Physical Science

A problem solving approach

Teachers' Edition with Annotations

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Joseph L. Carter

Paul M. Bajema

Russell W. Heck

Phillip L. Lucero

Joseph L. Carter, senior author of the group that developed this project, teaches science and is District Science Specialist in the Anaheim Union High School District in Anaheim, California.

Paul M. Bajema has taught science at all levels, elementary through college, and presently teaches chemistry at Loara High School, Anaheim, California.

Russell W. Heck is Science Department Chairman at Orangeview Junior High School, Anaheim, California.

Phillip L. Lucero is a chemistry teacher at Anaheim High School, Anaheim, California.

Home Office: Lexington, Massachusetts 02173
0-663-20857-2

introduction

General Philosophy of Physical Science: A Problem Solving Approach

This program was developed to teach physical science concepts to children in such a way that they learn through their own experiences. This approach has been used successfully in science programs at all levels of instruction. Such activity-centered programs tend to keep student interest high, since the learner must take an active part in his own education. The teacher must provide the conditions in which pupils can work effectively in a laboratory environment. This calls for different teaching skills from those needed when pupils are kept in their seats at all times while information is dispensed to them. The suggestions found in this Teachers' Guide will hopefully help the teacher to foster a classroom atmosphere that is conducive to individual student investigation.

The physical science laboratory program is built around four major units. They are *Principles of Measurement, Force and Motion, Forms of Energy*, and *Chemistry of Matter.* Each unit is divided into four or five chapters. Each chapter consists of a brief introduction followed by several specific problems to be investigated by the student in the classroom laboratory. It should be pointed out that the introductory material in each chapter pertains strictly to the problems that will be studied later in the laboratory investigations.

The problems are the heart of the teaching strategy of the program. The problems are much more than a set of instructions telling the student what to do. They are inquiry-structured and include, in addition to specific procedural directions, a series of questions that compel the student to think about the purpose and meaning of the laboratory activity that he has just performed. These Guide Questions are worded to bring out the key ideas and concepts included in the problem. This approach amounts to a form of self instruction; the student discovers facts and concepts for himself as he proceeds through the experiment. The more difficult ideas are reinforced by supplementary statements following some of the questions. The Guide Questions are to be answered by the student in his own notebook. They form the main basis for discussion of the laboratory results by the class. Class discussion is always more meaningful to the learner when he has had a hand in gathering the information under discussion.

Each chapter is concluded with two sets of questions, which are used to test the understanding of basic concepts by the student. The first set of questions, entitled *Review Questions,* may be answered from material given in the chapter introduction or problem contents. The more difficult questions are entitled *Check Your Understanding.* These questions call for a more sophisticated understanding of the concepts presented in the problems and generally may not be answered simply by looking up information in the text. Teachers should consider the ability level of the group when making assignments from the *Check Your Understanding* questions.

Organization of Laboratory Teams

The experiments should be performed by teams of students. The number of students in a team may depend upon the nature of the activity, the facilities available, or the ability of the pupils. It is usually recommended that teams consist of from two to four students.

Equipment and Supplies

Equipment and supplies are an essential part of any laboratory program. The best way to proceed is to select the units, chapters and problems your class will be working with and then arrange for the equipment and supplies that will be needed. When handled haphazardly, the obtaining of equipment and supplies can become such a headache that the teacher is tempted to avoid laboratory programs. However, most problems can be solved easily with a little advance preparation.

Starting and continuing a laboratory program is more expensive than a conventional "text-lecture-demonstration" science course. There are several methods of cutting equipment costs without sacrificing the quality of the program. For example, suppose you have thirty-six students in a class. If there are two students per team, you need 18 team "kits," but if there are four students in a team, you need only 9 team "kits"—a savings of 50 percent.

There is still another method of reducing supply needs. Suppose that in a chapter consisting of five problems there is one experiment which requires the use of a special piece of equipment, such as a recording timer. If every team in the class does the five experiments in strictly sequential order, you will need one recording timer per team. But if each team works on the problems in a different order so that no more than two or three teams are working on a particular experiment at any one time, the equipment needs will be reduced considerably. Such a "revolving sequence approach" assumes that the experiments in any given section are non-sequential, i.e., that they can be performed in any order. This is usually the case with the problems in this book. Where a certain problem must precede a related problem, it will be pointed out in the Teachers' Guide.

Housekeeping in the Laboratory

When thirty or more youngsters are engaged in several different laboratory activities at the same time, the amount of materials being used around the room is considerable. If the materials are not left in order at the end of a class period a major cleanup problem may face the teacher. To avoid this situation it is necessary to keep track of the time remaining in each period and announce cleanup about five minutes before the period ends. This permits each team to return materials to the common supply table or to store their own part of the experiment until the next day.

Each team should take the responsibility of washing and drying all glassware before returning it to a common storage area. A pitcher of soap suds and a few brushes kept in readiness near the sinks will encourage the laboratory teams to wash their own dishes. The assignment of some kind of grade or point penalty should be considered as a reminder for teams that fail to clean up their work space at the end of a laboratory period.

In addition to the group cleanup effort, it is often helpful to assign several specific cleanup groups. These groups, consisting of perhaps five students from different laboratory teams, should be given the responsibility of maintaining the cleanliness of the supply table area, the sink areas, the balance areas, and the stock room or storage area. A schedule of cleanup groups and specific responsibilities should be prepared and posted to remind students of their special cleanup responsibilities.

