Problems

1. The following men made contributions to man's knowledge concerning magnetism or electricity: Thales, Benjamin Franklin, Galvani, Hans Christian Oersted, Ampere, Joseph Henry, and Michael Faraday. Tell the nature of their contribution, its date, and the country of the man.

2. (a) What is electricity? (b) Find out the following information about an electron: (1) mass, (2) nature of its charge, (3) how it is influenced by a magnetic field (make a diagram showing how this may be demonstrated), and (4) their visibility. Can we see them?

3. Cause two pith balls to attract one another and then to repel each other. What is the explanation? What is static electricity and how does friction play a part in its creation?

4. Make a one-celled battery using dilute sulfuric acid, a copper and a zinc strip. Connect the wires to a voltmeter. What explanation can you offer for the working of the cell?
5. What is the explanation of magnetism? Is it related to atomic structure? Use diagrams to illustrate your explanation.

6. Demonstrate the nature of the magnetic field around a magnet using magnets, a plate glass square, and iron filings. With drawings indicate the nature of the field when like poles are influencing the iron filings and when unlike poles are. Note: Keep the iron filings separated from the magnet by the glass plate at all times.

7. Set up a demonstration that will show the magnetic field around a conductor. Make an electromagnet using a nail, a cell and an insulated wire. Change the number of turns in the wire and the amount of current flowing. How does this influence the effectiveness of the electromagnet?

8. Move a magnet back and forth through a coil of wire that is attached to a galvanometer. What kind of current is this? Make a diagram of our hand generator and explain why it produces an electric current.

9. Make a diagram of our electroplating apparatus and answer the following questions in your explanation: (a) Where does the metal come from that will form the plating? (b) Why is the material to be plated made the electrode to which the electrons are coming?
10. Make a diagram of our electrolysis apparatus. In your explanation, answer the following questions:
   (a) From where do the electrons come? (b) From where do the ions come? (c) What happens to electrons at each electrode? (d) What happens to ions at each electrode?

11. The following phenomena are related to the heating effect of an electric current. Can you explain them?
   (a) A toaster gets hot, the electric wire leading to it does not. (b) If the same current flows through two wires of the same size but different lengths, the longer wire produces the most total heat. (c) A larger diameter wire of the same length as a smaller diameter wire will produce less heat if the same current flows through them. (d) A fuse burns out when a short circuit occurs in a house circuit.

12. Make a diagram with explanation which illustrates in terms of an atom's electrons how a wire conducts an electric current.

13. (a) Make a diagram showing two cells in series and two resistances in series in a circuit.
   (b) Make a diagram showing two cells in parallel and two resistances in parallel in a circuit.
   List the advantages and disadvantages of each kind of wiring.
14. Design and carry out an experiment in which the effect on the amount of current flowing is determined as the voltage and the resistance in the circuit are changed.

15. Read your electric meter each day for several days and determine the cost of electrical energy for each day.

16. After trying out the demonstration electric doorbell, make a diagram explaining how it works. Include a diagram showing how you would wire it in a house so that it might be operated from both the front and rear door.

17. Assemble our demonstration electric motor and operate it. Make a labeled diagram of it. Explain why it runs.

18. Find out which lights and wall plugs and other outlets such as to an automatic furnace are on each circuit in your home. Develop a diagram to represent this. (Work only under your father's supervision on this.) Explain the purpose of the fuse (or circuit breaker) as used in your house.

19. Learn the vocabulary terms. Follow the vocabulary problem procedure.

20. Work the quantitative problems.

21. Diagram the wiring for a hall light that might be turned on by a switch located at each end of the hall.
22. Try making a battery using silver and copper coins, a salt solution, and pieces of a blotter. Using a voltmeter, make a study of the voltage produced as the number of coins used is increased. Can you offer an explanation of why the cell works?

23. Make a report on the nature of lightning. Include a discussion of the following: (a) its cause, (b) what happens to the air to permit the charge to move, (c) what lightning rods do, and (d) why the lightning rods are pointed.

24. Make a report on Franklin's experiment with a kite.
What did Franklin prove in his experiment? Explain why this experiment was very dangerous.

25. Construct an electric motor using dime store materials or materials you have at home. Explain why it runs.

26. Explain why these are dangerous practices with electricity: (a) putting a penny behind a fuse to put a circuit in operation, (b) touching a light or electrical appliance while you are bathing or standing on a wet floor, (c) leaning a metal ladder against a power line, (d) using an extension cord that has the insulation worn off, or (e) putting in a thirty amp fuse where a fifteen amp fuse should be located.

