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ABSTRACT

This teaching guide contains part one of the four parts of the first year of the Portland Project, a three-year secondary integrated science curriculum sequence. This part involves the student in a series of activities intended to increase his understanding of his perceptual abilities and their limitations. Organization and classification as parts of perception are emphasized, involving the introduction of the physical properties of matter as aids to organization. The first year program is not excessively formal or quantitative, based on the rationale that a new idea should proceed from an intuitive, non-quantitative experience to a more quantitative one. The Portland Project, intended to replace traditional courses in biology, chemistry, and physics, treats science as a structure that proceeds from observation to the development of general principles and then to the application of those principles to more involved problems. A review of the development of the three-year program, a discussion of its rationale, and a three-year course subject outline are included in this volume. Notes to the teacher, examples of data, materials and equipment needed, and problem calculations are included. (Author/SL)

TEACHER'S GUIDE

PERCEPTION AND QUANTIFICATION

AN INTEGRATED SCIENCE SEQUENCE

1970 EDITION

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Dedication

This volume is dedicated to the memory of Vernon Cheldelin under whose guidance and leadership integration of the sciences for Oregon secondary school youth was begun in 1963.

The Portland Project was initiated in the fall of 1962 when two secondary school teachers, one with background in CBA chemistry, the other having responsibility for PSSC physics, began to note and discuss the redundancy in their respective courses. Why should students be subjected to this repetitious and fragmented representation of the physical sciences? they asked. A Steering Committee met to pursue the problem further and perhaps enlist the support of a funding organization to permit its exploration in depth. Under the able and devoted leadership of Vernon Cheldelin, Dean of the School of Science at Oregon State University (deceased), two proposals prepared for support by the National Science Foundation were funded in the summers of 1963 and 1964.

Thirty-five scientists and teachers devoted various quantities of time as writers, consultants, pilot teachers, and evaluators, with the aim of ascertaining the feasibility and efficiency of the integration of chemistry and physics. Concurrently and subsequently, other groups in other parts of the country have carried on studies that are approximately parallel to this one.[1] Though the conceptual development and points of emphasis differ, the various groups are satisfied that integration of science courses is not only feasible but highly desirable.

Dr. Michael Fiasca of the Education and Science Staffs of Portland State University conducted an evaluation which revealed that subject matter achievement in chemistry and physics and critical thinking abilities are enhanced among students who studied the integrated courses over those who study the separate disciplines of

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[1] Federation for Unified Science (FUSE) was recently organized to act as a clearinghouse of information on integrated science courses. Victor Showalter at Ohio University is the chairman of this committee.

chemistry and physics. It should be emphasized that though these differences were apparent, it could not be demonstrated that they were statistically significant.[2] A concomitant result showed that enrollments in the two-year integrated courses were dramatically greater than in the separate courses.

A survey completed April 16, 1967 showed that there were forty-four schools in twenty states using the Portland Project integrated chemistry-physics course.[3]

Mounting evidence in the literature from prominent persons working in science education strongly supported this mode of organization. Dr. Jerrold R. Zacharias, the prime instigator of the PSSC physics program, exemplified the changing attitude of scientists and educators:

> The division of science at the secondary school level, into biology, chemistry and physics is both unreasonable and uneconomical.
>
> Ideally, a three-year course that covered all three disciplines would be far more suitable than a sequence of courses which pretends to treat them as distinct. Today such a three-year course would be difficult to fit into the educational system, but much of this difficulty might be overcome at once if such a course existed, and it might well be that present tendencies in education would soon overcome the rest.
>
> In any case, a greater coordination of the three subjects is possible even within the existing framework. It is understandable that the groups which developed the existing programs, each of which faced great problems of its own as it worked toward its goals, were reluctant to embark on the larger task of giving coherence to the sum of their efforts. With the programs now complete or approaching completion, it may be that the time has arrived for this necessary step.[4]

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[2] Detailed results of this study may be obtained by writing to Dr. Fiasca at Portland State University.

[3] Detailed enrollment figures and addresses of people who are using the Portland Project courses may also be obtained from Dr. Fiasca.