Student Laboratory Notebook

It is essential in this kind of a program for each student to keep a complete record of his work in the laboratory. He must frequently refer for information to some previous activity or result. To promote good record keeping by the student, a Laboratory Notebook is a requirement for this course. The notebook serves as a permanent record of his observations, measurements, and conclusions. In addition, the answers to the numbered Guide Questions in each problem, including various charts and graphs, are to be recorded there.

The notebook should be of the spiral-bound variety that lies completely flat when open so that the student can write in it easily while working. The student benefits most from the Guide Questions when he is required to answer them as he goes along. If students cannot afford a spiral notebook for this class, the teacher may give them 25 sheets of lined paper stapled together, or allow them to use a section of their ring binder as a laboratory notebook. The notebook remains in the hands of the student as his own permanent record. It may be evaluated by the teacher once or twice during each unit. This may be done as the teacher moves around the room supervising the work, or the teacher may collect all notebooks for a more careful evaluation. The notebook should be assigned some significant part of the student's grade commensurate with the importance of the laboratory work in the program.

Laboratory results should be discussed frequently by the class as a whole or by smaller groups. This activity helps to unify the thinking of the group and to raise questions about results that seem doubtful. Individual Laboratory Report Sheets may be required by the teacher for selected problems in which student results are desired right away. These report sheets may consist of lined notebook paper, plus graph paper if charts or graphs are called for in the problem. The teacher may wish to prepare a Laboratory Report Form that already has the Guide Question numbers listed on it. This adds some organization to the sheets but may tend to give the student the impression that he is doing a fill-in exercise.

In scoring the report sheets and laboratory notebooks, each problem may be assigned ten points maximum credit or it may be graded on the basis of one or more points for each acceptable answer to the Guide Questions. Even if a report is poor, it is probably good teaching psychology to give some credit for any laboratory report turned in. This encourages the student to continue his efforts, and recognizes the fact that he certainly has done more than the person who handed in nothing at all.

Features of the Teachers' Edition

The Teachers' Edition includes both Teachers' Guide and annotations right on the pages of the student text. A brief description of the organization and features of the Teachers' Edition follows.

Page Annotations

Each problem in each chapter in the Teachers' Edition of the textbook is annotated with answers to the Guide and Review Questions and special suggestions to the teacher. These annotations are placed on the page near the procedure step or question to which they refer. Although most annotations are answers to specific questions, some are teaching suggestions that have been found to be helpful in achieving the learning objectives of the problem. Included are suggestions for post-lab discussion, procedures that usually require additional clarification for some students, and precautions to be observed in maintaining a safe laboratory. Additional teaching suggestions are found in the Teachers' Guide section. If answers to Guide or Review Questions are too lengthy to appear as annotations, they are given in the Teachers' Guide.

Answers to Guide Questions. The questions are located at strategic intervals within each experiment. The student answers these questions in his notebook as he does the experiment. There is no better time for the student to write down what he observes and what he interprets it to mean than right after it happens. The answers in the annotated edition are those most likely to be given by the student if he works carefully, but a certain amount of variation in answers should be expected and accepted in some cases.

Answers to Review Questions. These questions for each chapter are placed at the end of the last problem in the chapter. The Review Questions are usually easy and the answers may be recalled or looked up by the student in the chapter. Answers given in the annotations will not usually require much explanation to be understood.

Teachers' Guide Section.

The Teachers' Edition contains, in addition to the annotated pages, a supplementary Teachers' Guide preceding the student text. This Teachers' Guide contains brief summaries of the major concepts and activities in each unit and chapter. It also contains supplementary Teaching Suggestions for each problem, including an estimate of the time required to complete the problem. The answers to the Check Your Understanding questions are found here, as are some of the more lengthy answers to Guide and Review Questions. The following are the major features of the Teachers' Guide:

Introduction to the Unit. This consists of a brief summary of the chapters comprising the unit. The scope and sequence of the unit are discussed, along with a rationale for including the topics indicated. A few reference sources are included for the benefit of the teacher.

Chapter Introduction. The contents of the chapter and the relationship between the problems comprising the chapter are discussed. This section gives a quick overview of the development of the chapter and points out the topics receiving emphasis. Following the introduction, detailed instructions for presenting each of the problems in the chapter are given.

Time Requirements. An estimate of the number of class periods normally required to complete the problem precedes the Teaching Suggestions for each problem. A normal class period is considered to be from 40 to 45 minutes in length. It has been the experience of the authors that the separate problems may be assigned over a longer period of time, such as a week, so that slower workers may still find time to finish.

Teaching Suggestions. This is perhaps one of the most helpful sections of the Teachers' Guide, since it anticipates teacher and student problems before they occur and suggests ways of minimizing them. This section includes not only timely hints about setting up the laboratory situation but also some suggestions for obtaining materials, giving pre-lab instructions, and points to be emphasized in the discussion following the laboratory work.

Suggested Answers to Check Your Understanding. These questions are more thought-provoking than the Review Questions. They are designed to test student understanding of concepts and principles presented in the chapter. Answers given in the Teachers' Guide will reflect the most likely responses based upon the experience provided in the problems as well as on the background material in the text. Some variation in student response to these questions should be expected.