27. Make a report on one of these occupations, covering educational requirements or training, type of work done, pay, and opportunities: (a) electrical engineer,
(b) electrician, (c) power company lineman, and (d) appliance repairman.

28. What is an electroscope? Make one and explain how it works.

29. Make a diagram of the ignition system of a car and explain its functioning as thoroughly as you can.

VIII. UNIT VIII--COMMUNICATION USING ELECTRICITY, MAGNETISM, AND ELECTROMAGNETIC WAVES

Concepts

1. Historical development of the field of communication
2. Telegraph
3. The Transformer
4. The telephone
5. Electromagnetic waves
6. Carrier wave, audio wave
7. Microphone to speaker through radio waves
8. The ionosphere, wave length, and radio reception
9. AM and FM broadcasting
10. The photoelectric effect
11. The television camera tube
12. The television picture tube
13. Radar

Quantitative Problems

1. Relationship between velocity, frequency, and wave length in electromagnetic radiation.
Vocabulary

antenna  microwaves
audio frequency electronics
microphone  ground waves
photoelectric cell  sky waves
radar  transformer
radio frequency  secondary transformer coil

telegraph relay  primary transformer coil

Quantitative Problems

One may liken the walking of an individual to the movement of electromagnetic radiation where the speed of walking (velocity) is equal to the length of the step times the number of steps per unit of time. In the movement of electromagnetic radiation in place of a step we could think of a wave length and the number of wave lengths per second is the frequency.

It is customary to represent velocity by the symbol v, the wave length by the Greek letter lambda, and the frequency by the letter f. The relationship then becomes:

\[ v = \lambda f \]

velocity = (wave length) (frequency)

1. A man can walk at a rate of three miles per hour for many hours (velocity). If he takes 120 steps per minute (frequency) what is the length of a step?

2. The spot on the dial that locates a radio station will also tell you the frequency at which a station is broadcasting. Station WHO broadcasts at a dial setting of 1020 kilocycles. A kilocycle is equal to 1,000 cycles. What would the wave length of the WHO signal be in feet? What would it be in meters?
3. What is the frequency (wave length/sec) of a radio signal that has a wave length of one hundred feet?

4. The velocity of electromagnetic radiation in meters/sec is 300,000,000. If the wave length of a radio wave at this frequency is five hundred meters, what is the frequency in kilocycles/sec?

5. Radar waves are about a meter long. What would their frequency be at this wave length?

Problems

1. Arrange the following developments in communication beginning with the first to occur. Indicate the date of the development and, if possible, the man who is credited with the contribution: radio, television, telegraph, telephone, Atlantic cable, wireless telegraph.

2. After observing the school's model telegraph set in operation, draw a labeled diagram of the sounder and the key. Explain the function of the key in causing the sounder to operate and the operation of the sounder.

3. Explain the principle of the transformer. Include also the following points in your explanation: (a) the purpose of the iron core, (b) the "step-up" (increase in voltage) transformer and the "step-down" (decrease in voltage) transformer, (c) the nature of the change in current that occurs as the voltage changes, and (d) transformers must have AC electricity.
4. Examine the school demonstration telephone. Draw a labeled diagram of the receiver and the transmitter. Starting with sound entering the transmitter, explain what occurs until the reproduction of sound in the receiver has occurred.

5. Make a chart of the electromagnetic spectrum showing the following: (a) list the common names for the types of radiation beginning with those of the shortest wave length, (b) tell how each type of wave may be generated, (c) tell of what use man has made of the different types of waves, and (d) the velocity of all electromagnetic radiation.

6. Explain what is meant by these terms: (a) audio frequency, (b) audio wave, (c) carrier frequency, and (d) carrier wave. Represent the effect of an audio wave on a carrier wave by means of transverse wave diagrams.

7. The ionosphere and the wave length upon which a radio station is broadcasting determine whether or not a distant radio station may be heard. In terms of these two factors, explain the following: (a) a distant station fades in and out, (b) some stations cannot be heard beyond a fifty-mile radius.

8. Starting with sound entering the microphone at the broadcasting station, briefly describe the way the signal travels until sound is reproduced in the loud speaker of a radio.
9. Radio signals: (a) explain what AM and FM mean in radio broadcasting, (b) using transverse wave diagrams, illustrate an AM and an FM signal, (c) why are FM stations not subject to static when you listen to them? and (d) why is reception from an FM station usually not good for a distance beyond fifty miles?