[4] From page 52 of Innovation and Experiment in Education, a Progress Report of the panel on Educational Research and Development to the U.S. Commissioner of Education, the Director of the National Science Foundation, and the Special Assistant to the President for Science and Technology, March, 1964.

Stimulated by the apparent success of their original work towards this kind of integrated course, persons close to the Portland Project began to discuss extension of their work to include biology with chemistry and physics in a three-year sequence. A third proposal was prepared in 1966 and granted support by the National Science Foundation. Dr. Arthur Scott, member of the Chemistry Department at Reed College who has had deep interest in the Portland Project since its inception, graciously offered his talents, energy and time to carry on the project after Dean Cheldelin's death.

A writing conference was conducted on the Portland State University campus during the summer of 1967 to develop materials such as teacher and student guides. Eight local pilot schools committed approximately five hundred students and twelve pilot teachers for testing and evaluation. Dr. Donald Stotler, Supervisor of Science for the Portland School District, has had an active part in this and other phases of this project.

Twenty-six persons whose functions were writing, consulting, analysis, and editing met on the Portland State campus beginning June 14, 1967 to begin preliminary work on the integrated course. Their first task was to formulate an outline that displayed logical content development utilizing concepts out of biology, chemistry and physics. Particular attention was paid to matching students' abilities, interest and maturity level with the sophistication of concepts as nearly as this was possible to do. Then the committee perused material developed by the national curriculum groups --PSSC, Project Physics, CBA, CHEMS, BSCS and IPS -- in search of material to implement the outline they constructed previously. In the absence of appropriate materials, major and minor writing projects were initiated.

The writing committee continued its work in the summers of 1968 and 1969 with Dr. Karl Dittmer, Dean of the Division of Science, as director. Four major projects were tackled and completed: (1) extensive revisions were effected in the three-year outline, (2) the first- and second-year courses were revised based upon student and teacher feedback, (3) the third-year course was developed incorporating Harvard Project Physics materials as a main vehicle, and (4) an evaluation program for the three-year course was developed.

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Pilot Schools

The following schools have served as pilot schools for the pilot course during one or more of the past three academic years.

Adams High School
Portland, Oregon
Glen Hampshire
Lloyd Meskimen
Thomas Miles

Aloha High School
Aloha, Oregon
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Elvis Dellinger
Nelson Doeleman
Ted Parker

Beaverton High School
Roger Berg
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Benson Polytechnic School
Howard Browning
W. B. Chase
Robert Franz
W. L. Hoffman

Central Catholic High School
Portland, Oregon
Jacob A. Mosbrucker
Peter Roerig

Cleveland High School
Portland, Oregon
John Brown
Edmund McCollough

Franklin High School
Portland, Oregon
John Neeley
Joseph Sklenicka

Grant High School
Portland, Oregon
Myra N. Rose

Jefferson High School
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Kathryn Ann Torvik - Artist

Shirley Tsang - Laboratory Assistant

Barbara Wiegele - Secretary

STUDENT PARTICIPANTS

Patrick Moore - Jefferson High School (sow bug experiment)

The decision to try to develop a three-year integrated science course which would replace the traditional three courses in biology, chemistry and physics is based on several considerations. Among them are:

(1) a conviction that modern developments have made the division of science under these three headings obsolete;

(2) a recognition that the traditional courses overlap in many areas, resulting in a great deal of duplication and repetition as in the gas laws, atomic and nuclear structure, calorimetry and the kinetic molecular theory;

(3) a feeling that terminal students, who take no more than one year of science, deserve to get a taste of all of science rather than just one aspect, as they do in the conventional programs; and

(4) a desire to emphasize the unity in the approach to natural phenomena and the similarity in the methods, techniques and apparatus used by scientists in all fields.

A natural question arises as to what distinguishes this course from a general science course expanded to three years. The answer is that this course does not consist of a number of unrelated topics that might be taken up in any order; rather, it treats science as a structure that proceeds from observation to the development of general principles and then to the application of those principles to more involved problems. The emphasis in a general science course is on the results of science; the emphasis here is on the methods and reasoning by which scientists have arrived at these results.