Recommended Films and Filmstrips. Each chapter of the Teachers' Guide is concluded with some suggestions for films or filmstrips suitable for the enrichment of the material in the chapter. The teacher should use discretion in showing films, so that no duplication of laboratory activities is presented in a film unless it is for review purposes. The films listed are intended to increase the understanding of students rather than to repeat what they already know.

Transparency Masters. These are bound in with the Teachers' Guide. They may be used to complement the laboratory activities and text.

unit 1 principles of measurement

It is necessary for students to learn how to measure length, mass, and volume in order to answer quantitative questions about matter and energy. The metric system is introduced in the first chapter in connection with the measurement of length, area, and mass. The concept of uncertainty is introduced to make the student aware of the limitations of all measuring instruments.

Numerical relationships, such as ratio and proportion, are developed as a part of the task of presenting numerical information. The storing of data in tables is introduced in this unit and continued throughout the book. Graphing is introduced and gradually developed as a means of clarifying and interpreting the data that the student has collected.

Helpful reference sources for teaching this unit include the following:

The Realm of Measure. Isaac Asimov. Houghton Mifflin, New York, N.Y.

Physics for High School. W. C. Kelly and T. D. Miner, Ginn and Company, Boston, Mass. See Chapter 1, "Physics and Measurement."

Chapter 1 Measuring Length, Area, and Mass in the Metric System

The purpose of this chapter is to teach the student how to make careful measurements of several properties of matter. The metric system is introduced as a convenient system of measurement. The teacher should emphasize that this system is useful because it is easy to convert from one metric unit to another. The teacher should point out that the metric system is used by most scientists as is the official system of measurement in most countries. Emphasis is placed upon the most common prefixes, such as milli, centi, and kilo.

A comparison of the length measurements of the same object as recorded by different students should reveal the presence of uncertainty in every measurement. This uncertainty is further revealed in the measurement of the area of a rectangular figure.

The concepts of precision, uncertainty, and significant figures are often confusing at first. However, the need for uniformity of procedure and accuracy of results in all branches and at all levels of science makes the study of this topic an important one. The following information includes both background information and hints and suggestions that will apply throughout the book wherever significant figures are encountered.

Rules. In view of the basic treatment and limited use of significant figures in this program, few if any serious difficulties should be encountered. However, the following rules for determining the number of significant figures have been established, and are included here as an aid to the teacher.

1. All nonzero digits **are** significant. The number 12.34 contains *four* significant figures.

2. All zeros between two nonzero digits **are** significant. The number 120.003 contains *six* significant figures.

3. Zeros to the right of a nonzero digit but to the left of some understood decimal point are **not** significant unless specifically indicated to be significant. The rightmost significant zero is identified by a bar placed above it. 102,000 contains *three* significant figures; 102,0$\bar{0}$0 contains *five* significant figures.

4. All zeros to the right of a decimal point but to the left of a nonzero digit are **not** significant. The number 0.00123 contains *three* significant figures.

5. All zeros to the right of a decimal point and to the right of a nonzero digit **are** significant. The numbers 0.01020 and 10.00 both contain *four* significant figures.

Expressing Measurements. The limits of direct measurement of most of the instruments used by the students will be tenths of a unit (0.1 cm; 0.1 ml; and 0.1 g). Based on our definition of significant figures, the students should be able to make measurements to these limits *plus* one unit increment smaller, which will be estimated and uncertain. Experience has shown that, due to the small size of these increments, students should not be expected to estimate with an accuracy greater than ±0.5 of an increment.

For example, a reading of 10.5 cm on a meter stick would be directly read and therefore precise. Theoretically, one should be able to *estimate* the measurement to the next digit (hundredths of a centimeter). However, because the distance between 10.5 cm and 10.6 cm is so small, the student should only be expected to estimate whether the object (or distance) being measured is less than or greater than half-way between 10.5 and 10.6 cm.

It is suggested that students should round off their estimated measurements and express their measurements to the nearest tenth of a unit. All answers to student responses and questions have been calculated on this basis.

Operations with Significant Figures. The results of mathematical operations cannot be expressed with greater precision than the measurements themselves. In order to ensure validity of derived quantities, the following rules should be followed.

1. Addition and Subtraction: The result of an addition or subtraction operation should only be as precise as the least precise number involved in the operation.

Example:
$$\begin{array}{r} 6.23 \\ 10.4 \\ \underline{0.255} \\ 16.885 \end{array}$$

The least precise number in this operation is 10.4. Thus, the sum should be rounded off to the nearest tenth's place. The most precise answer to this operation would be 16.9.

2. Multiplication and Division: The product or quotient of an operation should contain the same number of significant figures as does the least precise factor.

Example: 10.5 × 2.2 × 110.1 = 2543.310

The least precise factor (2.2) contains two significant figures. Thus, the product should be rounded off to that precision. The product should be expressed as 2500.

Problem 1-1: Teaching Suggestions

Pages 10-14

Time Required: Two periods.

- Have students bring in tennis balls. One per team is recommended. Tennis balls in any condition, new or used, are suitable for this problem.

- Two clean, smooth, wood blocks per team are needed for this problem. Two-by-four inch blocks cut approximately 6-inches long are suitable. These could be prepared by the industrial arts department or an enterprising parent. The corners must be square.

■ In your pre-lab presentation, show the class a meter stick and identify the various divisions: centimeter, millimeter, and decimeter. Then use a transparent ruler or a prepared transparency on an overhead projector to help students learn to read the meter stick correctly.