10. Observe the photoelectric cell in operation. Make a diagram of the cell and explain its operation. List ways in which man has applied the photoelectric principle.

11. Make a labeled diagram of a television camera tube. Explain how it works.

12. Make a labeled diagram of the television picture tube. Explain how it works.

13. Explain why radar can be used to find out the following information: (a) locate objects at night or behind clouds, (b) determine the distance to objects, and (c) determine how fast an object is moving.

14. Complete the quantitative problem list.

15. Complete the explanation and study of the vocabulary terms.

16. Visit one of the following and report on what you see: (a) a power station, (b) a telephone exchange, (c) a radio station, and (d) a television station.

17. The shorter radio waves are not reflected effectively back to the earth's surface by the ionosphere. There-
fore, stations using these wave lengths have a limited broadcasting range. If you figure the earth as a perfect sphere having a diameter of 8,000 miles, can you determine how much the earth curves for each mile of surface? How high would a broadcasting antenna need to be in order to send out a signal that could be picked up at the earth’s surface fifty miles away?

18. Make a diagram and explanation of how a crystal radio works.

19. Make a report on radio telescopes. What are they and how do the astronomers use them?

20. An electromagnetic wave is thought to be a disturbance of an electrical and a magnetic field which exist at right angles to each other. Draw a diagram of this phenomena. (Look in a physics book.)

21. How is it possible that a radio may be tuned to one station when the radiation from many broadcasting stations is cutting across its antenna?

22. What are transistors? Of what materials are they made? Why have they become so important to the electronics industry.

23. Using coils of wire, an iron core, and AC power source with appropriate electric meters, demonstrate the principle of the transformer.
IX. UNIT IX—SOUND

Concepts

1. The nature of sound
2. Sound waves
3. Frequency and pitch
4. Amplitude and loudness
5. Sound and a vacuum
6. Speed of sound in air
7. Speed of sound in various media
8. Reflection of sound
9. The ear and hearing
10. The voice box and the production of sound
11. Sympathetic sound vibrations, resonance
12. Sound production in musical instruments

Quantitative Problems

1. Velocity, frequency and wave length of sound

Vocabulary

vibration compression rarefaction percussion pitch fundamental sound wave echo timbre

musical scale wave length discord octave major chord overtone even-tempered scale music noise

Quantitative Problems

1. A tuning fork has a vibration of 256 c.p.s. What is the wave length of the sound produced?
2. The note A on the piano is tuned to a frequency of 440 vibrations/second. What is the wave length of the sound produced?

3. A clap of thunder is heard ten seconds after a flash of lightning is seen. How far away from the observer did the flash of lightning occur?

4. A ship sends out a depth sounding signal and the echo is returned in five seconds. How deep is the water at the location of the ship?

Problems

1. Demonstrate and explain with a tuning fork the nature of sound. What evidence do you have for your explanation?

2. Use a long spring to demonstrate sound waves. Make a diagram which represents sound waves. Explain the nature of sound waves. How are sound waves similar to and how do they differ from water waves? What are transverse waves and longitudinal waves?

3. Using tuning forks, demonstrate the relationship between frequency and pitch. Record your observations.

4. Using tuning forks, demonstrate the relationship between amplitude and loudness. Record your observations.

5. Using the vacuum pump, investigate this hypothesis: as the density of the air decreases, the efficiency of the transmission of sound decreases. What is the explanation? Could sound be heard in a vacuum?
6. Determine the velocity of sound in air experimentally.
7. Find out and list in tabular form the speed of sound in various media. Why does the speed of sound vary in these substances?
8. What is an echo? Why do we not hear echoes in an ordinary schoolroom? How are they prevented in large auditoriums?
9. Prepare a labeled diagram of a human ear. Starting with sound waves outside the ear, explain in detail the process by which it becomes the experience that we recognize as sound.
10. Explain how we are able, with our voice box, to produce sound and different kinds of sounds.
11. Using the tuning forks, demonstrate resonance (sympathetic vibrations), interference and reinforcement of sound waves, forced vibration. Briefly describe what these terms mean and what is happening when they are produced.
12. Using diagrams or the actual instrument, present to the class a thorough explanation of how various sounds are produced in a musical instrument.
13. Complete your written study of the vocabulary terms.
14. Complete the quantitative problems.
15. Using a watch and a quiet room, experimentally compare the hearing in your left and right ear. Report your results in organized form.
16. Compare experimentally the transmission of sound in air as compared to under water.

17. Describe a room or structure that would permit two people at opposite ends facing away from each other to converse with each other without a person standing in the middle of the room being able to hear them. Explain why this phenomena can occur.