The three-year course outline shows that a number of topics such as properties of matter, energy, heat, and certain biological concepts are discussed at the first-year level and again later in the course. This re-cycling is deliberate. It is intended to introduce students in a semi-quantitative way to some of the significant generalizations of science and to show how these generalizations arose. These topics are treated again in the second and third years when greater facility with mathematics on the part of students makes it possible for them to understand and appreciate discussions of these topics in the succinct and precise language of mathematics.

An excessively formal and quantitative approach is avoided in the first year for several reasons. Students at this level do not extract essential meaning from such a presentation of information; furthermore, first encounters with new ideas should proceed from an intuitive, non-quantitative confrontation to one that is more quantitative. Teachers have spoken out against teaching and learning methods which substitute equations, formulas and other quantitative representations for first-hand experience, word descriptions, examples and illustrations. These criticisms are just as valid for students who are very capable and very interested in science as they are for other students. Moreover, the mathematical sophistication of students at this level is such that they are unable to follow most mathematical arguments as explanations for natural phenomena.

The typical science experiences of most secondary school students consists of one or two years devoted to general science and biology. Few study physics and chemistry. A significant advantage to the course of study described here is that students are given a chance to study physics and chemistry at a level of rigor that is consistent with their ability and their mathematical maturity. Students who terminate their study of science at the end of one year get a significant exposure to the structure of biology, chemistry and physics as they are presented in the latest curricular developments. Students who might not elect science beyond the first year because of lack of interest in biology may be attracted by the chemistry or physics portions of the course and elect to take an additional year or two of science. Students who are "turned on" by biology may wish to pursue further study of biochemical topics in Years II and III.

FIRST YEAR COURSE

After considering these problems and goals, the general course outline for the first year of the course was derived. It consists of four main parts:

(1) Perception and Quantification

(2) Heat, Energy and Order

(3) Mice and Men

(4) Environmental Balance?

The year begins with a study of the perceiver, moves on to the perceived, and ends with the interaction of the perceiver with the perceived. The first-year student starts out by gaining a better awareness of the nature of his perception and senses -- the faculties that make him aware of the world around him. With an increased understanding of these perceptual abilities, he can turn to the environment and then relate himself to it. He finds that his perception is limited and that he often needs to call on technological and conceptual extensions and that even these have their limitations.

The importance of organization and classification as parts of perception is emphasized. The physical properties of matter are introduced and studied as aids in organization and classification of chemicals. The identification of unknowns by study of their physical properties and use of organized data on punch cards is the culminating experiment of the Perception unit.

Apart from the great diversity exhibited in nature, which the scientist must organize in order to comprehend, certain unifying principles are essential for deeper understanding. The most powerful of these is the energy concept, which is explored in the "Heat, Energy and Order" unit in several of its ramifications - physical, chemical and biological. The discussion begins by developing an experientially important energy form, viz., heat. The macroscopic aspects of heat as embodied in calorimetry are related to the microscopic in terms of random molecular motion. This builds confidence in the idea of the atomic nature of matter, which is essential to much of the unit. Various energy conversions form the vehicle for extending and generalizing the energy concept. Nuclear energy is developed in sufficient detail to underscore its environmental and social significance. Finally, the thermodynamic limitations and implications of energy conversion are explored, ending with a view of life as a supremely artful organizer in nature, a mechanism powered by energy which creates wondrous "local order", but always at the expense of influencing its environment.

The growth of a mouse colony carries the thread of the unit "Mice and Men." As the colony develops, students learn many things about the concept of population. The food and water consumed and products eliminated tie the mouse colony back to the unit "Heat, Energy and Order", and point ahead to the chapter on communities and to the unit "Environmental Balance?".

The cell concept is given prime position in this unit. It is used to enter topics on reproduction, embryology and maturation which are observed in the mice and other organisms. The mice selected for the original colony are such that an experiment in Mendelian genetics comes out of the observations students make as the colony develops. In most of the chapters man is an important organism and receives as much attention as the mouse, although the data are often secondhand.