■ Place meter sticks, tennis balls, and blocks on a supply shelf or table that is accessible to students.

■ Instruct students that there is little value in picking up all listed materials before they are needed because work tables become cluttered, breakage of equipment may be more frequent, and time may not permit completion of the whole problem.

■ To avoid confusion when the class is ready to begin lab work, excuse only one member of each team to pick up materials needed and take them to a table or other work area.

Problem 1-2: Teaching Suggestions

Pages 15-17

Time Required: One period.

■ Instruct students that each member of the team makes three separate measurements of the longer dimension of the table top in Procedure A.

■ Direct students to read procedures and examples very carefully in this problem.

■ A post-lab discussion of the problem and the meaning of significant figures is recommended.

■ Use the same materials used in Problem 1-1.

Problem 1-3: Teaching Suggestions

Pages 18-32

Time Required: One period.

■ Have all materials ready.

■ Distribute one sheet of quarter-inch graph paper per student. Some schools may expect students to supply the graph paper or make their own from lined notebook paper.

■ In your pre-lab presentation tell students that they should begin by making a rectangle on the graph paper ten squares in length and five squares in width. The longer dimension is always length and the shorter is the width. The rectangle may be placed anywhere on the paper so long as there is enough margin to label the side of one square "s." However, to match the procedure in the text, the rectangle must be placed on the paper so that the length is vertical and the width is on the horizontal axis.

■ In post-lab discussion point out that uncertainty is related to the precision of the instrument, not the skill of the person using the instrument. There is no way of assigning an uncertainty value to the careless measurements of some people.

Problem 1-4: Teaching Suggestions

Pages 22-25

Time Required: One period.

■ If your lab is not equipped with a triple-beam balance, the procedures in this problem, with minor revisions, can be readily adapted to accommodate the type of balance available to your students.

■ Place large rubber stoppers, small rubber stoppers, and small beakers on supply table accessible to students. One of each per team is recommended.

■ If practical, have balances arranged in permanent locations in several places around the room. This removes the need for moving balances around.

■ Make sure that scales are in working order and are properly balanced.

■ Demonstrate use of the balance to each class.

■ Emphasize that the balance is a delicate instrument, and that if it is not handled carefully it will not give accurate readings.

■ Caution students to use both hands if balance must be moved.

■ Discuss why students should not move the adjustment screw on the balance. Once it is adjusted correctly, no further moving should be required.

■ Insist that students follow weighing procedure carefully each time they use the balance.

Suggested Answers to Check Your Understanding *Page 26*

14. (a) Since the metric system is based on powers of ten, it is easy to convert from one unit to another.
(b) The same prefixes apply to all units of length, mass, and volume.
(c) In the English system weight is measured in pounds, volume in gallons, and area in acres. There is no relationship among these measures. In the metric system, area measured in square meters or kilometers, and volume measured in cubic meters or kilometers, are directly related.

15. (a) It would cost industrial concerns a great deal of money to convert tools and machinery to the metric system. Small businesses might be hurt even worse.
(b) Homemakers would need to learn the metric system and purchase new cookbooks and measuring devices.

16. Both are deicmal systems based on powers of ten.

17. All digits in a number which are certain plus one which is uncertain. The uncertain digit is an estimate of one digit beyond the smallest division which can be read from the measuring device.

18. (a) Anything that affects the position of the sun in relation to the earth: the time of day or the season of the year.
(b) The growth of the tree.
(c) Bending of the tree in the wind.

19. (a) There is a sequential order to the problem. The student can refer to previous experiments for answers to questions.
(b) It facilitates evaluation. The teacher and student can check for improvement.

20. 12 X 2.54 = 30.48 cm.

21. Meters, because the metric system is used almost universally in Europe.

22. 39.37 inches ÷ 12 inches = 3.3 feet to two significant figures.

23. The mass of an object, in the metric system, is numerically equal to the weight of an object at the earth's surface and always remains the same. Since weight is determined by the gravitational pull of the earth, there would be a difference between the weight and mass of a body if it changed its position in relation to the earth's surface. For example, as a body rises in a space capsule the mass remains the same, but the weight eventually becomes zero.

24. (a) gram (b) milligram (c) kilogram (d) gram

25. You must move the heaviest weight first. If you were to start with the lightest, you would have to move the rider more than once when the object weighed more than the capacity of the lightest rider and you would have to estimate the position of the larger riders.

26. (a) Area = X^2 (b) Total area = 15 X^2

27. 2.35 m X 1.63 m = 3.8305 m^2. Since only 3 significant figures are justified, the answer should be reported as *3.83* m^2.

28. Area = 5,130 m^2. The area may be found by subtracting the area of the small rectangle, 720 m^2, from the area of the larger rectangle, 5,850 m^2.

Recommended Films and Filmstrips for Chapter 1*

The Metric System (Coronet). 11 minutes, black and white. The history of the metric system and its uses today. The advantages of the metric system are noted.

Measurement–Second Edition (Coronet). 11 minutes, color. Illustrates standard units of measure, selection of unit appropriate to purpose, meaning of precision, possible error.

The Metric System (McGraw-Hill). Approximately 40 frames. General Mathematics Series 043010. (*Filmstrip*).

Chapter 2 Measuring Volume in the Metric System

The purpose of this chapter is to extend the experience of metric measurement to include volume as well as length, area, and mass. The concept of uncertainty is extended to the volume measurements made in this chapter.