18. Explain how phonograph records are made and played. What produces the sound?

19. Explain the stethoscope, its use, of what it consists, and how it functions.

20. Explain briefly the nature of an electric organ and how it reproduces sound.

21. Construct an instrument that will produce sounds of varying pitch and loudness.

22. The sound of a train whistle sounds higher as the train approaches and lower as the train goes away. How may this be explained? (Investigate the Doppler effect.)

23. It is possible to buy a whistle that cannot be heard by the human ear but still may be used as a signal that a dog may be trained to answer. What is the explanation?

24. Investigate the effectiveness with which sound can pass between two mediums; for example, air to water and water to air. Describe your experiment and report your observations.
I. UNIT X—LIGHT

Concepts

1. Historical development
2. The nature of the sun's radiation coming to the earth
3. The effect of the atmosphere on the sun's radiation
4. Shadows and eclipses
5. Absorption, reflection, transmission of light
6. Angle of incidence, angle of reflection
7. The image in a plane mirror
8. Refraction of light
9. Formation of images by lenses
10. The telescope
11. The microscope
12. The spectrum
13. The color of a transparent object
14. The color of an object that reflects light
15. Primary colors
16. Primary pigments
17. The camera
18. The eye
19. Defects of vision
20. The intensity of light and effect of distance upon it
21. The incandescent light and temperature relationship
22. The fluorescent light
23. The movie projector
24. The spectroscope

25. Color vision

Skills
1. The use of the microscope

Quantitative Problems
1. Speed of light
2. Spreading of light
3. Distance to stars in terms of light

Vocabulary

incandescense  focal length
opaque         luminous body
translucent   pigment
transparent    illuminated body
shadow         complimentary colors
incident ray   near sightedness
umbra          far sightedness
penumbra       astigmatism
real image     candle power
virtual image  lumen
reflection     concave lens
diffusion       convex lens
spectrum

Quantitative Problems
1. How long would it take for light to get from the sun to the earth in minutes?
2. The wave length of green light is about 1/50,000 of an inch. What is the frequency of green light?
3. The distance from a surface to a source of light such as a light bulb is doubled. How does the amount of light that is falling on the surface at the far distance
compare to the amount of light that was falling on it before it was moved? Can you illustrate this with a diagram?

Problems

1. What contribution did the following men make to man's knowledge of light or how to use it? Edison, Galileo, Janssen brothers, Newton, Daguerre, Michelson. Give the date of the contribution.

2. (a) Represent by a graph or chart the approximate relative amounts of the sun's radiation that is composed of ultraviolet light, visual light, and infra-red radiation.

(b) What are the effects of and how are ultraviolet light and infra-red radiation of use to man?

3. (a) How do the layers of the atmosphere and clouds affect the amount of the different types of radiation that reaches the earth's surface from the sun?

(b) What is the chemosphere? How does it affect the amount of ultraviolet light radiation that reaches the earth's surface?

4. Draw a diagram which illustrates how it is possible for a shadow to have varying intensity. Use proper terminology in labeling the shadow areas.

5. Represent by diagram the relationship that exists between the earth, the sun, and the moon when (a) an
eclipse of the sun occurs, (b) an eclipse of the moon occurs.

6. (a) With respect to a beam of light striking a surface, what is meant by the angle of incidence and the angle of reflection of the light?
   (b) Using a plane mirror, determine the relationship of the angle of incidence to that of the angle of reflection.

7. Using a mirror, establish the relationship between the object and the image in a plane mirror in terms of
   (a) apparent distance of image from the mirror as compared to actual object distance from the mirror,
   (b) the reversal of the image as compared to the object.

8. (a) Using a beaker of water and a coin, illustrate the bending of light as it goes from one medium to another.
   Explain the observed phenomena with a diagram.
   (b) Why do fish appear to be closer to the surface of water than they usually are? (Explain with a diagram.)

9. Demonstrate the following and illustrate with diagrams:
   (a) a convex lens bringing parallel rays of light to a focus, (b) formation of a real image by a convex lens, (c) formation of a virtual image by a convex lens.

10. Using two convex lenses and a cardboard tube, arrange them so they function as a refracting telescope.
   Diagram the lens arrangement and show how the images are formed.
11. Using two convex lenses, arrange them so that a compound microscope is formed. Show by diagram how light passes through the lenses to form the real and the virtual image.