A rather unpleasant fact that must be faced is that as our population increases, and human activities are directed towards increasing the standard of living for this population, strains are placed upon the environment. As students discover in "Mice and Men," the size of the community has a relation to both the quantity of the food, water and energy required and the quantity of waste products produced. To develop the concept of a closed system and point out the necessity for environmental management, an analogy between the earth and a spaceship is made. Students are then introduced by a multi-media approach to the nature of some of our common pollutants (with emphasis upon air, water, heat, noise and radiation) as well as their effects. Following this students are encouraged to undertake a rather detailed study of a particular type or aspect of pollution. Emphasis here is placed upon student activity, which may take any number of forms. The culminating activity centers around discussion of these special studies together with the complex relations involved within the environment. It is hoped that out of these studies students will become aware of threats which exist to man's future on this planet.

THE SECOND YEAR COURSE

The second year of the course is considerably more quantitative in its approach than the first. This is the case because (1) the students are one more year along in their mathematical preparation, (2) the students who elect to take a second year of science are more likely to exert the effort to master more difficult topics, and (3) many of the quantitative aspects of physics and chemistry are basic to an understanding of molecular biology, which is an important part of the following year's work.

The second year consists of two parts:

(1) Motion and Energy

(2) Chemical Reactions

Year II begins with the study of motion, going from the quantitative description of motion to a consideration of what causes motion and a discussion of Newton's laws. There follows the development of the laws of conservation of momentum and energy, including a discussion of energy in biological systems. This section, which is primarily mechanics, culminates with a discussion of kinetic molecular theory.

Due to recent advances in both molecular biology and biochemistry, the descriptive approach to biology has gradually given way to one that is primarily analytical. It is now necessary, even on the high school level, for the serious biology student to have a more thorough understanding of those concepts normally (xii embodied in the "modern" high school physics and chemistry courses. The major objective of "Chemical Reactions" is to build some of those basic chemical concepts that are necessary for an analytical study of "The Chemistry Of Living Matter" and "Energy Capture and Growth."

The following subtopics of this section help in the realization of the major objective: Some of the topics discussed are the mole concept, equation writing, energetics associated with chemical reactions, the dynamic nature of particles and their interactions and the application of energy and equilibrium to chemical systems.

THE THIRD YEAR COURSE

Year III consists of four parts:

(1) Waves and Particles

(2) The Orbital Atom

(3) Chemistry of Living Matter

(4) Energy Capture and Growth

The underlying rationale of the third year is a study of energy and its importance to life. The first thrust is to build the orbital model of the atom using, as background, waves, electromagnetism and historical models of the atom. Once the orbital model is established as a representation of the localization and directionalization of electronic energy, structural models are built to show how biopolymers are spatially arranged and experiments are done to give evidence of energy relationships. With shape, size and energy relationships of molecules established, the DNA molecule is introduced. The culmination of this work comes in the final section when photosynthesis is considered. With this topic, much that has gone before is brought to a logical focus.

These topics are most appropriately placed in the third year of the integrated sequence after students have developed some facility with basic ideas from chemistry and physics - e.g., quantitative knowledge about energy, mechanism of chemical reaction, equilibrium, rate of reaction, the photon and wave nature of light, electrical phenomena, and kinetic molecular theory. They should not now simply parrot biochemical processes such as photosynthesis and cell respiration but should understand the many chemical and physical principles which underlie these processes.

Time is allotted at the conclusion of Year III for individual investigation and studies.

Three-Year Course Outline

TOPIC		REFERENCE
	<u>First Year</u>	
Part One:	Perception and Quantification	
	I. Sensing and Perceiving	PP*
	II. Measurement, Distribution, Organization and Communication	PP
Part Two:	Heat, Energy and Order	
	I. Heat	PP
	II. Temperature and Chaos	PP
	III. Energy	PP
	IV. Nuclear Energy and Radioactivity	PP
	V. Trends in Nature	PP
Part Three:	Mice and Men	
	I. Reproduction and Development	PP
	II. Genetics	PP
	III. Genetics and Change	PP
	IV. Populations	PP
	V. Ecology	PP
Part Four:	Environmental Balance?	PP

* PP designation signifies materials produced by the Portland Project.