*Filmstrips are specifically designated as such; all others are motion picture films.

The volume of a regular solid is found by linear measurement of the dimensions of the object. Liquid volumes are found by the use of a graduated cylinder. Objects with irregular shapes are immersed in water in a graduated cylinder in order to find their volume. Gas volumes are found by measuring the volume of water displaced by the gas from an inverted jar of water.

Finally, an introduction to the effect of temperature and pressure upon gas volume is given. For this experiment, plastic syringes are used as gas containers. The concepts are further developed in Unit IV in connection with the Kinetic-Molecular Theory of gas behavior.

Problem 2-1: Teaching Suggestions

Pages 30-34

Time Required: Two periods.

- Have students bring one-third quart or half-pint cardboard milk containers. Fruit punch and orange drink are also sold in similar containers. These may often be obtained from the school cafeteria.
- If containers are brought in the day before Part Three is done, the teacher or a laboratory assistant may cut off the upper portion. It is not necessary that all containers be of uniform size. A simple cutting jig can be made by nailing together the ends of two pieces of wood about 6 centimeters wide and 15 centimeters long to form a right angle. A sharp razor blade cuts better than scissors.
- If glass graduated cylinders are used, equip each cylinder with a rubber or plastic guard to prevent breakage.

Problem 2-2: Teaching Suggestions

Pages 35-37

Time Required: One period.

- Have students bring in half-gallon milk cartons, small rocks which fit inside the cartons, and bolts, preferably with nuts. A 7/16-inch bolt 1½-inches long is ideal to fit in the graduated cylinder. The nut, as well as the bolt, is needed in Problem 3-3.
- Check out the bolts to one member of each team to make sure they are returned.
- If cartons are brought in a day or two in advance, the teacher or a laboratory assistant may prepare the overflow spouts. They require a sharp reverse crease so that water runs down the spout rather than overflowing at the corners.
- If the budget permits, commercial displacement cans may be purchased, saving the time needed to construct them from milk cartons.

Problem 2-3: Teaching Suggestions

Pages 38-40

Time Required: One to one and a half periods.

- Have students bring in pea gravel and BB shot. Pea gravel can be easily obtained where building materials are sold. Aquarium sand can be substituted for BB shot.
- Set up containers in which students can empty the cylinder of wet gravel and wet BB shot or sand. When dry, these materials can be used over again.
- Procedures F and G work very well as class demonstrations. Use a 25 X 200 mm test tube about one-third full of wax shavings. Use a paraffin purchased in a grocery store. Save this test tube and contents for future use.

Problem 2-4: Teaching Suggestions

Pages 41-45

Time Required: Two periods.

- Ask students to bring soda straws, baby food jars, seltzer tablets, and aluminum pie tins. Frozen pie tins are ideal for this problem. Alka-Seltzer, Bromo-Seltzer, or Fizzies may be used. Tablets wrapped in foil remain fresh longer and produce more gas than tablets in bottles. Gas collecting bottles may be substituted for baby food jars. Plastic straws are easier to use than paper straws.
- It is not necessary to use equal size pieces of seltzer tablets since no comparison of results is made. Distribute one piece to each team. Caution the students to keep the tablet perfectly dry until they insert it under the jar. (Students are often wasteful of tablets when allowed to help themselves.)

■ Plastic syringes without needles can be obtained from retail medical supply stores and from scientific supply houses for about fifteen cents. Doctor's offices and hospitals may provide used syringes (without needles) which can be used after washing with hot detergent solutions.

■ If gas collecting bottles are used, a 2 X 2-inch glass plate or a lid is needed to retain the water while the bottle is being inverted into the shallow dish (pie tin). A 6-inch square of plastic wrap also works well in place of the lid or glass plate, if the latter are not available.

■ Have hot water and ice water available when students reach Procedures P and Q.

Suggested Answers to Check Your Understanding *Page 46*

12. Gases that are heavier than air can be collected in open containers. In this case, the mouth of the container would be up rather than down. Gases that are soluble in water could be collected by displacement of other liquids.

13. A gas occupies space and exerts pressure. Two objects cannot occupy the same space at the same time.

14. The balloon is only partially filled with gas because as the balloon rises the gas inside expands due to the decreasing pressure of the air outside the balloon.

15. (a) You could squeeze the bulb to pick up as much liquid as the dropper would hold, then empty the liquid into a dry, graduated cylinder and measure the volume of the liquid in the cylinder.
(b) You could mark the level of liquid picked up by the dropper, empty the dropper, and remove the bulb. Put a measured amount of liquid in a graduated cylinder, then pour liquid from the cylinder into the dropper until it reaches the mark, being careful not to lose any liquid. By subtracting the final reading of the liquid in the cylinder from the original reading, you would know the volume of water in the medicine dropper.

16. Fill the measuring cup to the one-cup mark and pour the liquid into a graduated cylinder. The volume can be read directly from the cylinder in either milliliters or cubic centimeters.

Recommended Film for Chapter 2

Volume (McGraw-Hill). Approximately 35 frames. Set #1, 043020. *(Filmstrip).*

Chapter 3 Measuring the Density of Liquids and Solids

The first two chapters presented techniques for measuring mass and volume for both liquids and solids. In this chapter, the students discover that the density of a substance is the relationship between its mass and its volume. Students are shown how to determine the density of a substance by measuring both its mass and its volume.