12. Hold a prism up to light so that a spectrum is formed. Represent by diagram the spreading of light as it passes through a prism. Indicate the arrangement of the colors of light according to degree of refraction as it falls on a target.

13. Using a glass square and pins, demonstrate this statement concerning the refraction of light: light is bent toward the normal as it enters a medium of greater optical density and away from the normal as it enters a medium of lesser optical density.

14. Using colored transparent glass plates and a source of white light, gather data which will permit a statement to be made on the nature of the color of a transparent object.

15. Expose variously colored objects to various colors of light from one source. Catch the reflected light on a white screen. Form a summarizing statement as to the color of an object that reflects light.

16. Using the colored light projector, observe and record the result of projecting the primary colors of light (red, blue-violet, and green) on to a white screen. Make a chart of the colors produced; include the areas of overlap.
17. Using the chart developed in problem 16, predict which pairs of colors will be complementary combinations. Check your predictions with the color projection apparatus.

18. Using the color projection apparatus, subject the primary colors of light to their complementary color of paper. Catch any reflected light on a white screen. What happens to the light? The colors of the complements of the primary colors of light are the primary pigment colors. Explain the color of an object that appears black when white light shines upon it in terms of pigments and how they effect light.

19. Explain by means of a diagram the image formation in a camera.

20. Draw and label a diagram of the eye, indicate the function of each part of the eye and show the path of light through it in such a way as to indicate how images are formed.

21. Describe the sight problems that the following eye conditions refer to: (a) near-sightedness, (b) far-sightedness, (c) astigmatism. Indicate how each of these conditions may be corrected. Use diagrams if you wish.

22. The most generally accepted theory of color vision is called the Young-Helmholtz Color Vision Theory. How is color vision explained by this theory?
color blindness explained?

23. Observe the color wheel as it is rotated. What do you observe? How do you explain this?

24. Explain the relationship between the color and the amount of light that is produced by a heated wire and the temperature of the wire. How does the ordinary incandescent light bulb function?

25. Observe the fluorescent light produced as ultraviolet light is directed at appropriate samples. Discuss the production of this light and the functioning of the fluorescent room lights as thoroughly as you can.

26. Observe several spectra with a spectroscope. Record your observations. How may your observations be accounted for in terms of atomic structure? Use a diagram of an atom in making your explanation.

27. Complete the work on the vocabulary list.

28. Complete the quantitative problem list.

29. Explain these aspects of motion pictures: (a) the projection of the image onto the screen (diagram), (b) the film comes to a stop twenty-four times/second as it passes through the film gate. Why? (c) the image appears to be in constant motion as we observe the film. Why?

30. Stare intently at a one-inch (in diameter) red circle for a period of two minutes. Now look quickly at a white paper. What do you observe. Try the same
thing with a blue dot. How do you explain your observations?

31. Using a diagram, explain how Albert A. Michelson was able to determine the velocity of light.

32. Explain with a diagram why it is that the sun appears red at sunset and sunrise.

33. Why is it that the sky appears to be blue on a cloudless day?

34. Light is said to travel in straight lines. Why is it possible to see a flashlight beam at night that is not pointed towards you?

35. Describe what light conditions would be like in space. Explain why these conditions would exist.

36. We see the sun in the morning before it is above the geometric horizon and after it is below the geometric horizon in the evening. In terms of refraction of light, explain these phenomena.

37. Diagram and label the parts of one of our microscopes. List the rules for adjusting and safe operation of a microscope. Check the magnification under low and high power by putting an object of known size under the microscope and compare this to the drawing you make of the image you see in the microscope.
XI. UNIT XI--ASTRONOMY, EARTH, AND TIME

Concepts

1. Kinds of heavenly bodies, and groups of bodies
2. Our solar system
3. Observed and actual magnitude of stars
4. Measurement of distance to stars
5. The earth and the milky way
6. Relative motions of the heavenly bodies
7. Relative motions of the earth and the moon
8. Tides
9. Eclipses
10. Seasons and their lag
11. Time on the earth; international date line
12. Tilt of the earth and its effects on daylight
13. Locations on the earth
14. The pendulum and time
15. The age of the universe
16. Evolution of stars
17. Evidence that the earth is round

Quantitative Problems

1. Velocity of the earth in its orbit around the sun
2. Velocity on various parts of the earth due to the motion of the earth on its axis
3. Time relationships for different places on the earth
4. The earth's shadow
Quantitative Problems

1. How far does the earth travel in its orbit around the sun each year?

2. How fast is the earth traveling as it moves in its orbit around the sun?

3. Objects on the surface of the earth have motion from the rotation of the earth on its axis. Consider only this motion and determine the velocity of (a) a man at the equator, (b) a man at a latitude of 45° north or south, (c) a man at the North Pole.