TOPIC		REFERENCE
	Second Year	
Part One:	Motion and Energy	
	I. Motion	HP*
	II. Newton Explains	HP
	III. Multi-Dimensional Motion	HP
	IV. Conservation	HP
	V. Energy - Work	HP
	VI. Kinetic Theory of Gases	HP
Part Two:	Chemical Reactions	
	I. The Mole as a Counting Unit	PP
	II. Combinations of Gases	PP
	III. A Useful Form of P=kDT	PP
	IV. Chemical Equations	PP
	V. Electrical Nature of Matter	CHEMS+
	VI. Basic Particles	CHEMS
	VII. Energy Effects in Chemical Reactions	CHEMS
	VIII. Rates of Reactions	CHEMS
	IX. Equilibrium	CHEMS
	X. Solubility	CHEMS
	XI. Acid-Base	CHEMS
	XII. Oxidation-Reduction	CHEMS

* HP designates Harvard Project Physics material.
\+ CHEMS designates material derived from the Chemical Educational Materials Study.

TOPIC		REFERENCES
	XIII. Stoichiometry	CHEMS

<u>Year Three</u>

Part One:	Waves and Particles	
	I. Waves	HP
	II. Light	HP
	III. Electricity and Magnetic Fields	HP
	IV. Faraday and the Electrical Age	HP
	V. Electromagnetic Radiation	HP
	VI. The Chemical Basis of Atomic Theory	HP
	VII. Electrons and Quanta	HP
	VIII. The Rutherford-Bohr Model of the Atom	HP
	IX. Some Ideas from Modern Physical Theories	HP
Part Two:	The Orbital Atom	
	I. Atoms in Three Dimensions	PP
	II. Many-Electron Atoms	CHEMS
	III. Ionization Energy and the Periodic Table	CHEMS
	IV. Molecules in the Gas Phase	CHEMS
	V. The Bonding in Solids and Liquids	CHEMS
Part Three:	The Chemistry of Living Matter	
	I. Monomers and How They Are Built	PP
	II. Polymers or Stringing Monomers Together	PP
	III. Polymers in 3-D or The Shape of Things to Come	PP
	IV. Where the Action Is--The Active Site	PP

PERCEPTION AND QUANTIFICATION

Outline: Perception and Quantification

TEXT SECTION	ROUGH TIME ESTI-MATES	EXPERIMENTS	DEMONSTRATIONS	TEACHING AIDS	OTHER STUDENT ACTIVITIES	OUTSIDE READING	PROBLEMS
Portland Project I Sensing and Perceiving	2 Days	A The Sowbug					
B Optical Illusions	3 Days	B.1 Size Illusions		Film "Visual Perception"	The Pendulum The Trapezoid	The Mind Elements of Psychology Experiments in Optical Illu-sion	
B.2 Using Illusions							
			B.3 Seeing through hearing	Film "Blind as a Bat"			
C Limita-tions of our Senses	12 Days	C.1 Touch					
		C.2 Depth Perception					pg.35 1-3 pg.36 1-4

TEXT SECTION	ROUGH TIME ESTIMATES	EXPERIMENTS	DEMONSTRATIONS	TEACHING AIDS	OTHER STUDENT ACTIVITIES	OUTSIDE READING	PROBLEMS
C.3 Reliability and Validity							pg.42 1-4 pg.43 1-6
		C.4 Peripheral vision C.5 Visual Reaction Time		Films "Nature of Color" "Discovering Perspective"			
		C.6 Auditory Reaction Time		Films "Sense Perception" Part 1: Wonder of the Senses			pg. 51-53 1-7
			C.7 Paramecia and their Speed C.8 Size and Weight	Part 2: Limitations of the Senses Note: Last 2 films should be shown after Exp. C.6			pg.57,59-61 1-6 pg. 62 1-2
	3 Days	D Responses of Sowbugs					