Since density is always expressed as the ratio of mass to volume, this is an appropriate point at which to discuss ratios and ways of representing numerical relationships. Three problems in this chapter contain exercises that teach the student how to prepare graphs and present numerical information.

The densities of liquids are found and graphed in Problems 3-1 and 3-2. The use of hydrometers for measuring liquid densities is discussed briefly before densities of solids are measured in Problem 3-3. The water-displacement method of finding the volume of an irregular solid is used again.

The final problem in the chapter seeks to determine why some solid objects float in water while other solid objects sink. The students place blocks of different densities in water and note whether they sink or float. The respective densities of the blocks are calculated and a graph is prepared to show the mass/volume relationship for each block. When the density of water is marked on the graph, it is seen that the densities of those blocks that float are all less than that of water, while the densities of the blocks that sink are greater than that of water.

A summary discussion of the buoyant force of liquids concludes the chapter.

The marks on the bow of the ship in the chapter opening photograph indicate the relative density of the ship. A heavier cargo makes the ship more dense, thus causing it to sink lower into the water.

Problem 3-1: Teaching Suggestions

Pages 54-59

Time Required: Two periods.

■ Assign the copying of Table 3-3 for homework the day before the students are to begin this problem.

■ Discuss why it is best to prepare a data table and write-up sheet before starting a problem, rather than after all the information has been collected.

■ It is helpful to number the graduated cylinders so that a student can select the same one when a problem takes more than one period to complete. This is best done by applying a mark directly to the cylinder rather than using tape, which may be loosened by alcohol or other solvents.

Problem 3-2: Teaching Suggestions

Pages 60-63

Time Required: One and a half to two periods.

■ In pre-lab discussion explain that the glycerine used here is not nitroglycerine. It is a harmless by-product formed in the manufacture of soap. If denatured alcohol is used, explain that it is a combination of ethyl alcohol and methyl alcohol that is poisonous to take internally. All liquids used here are harmless to the skin.

■ Place the liquids in some convenient location and insist that students return the materials to that same location with caps or lids on bottles after use.

■ Review the concept of density. Show how to make calculations using the proper units.

■ Have students copy Table 3-4 before starting the problem.

■ Denatured alcohol is inexpensive to use here. Rubbing alcohol (2-propanol), motor oil, mineral oil, syrup, or a salt solution may be used as substitutes for the liquids in the problem, or they may be added to the list (Procedures C and H).

Problem 3-3: Teaching Suggestions

Pages 65-67

Time Required: One period.

■ Nuts and bolts can be brought in by students, acquired from the industrial arts department, or purchased from the local hardware store. A 7/16 X 1½-inch bolt with nut fits well in the 50 ml graduated cylinder. Use the nut and bolt obtained for Problem 2-2.

■ Review determination of the volume of a regular-shaped object by multiplying length X width X height and of objects with irregular shapes by the water displacement method.

■ Because of adhesive attraction between water molecules and the milk carton, when determining the volume of small objects it is usually more accurate to use the graduated cylinder than the overflow container. Since the graduated cylinder is to be used, the milk carton, scissors, and beaker have been eliminated from the required materials for this problem.

Problem 3-4: Teaching Suggestions

Pages 68-70

Time Required: Two periods.

■ Cubes of brass, iron, and aluminum may be purchased from a science supply house. These cubes are available in 1.0 cm and 3.2 cm sizes. The larger size is easier to work with. Have a student or industrial arts teacher make three other cubes of the same size but of different materials. At least two of these blocks should float in water. They can be made of different kinds of wood, metal, or plastic. Letters A through F can be stamped on the blocks with a tool and die set. All blocks should be painted the same color so that they look alike. An aerosol can of paint does a good job.

■ Check out a set of these blocks to one member of each lab team so that they will be returned at the end of the class period.

■ Density of Various Block Materials. The density of wood can vary considerably, depending on the condition that it is in (moisture content, porosity, etc.)

Metal	
Copper	8.85 - 8.95 g/cm^3
Brass	8.44 - 8.70 g/cm^3
Iron	7.60 - 7.88 g/cm^3
Aluminum	2.69 g/cm^3
Wood	
Ash	.52 - .63 g/cm^3
Birch	.55 - .71 g/cm^3
Oak	.65 - .97 g/cm^3
Pine	.37 - .63 g/cm^3

Suggested Answers to Check Your Understanding *Pages 72-73*

15. (a) 15.0 g (b) 30.0 ml (c) 32 g (d) 15 g ÷ 25 ml = 0.6 g/ml (e) 10.0 ml

16. You would use a line graph because the numerical relationships are proportional. The data shows that when the mass is doubled, the volume is approximately doubled also.

17. Density. If the density of the object is greater than the liquid, it sinks; if its density is less than the liquid, it floats.

18. Yes, objects B and D will float since their densities are less than that of water.

19. Liquid A forms the bottom layer, liquid B forms the top layer, and liquid C is probably water.

20. You would expect the density of lemonade to be greater than water alone because the volume of the lemonade is the same as the volume of the water alone (1 cup). Adding sugar and lemon extract would increase the mass of the solution. As a result, the ratio of the mass to volume (density) would increase.

21. The density is the mass per unit volume of a substance and it must have a mass and volume label such as grams per cm^3. Specific gravity is a comparison of the density of a substance to the density of a standard such as water. The specific gravity of aluminum is 2.7, which indicates that aluminum is 2.7 times as dense as water.