4. It is 3:00 AM on a Monday in Ankeny, Iowa. What day and time is it in the following places: (longitudes are approximate) (a) London, 0° longitude, (b) Moscow, 45° E. longitude, (c) Tokyo, 145° E. longitude, and (d) Honolulu, 165° W. longitude.

5. How long is the earth's shadow?

6. What is the diameter of the earth's shadow where the moon passes through it?
Problems

1. List and describe the different types of heavenly bodies or groups of bodies (moon, star, planet, galaxy, constellation, comet) in terms of size, motions, density, distance from us.

2. Describe our solar system. Use a diagram and explanation.

3. Considering ourselves with the universe as a frame of reference, describe the various types of motion we are experiencing.

4. What is the difference between apparent and actual magnitude of stars. Two stars are of equal actual brightness and size if they could be observed from the same distance. Star A, however, is five times as far away as Star B. How will they compare in apparent magnitude? (The brightness of a point source of light varies inverse with the square of the distance from the source to the observer.)

5. By using a diagram and by expressing distance in terms of light years, discuss the shape and size of the galaxy in which the earth is located, the "Milky Way." Also indicate the approximate location of the earth in the galaxy.

6. Assuming that the moon is 240,000 miles away, determine experimentally its size.

7. Explain what is meant by parallax and how this may be used to determine the distance to a close star.
8. How may the light coming from distant stars serve as a means of approximating the distance to them?

9. By diagram represent the motions of the earth and the moon with respect to each other and the sun. Is the earth's orbit affected by the moon?

10. Explain how it is possible for a satellite from earth to be placed in orbit. Why have some of these satellites from the earth returned to the earth's atmosphere and have been destroyed?

11. What is the cause of tides? What bodies are involved? Show by diagram under what conditions of moon, sun, and earth position strong and weak tides will occur.

12. Explain by diagram an eclipse of the sun and of the moon.

13. Explain the system of latitude and longitude which enables any point on the earth to be referred to with precision. Is it usually demonstrated the relation of

14. How can longitude be determined by time? How may latitude be determined by sighting the stars?

15. Explain the following: (a) our nine hours of daylight in winter and fifteen in summer, (b) twenty-four hours of daylight part of the year above the arctic circle, (c) the middle of the heating season occurs about a month after the shortest day, our hottest weather a month after the day with the most light.

16. Make a device using concentric circles of varying size that will illustrate the relationship between the
International Date Line, longitude, the day, and the
time anywhere on earth, when it is a certain time
at Ankeny, Iowa.

17. Establish experimentally whether it is the length of
the pendulum, the size of the arc the pendulum fol-
 lows, or the weight of the pendulum bob which deter-
mines its frequency.

18. Explain why these observations of the early Greeks
(before Christ) led them to believe that the earth
was round: (a) the nature of the shadow that traveled
across the moon during an eclipse of the moon, (b) the
gradual disappearance into the sea of ships as they
traveled toward the horizon, (c) the change in angle
above the horizon that was noted concerning stars
as they (men) traveled either north or south.

19. How did J. B. L. Foucault demonstrate the rotation of
the earth on its axis? Explain.

20. What is meant by the Coriolis effect? Explain how it
is an indication that the earth is rotating on its
axis?

21. What is meant by the terms heliocentric and geocentric?
What evidence can you cite that would show that the
earth is going around the sun rather than the sun
around the earth?

22. Complete the vocabulary definitions.

23. Complete the quantitative problems.
24. Report on the age of the universe. Upon what evidence is this estimate of the age of the universe made?

25. How are stars thought to be formed?

26. Present one or more theories of the origin of the solar system.


30. Explain why the North Star will not always be directly above the earth's geographic north.

31. From an up-to-date source, secure information for a report on the nature of space.

XII. UNIT XII--MACHINES AND THE STEAM AND GAS ENGINES

Concepts

1. Work and how it is measured

2. Power, horsepower

3. What machines can do, mechanical advantage

4. Friction

5. Efficiency of machines

6. Three classes of levers

7. The pulley

8. The wheel and the axle

9. Inclined plane and the wedge

10. The screw
11. Belts, gears, chains
12. Compound machines
13. The power from fuels and steam
14. The steam engine
15. The gasoline engine

Quantitative Problems

1. Work
2. Power, horsepower
3. Lever
4. Efficiency
5. Inclined plane
6. Mechanical advantage

Vocabulary

<table>
<thead>
<tr>
<th>work</th>
<th>compound machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>power</td>
<td>foot-pound</td>
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<td>force</td>
<td>fulcrum</td>
</tr>
<tr>
<td>machine</td>
<td>resistance</td>
</tr>
<tr>
<td>lever</td>
<td>horsepower</td>
</tr>
<tr>
<td>pulley</td>
<td>input of machines</td>
</tr>
<tr>
<td>wheel and axle</td>
<td>output of machines</td>
</tr>
<tr>
<td>inclined plane</td>
<td>actual mechanical advantage</td>
</tr>
<tr>
<td>wedge</td>
<td>theoretical mechanical advantage</td>
</tr>
<tr>
<td>screw</td>
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</tbody>
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Quantitative Problems

Work = (Force) (Distance), \( W = F S \)

1. A five-pound object is lifted to a height of ten feet.

What would be the work accomplished in ft-lb?

2. A fifty-pound push is required to slide a heavy box over a warehouse floor. The box is moved fifteen feet.
What work must be performed in overcoming friction to move the box this distance?

\[
\text{Horsepower} = \frac{\text{Work in ft-lb}}{(550 \text{ ft-lb/sec}) (\text{time in sec.})}
\]

3. What is the horsepower of an engine if it can do 3,300 ft-lb of work in three seconds?

4. An input of one hundred ft-lb is required to lift a twenty pound load four and one-half feet. What is the efficiency of this pulley system?

5. (a) Explain by means of a diagram how a first-class lever six feet long may be used to lift a resistance of one hundred pounds with a force of twenty-five pounds.

(b) Solve the problem algebraically. This relationship exists for levers: \( (\text{length of force-arm}) \times (\text{force}) = (\text{length of resistance arm}) \times (\text{resistance}) \).

6. What force would be required to push a five hundred pound barrel up an inclined plane that is one hundred feet long and five feet high? (Disregard rolling friction.)

Note: In simple machines, the distance the force moves divided by the distance the resistance moves (in case of the inclined plane vertical distance of the resistance) gives the theoretical mechanical advantage.

7. For problem six, assume the force required to overcome rolling friction of the barrel is five pounds. What
is the theoretical and actual mechanical advantage for the inclined plane in problem six?

Problems

1. How much work do you accomplish in moving your body and what horsepower do you generate as you first walk up a flight of steps and second, run up the steps?

2. Explain the following: (a) list three ways that machines can serve us, (b) what is meant by the term mechanical advantage? (c) if force is multiplied by a machine, how are distance and speed effected?

3. Using a spring balance, compare rolling and sliding friction for a flat object by pulling it with and without rollers under it. How do your results compare with the statement found in the physics book which says that sliding friction is one hundred times greater than rolling friction for some materials? Would it be possible to have a 100 per cent efficient machine? Explain.

4. Diagram the three classes of levers and explain how each type may be used to advantage.

5. Design and put together a pulley system that will enable you to lift a resistance of 300 g with a force of less than 100 g. By counting the number of lines coming from the moveable pulley you can determine the mechanical advantage of the system. By comparing the force
required to lift the resistance to the theoretical force required were the pulleys frictionless, determine the efficiency of the system.

6. How are the handle bars of a bicycle together with the goose-neck, the front fork, and wheel similar to a wheel and axle of a simple machine? Calculate the mechanical advantage that is available to turn a bicycle by comparing width of the handle bars to the length of the tire surface on the ground when a rider is on the seat.

7. Using our inclined plane, the car, and a protractor, determine how much force is required to lift a 1000 g load up a 5 per cent, a 10 per cent, and a 30 per cent incline. What actual mechanical advantage exists in each case? What theoretical mechanical advantage exists for each trial?

8. Explain with diagrams how a screw and a wedge are similar to an inclined plane.

9. Explain with diagrams what is meant by a worm gear, a level gear, and a spur gear.

10. By the use of diagrams, show how different size wheels may be connected by belts or chains to gain force, to gain speed, or to change direction.

11. What simple machines are found in each of the following compound machines: (a) vice, (b) meat chopper, (c) faucet, and (d) can opener?
12. By working with a small measured amount of water in a flask and a balloon, determine the approximate expansion of water as it turns to steam.

13. Diagram the valve arrangement for the piston and cylinder of a steam engine as used on a steam locomotive. Explain how it functions.

14. Draw a series of diagrams which illustrate the strokes in a four-cycle gasoline engine. Indicate the direction of the piston's motion and whether or not the valves are open or closed during the stroke.