Recommended Film for Chapter 3

Using Graphs (McGraw-Hill). Set #1, 405442. (*Filmstrip*).

Chapter 4 Measuring Rates of Events

The final chapter in this unit considers the measurements that must be made in order to express the rate at which some event takes place. The general relationship for expressing rate—"events per unit of time"—is presented here.

The student first measures the rate at which water leaves a can through holes of different sizes. The rates are calculated in milliliters/second. Two graphs are prepared. One graph relates the *time* needed for the water to drain out of the can to the diameter of the hole. The other graph compares the *rate* at which the can is emptied to the hole diameter.

The next problem introduces the use of a vibrating recording timer as a timing device. A rolling object is timed as it moves across a table. This timing device will be used later to time a falling object.

The final problem in the chapter measures a changing rate—the pulse of a student before and after he has exercised. Graphs are prepared to relate respiration and pulse rates to varying amounts of exercise.

Direct and inverse relationships are demonstrated and explained. The student is again asked to make predications of unmeasured values based upon the trends shown on his graph.

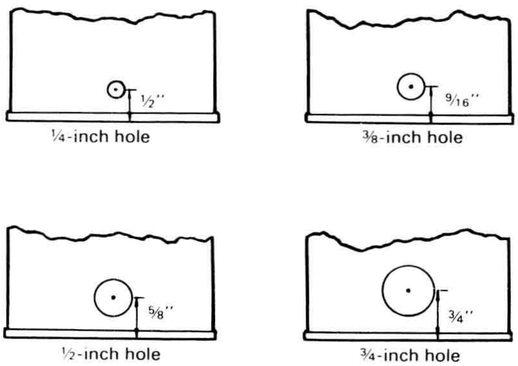
Problem 4-1: Teaching Suggestions

Pages 80-84

Time Required: Two periods.

- Request that students bring in empty one-pound coffee cans several days before assigning this problem.

- Request the industrial arts department to cut a different-sized hole in each of four coffee cans. The hole diameters are 1/4, 3/8, 1/2, and 3/4 inch. There should be one set of cans for each laboratory team. So that the same volume of water is emptied from each can, all cans must be of equal size and all holes must be the same distance from the bottom. Using the measurements given in the illustration on the following page, center the hole in each can so that the bottom of every hole is 3/8-inch from the bottom of the can.



■ For extra convenience, paint the cans with aerosol paint of four different colors to color-code the cans. Paint all cans having the same size hole the same color.

■ It is well to demonstrate to students how to recognize the point at which the stream of water falls back along the can. Be sure students use this point in determining both the volume of the can and the "empty point."

■ With the hole 3/8-inch from the bottom, a one-pound coffee can contains approximately 920 milliliters of water. A wide-mouth container is easiest to use in catching the stream of water. A 1000 ml graduated beaker can be used, and the student can read the volume directly from the beaker. For a more accurate reading the water may be poured into a large graduated cylinder.

An alternate method is to calibrate the outside surface of a glass quart or half-gallon milk container and read the volume directly. It is best to start marking the bottle at 800 ml and continue marking off 20 ml divisions until the top is reached.

Problem 4-2: Teaching Suggestions

Pages 85-88

Time Required: One to one and one-half periods.

■ Recording timers are sold in kits. They should be assembled by the teacher or a lab assistant before starting the problem.

■ To prevent damage to the recording timer, it is helpful to attach a hard wood block about 2½-inches in width and 7½-inches in length to the metal base with round-headed screws. When the timer is fastened to a table, the clamp can be applied to the wood rather than the metal base of the timer.

■ Students must understand the purpose of the timer. They should see the set up, listen to it, and understand that they should wait until it is running smoothly. A demonstration is usually necessary.

Problem 4-3: Teaching Suggestions

Pages 89-92

Time Required: Two periods.

■ Be sure students prepare the data table. This could be done as a homework assignment.

■ It may be well to practice measuring pulse rates with the class before beginning the problem.

Suggested Answers to Check Your Understanding *Pages 92-93*

11. Every swing of a pendulum takes the same amount of time, regardless of how far the pendulum travels each time it swings.

12. This is the length of time required for one rotation of the earth on its axis, and it is a phenomenon that occurs regularly. Daylight regularly alternates with darkness. People use daylight as an activity period and darkness as a rest period. This is a natural cyclical event by which people govern their lives.

13. Revolution of a planet around the sun; rotation of a planet on its axis; revolution of a moon around a planet; appearance of certain stars above the horizon; seasons of the year on Earth; alternate growth and decline of plants; alternate freezing and thawing of water in certain regions.

14. (a) dollars per hour (b) feet per second
(c) miles per hour (d) dollars per month

15. 2,500 liters per hour = 694.4 cm^3 per second.

16. 4 hours X 750 miles per hour = 3,000 miles.

17. The time predicted would be between 3/4 of a second and 1 second.

18. $\text{Rate} = \frac{\text{Velocity, cm}^3}{\text{Time, seconds}} = \frac{200\ \text{cm}^3}{4.0\ \text{sec}} = 50\ \text{cm}^3/$ sec. Since 1 cm^3 = 1 ml, Rate = 50 ml/sec

19. Graphs reveal numerical relationships between experimental values. A graph enables a person to determine the value of the dependent variable for any value of the independent variable that may fall between quantities measured experimentally. By extending the curve one can predict quantities that are not measurable with the equipment or the measuring device available.