15. Discuss how the force from the pistons is transferred to the road surface by a car. Mention any simple machines that you recognize in the power transfer. Name the parts of the car that are involved.

16. Complete the vocabulary definitions.

17. Complete the quantitative problems.

18. What mechanical relationship in terms of force applied and force to move the bicycle exists between the pedal and the rear wheel of a bicycle? How would you design a bicycle so that you could ride it up hills more readily? Why would this work?

19. Write a report on the history of an early tool or machine; for example: the plow, the sewing machine, the reaper, the steam or gas engine, and the Diesel engine.
20. Secure an old clock or similar instrument and mount a display of different type gears.

21. Calculate the theoretical mechanical advantage of a car jack.

22. Calculate the mechanical advantage of a hammer. A fifty pound pull on the hammer handle could exert how much pull in removing a nail?

23. Report on how the pyramids were built and the use of simple machines in building them.

24. Determine the friction in a bicycle in transferring force from the pedal to the rear wheel.

25. Make a report on the nature of friction considering the cause and methods used to overcome it.

26. Discuss the arm and hand as levers. Use diagrams to illustrate your report.
CHAPTER IV

SUMMARY

The purpose of this study was to develop science problems for a problems approach to the teaching of general science in the ninth grade at Ankeny High School. A science problem in this study was considered to be a question or statement pertaining to science that would provide a basis for a student investigation. The problems were prepared and used to teach a general science class during the 1960-1961 school year. The class using the problems was a select group of students. These students represented the more mathematically inclined one-third of the 1960-1961 ninth-grade class. Student class work during the year consisted of a series of problem investigations.

A survey of the literature was made to determine:
(1) criteria for the development of science problems, and
(2) the effectiveness of a problems approach as a method of teaching science.

The procedures employed in the development of the problems involved several steps. The first of these was the establishment of course objectives. These were established by considering the needs of the Ankeny High School general science program and objectives common to science courses.

Course content was established and organized into the following units:
1. Measurement
2. Matter and Energy
3. Chemistry
4. The Atmosphere and Air Pressure
5. Fire, Temperature, and Heat
6. Water and Water Pressure
7. Magnetism and Electricity
8. Communication Using Electricity, Magnetism and Electromagnetic Waves
9. Sound
10. Light
11. Astronomy, Earth, and Time
12. Machines, and the Steam and Gas Engines

The units were concerned essentially with the physical sciences. Biology topics usually found in general science were omitted because of the emphasis upon them in seventh and eighth grade, and because of the number of Ankeny High School students who elect biology in the tenth grade. The information in each unit was classified into the following categories: (1) concepts, (2) quantitative relationships, (3) skills, and (4) vocabulary. The types of problems required to satisfy course objectives and types of learnings within the units were determined.

The class was organized in the use of room facilities, time, and method of problem reporting. A system of evaluating problems and grading was established. Unit tests were developed. The problems were developed in the context of the
foregoing organizational procedures. The ideas for some of the problems were taken from textbooks and laboratory manuals. Other problems were developed by the writer. The problems were used in class as the units were developed. The problems were of the following types: (1) investigation requiring use of the "scientific method", (2) learning vocabulary terms, (3) quantitative relationships, (4) learning of a skill, and (5) those requiring explanation or information. A system of checking the problems to determine how adequately course objectives and unit subject matter content had been covered was established. This system was used to check the coverage in Units I, IV, and V.

At the end of the school year, the class taught by the problem method was given the same final test that had been used with a general science class in the previous year. The classes, in the opinion of the writer, were similar in that the same method of screening was applied to the incoming freshmen groups in establishing classes. The class from the previous year was taught using a traditional assignment-recitation approach. The test was objective in nature. The results of the test suggested that the use of problems as a method of teaching science compares favorably with the assignment-recitation method of teaching in terms of imparting information.

It is the writer's opinion that the problems approach, using the problems developed in this study, contributed in several ways to the general science program at Ankeny High School.
Increased opportunity for problem solving was provided. The range of problems permitted an increase in the depth of course content, and made it possible for students to work in terms of their interests and ability. The definiteness of the problems and the fact that they would be evaluated was a factor in motivating student work. The quantitative problems permitted an increased emphasis upon quantitative thinking.
BIBLIOGRAPHY

A. BOOKS


B. SCIENCE TEXTS USED TO DETERMINE COURSE CONTENT


C. PERIODICALS


D. UNPUBLISHED MATERIALS