A straight line usually indicates that two factors are directly proportional to each other. A curved line indicates a direct or an inverse *relationship* that is not necessarily an exact proportion.

Recommended Film for Chapter 4

Time and Clocks (Modern Learning Aids). 27 minutes, black and white. Discusses concepts of time measurement and shows various devices used to measure and record time intervals.

unit 2 force and motion

Force is responsible for all motion and work. The introduction to this unit considers the ideas about force first developed by Galileo and Newton, leading up to our present conception of what a force is and how it may be measured. The chapters in this unit explore many familiar kinds of forces.

Gravity is the first force that is investigated. The acceleration of an object by gravity is measured with a recording timer. As part of the activity, spring scales are introduced as a means of measuring force. The results of this experiment on the effects of gravity are applied later in the same chapter when the student tests the factors that affect the period of a pendulum.

The relationship between force and work is studied in Chapter 6. Inertial forces, frictional forces and opposing forces are studied in separate experiments. The work done by simple machines is measured in the final three problems in this chapter.

Two short chapters conclude the unit on force and motion. The intermolecular forces of cohesion and adhesion are studied in Chapter 7. The student observes the cohesive and adhesive behavior of water and other liquids. He learns about capillarity and surface tension, and what factors affect these two properties of liquids.

The unit is concluded with a look at magnetic and static electrical forces. These two topics are sometimes included in a unit on electricity; however, since static electricity and magnetism are forces, they are appropriate for study in this unit.

Helpful reference sources for teaching this unit include the following:

Matter, Earth, and Sky. George Gamow. Prentice-Hall, Englewood Cliffs, N.J. See Chapter 1, "Bodies at Rest."

Modern Physical Science. Brooks, Tracy, Tropp, and Friedl. Holt, Rinehart, Winston, New York, N.Y. See Chapter 4, "Mechanics and Energy."

Physics for High School. Kelly and Miner. Ginn and Company, Boston, Massachusetts. See page 234 for help in figuring data calculations on the pendulum.

Chapter 5 The Force Called Gravity

In this chapter the student investigates gravity, the fundamental force of attraction between all objects in the universe. Gravity is a natural subject with which to begin the study of force, since it is so basic to human experience that we seldom think about its existence.

The initial experiment utilizes recording timers to show the acceleration of a falling object caused by gravity. The student finds that the acceleration of a freely falling object is independent of its mass. This chapter introduces the idea that a force on an object causes it to change its motion, unless this initial force is opposed by an equal and opposite force.

Springs are among the most common devices used to measure forces. The student learns how to make his own spring scale by calibrating a spring using weights of known value.

Gravitational forces acting upon matter create a downward pressure that is measured in Problem 5-3. The student calculates the pressure at the bottom of a container of water by dividing the area of the base into the weight of the water.

In Problem 5-4, the student learns that the entire mass of an object seems to be concentrated at one point, its center of mass. A plumb line is used to find the center of mass of a flat object with an irregular shape.

The final problem explores the factors which might affect the period of a pendulum. The student learns that the period of a pendulum is dependent on the length of the string, but independent of the mass of the bob. The text material explains why a pendulum is a good device for measuring time.

In the chapter opening picture, the action of gravity is shown by a time-lapse photograph of the simple harmonic oscillation of a weight suspended on a spring.

Problem 5-1: Teaching Suggestions

Pages 101-105

Time Required: One to one and one-half periods.

■ Make sure timers are in good working order. One per team is needed. It is usually necessary to re-determine the period of the recording timer because of changes in the battery. etc.

■ Alligator clips on one of the lead wires facilitate starting and stopping the timer.

■ Have extra carbon discs on hand.

■ Demonstrate how tape should be numbered, cut, and pasted to make the bar graph.

■ An alternate procedure for mounting the tape sections is to cut only 8 or 10 sections from the first part of each tape. The three tapes in Part One can then be pasted to one page of regular notebook paper and the tapes in Part Two can be pasted to a second sheet of notebook paper.

■ In parts J and K, call attention to the shape of the graph formed by the strips. In each case, the weight fell a greater distance in each succeeding time interval or period of the timer. The shape of this graph is similar to that found in Problem 4-1, where the students plotted time required to empty water from coffee cans with holes of different sizes.

Problem 5-2: Teaching Suggestions

Pages 106-110

Time Required: Two periods.

■ The springs to be used in Part One can be purchased at hardware stores. The spring must be elastic enough to respond to a 200 gram mass, as well as rigid enough to support 1,000 grams, or the weight of the book used in the problems—whichever is greater.

■ Demonstrate how to determine the reference point on the bottom of the hook of the spring.

■ 1,000 gram spring scales are most convenient to use in Part Two; however, 2,000 gram scales may also be used.

■ Be sure that the book used in Procedure H does not exceed the elastic limit of the spring.

Problem 5-3: Teaching Suggestions

Pages 111-114

Time Required: One period.

■ 1,000 gram spring scales may be used in Procedure A if lightweight books are used.

■ Ask students to bring in empty plastic bottles, such as dishwashing detergent bottles, prior to the lab. Tall bottles are preferable. Holes may be punched in advance to eliminate Procedure B and save lab time. Bottles may be saved for re-use.

■ Have students bring in small milk cartons prior to the lab. Tops may be cut off before use in Step D to save time.