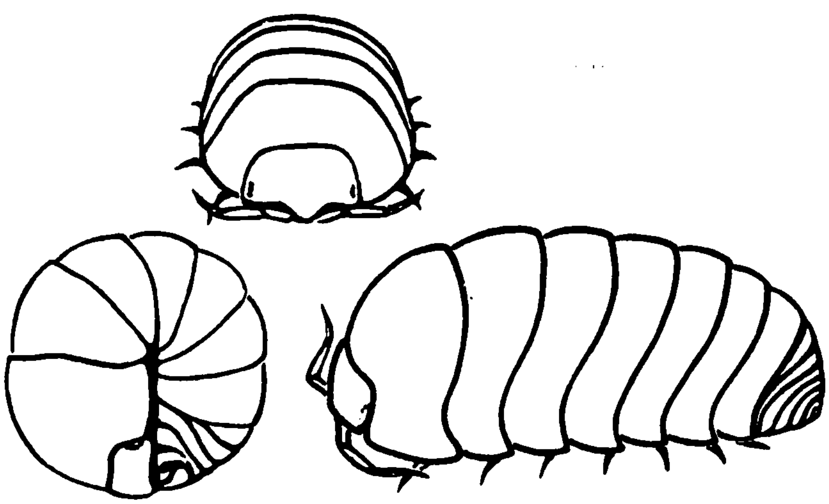
Equipment and Materials:
Suggested: 5 animals per student.

A. Experiment: The Sow Bug

How good are your powers of observation? Do you have the patience and the know-how that it takes to be a really good observer? In this experiment you will be observing a familiar object -- a sow bug.

Write a description of the sow bug your teacher places before you on the table. Make it as complete and detailed as you can.

When you have completed your individual lists, one person at each table will be assigned the task of itemizing all the different observations made by your table.



The less you structure this experiment for the student, the better his learning experience may be.

A class of thirty students might be arranged in groups of six. Each student is given sow bugs to observe. With many sow bugs on a table there could be interaction between the sow bugs as well as between the students.

Instruments such as magnifying glasses, rulers, meter sticks, balances, and graduated cylinders should be available in the event they are asked for. If students raise questions while observing the sow bug and its activities, these should be written in their data books.

10 to 15 minutes may be all the time needed by the students to complete their lists.

Assign one person at each table to report the observations for the rest. These could be listed on the blackboard and only non-repetitive observations added as each table reports.

The students could make a contest out of this; the winning table (team) would be the one that has the greatest number of observations. Of course, all interpreting or inferences would have to be ruled out.

10 *During the class discussion that follows, it may prove worthwhile to:*

(1) Ask the students to tell which sense or senses they used when making each observation. Note these next to each observation on the blackboard using initials as in the following:

Eyesight - E
Feel - F
Hearing - H
Taste - T
Smell - S
Temperature - Te

(2) Ask the students to consider what conditions can be controlled or need to be controlled as they observe their subject. Have them name some conditions which might not be important in this one. Examples would be:

--The experiment is done on the second floor.

--The lab table is near the back wall.

Ask them to consider some conditions which might have been important to the experiment they just carried out. Examples here would be:

--The experiment was done in the morning (or the middle of the afternoon).

--The sow bug was on the table out of its environment.

--The temperature of the room is around 70° F (about 21° C).

(3) Also, you might offer questions like those that follow:

--Why do you think these conditions are important?

--How might they be different from those in the animal's natural habitat?

--What do you think is the natural habitat of these animals?

Many times it is difficult to recognize conditions that might seriously affect what is being observed in an experiment.

This experiment should point up (1) the need for a student to improve his techniques used in making observations, (2) the answer to which sense or senses are most commonly used in observing (and the need to bring more into use), and (3) the important difference between observing and inferring.

* * *

Some possible observations:

One very important observation should involve behavior. About 70% of the isopods should be able to roll up in a ball. The others will not be able to do this even when tormented quite a lot. YOU SHOULD SEE TO IT THAT BOTH KINDS ARE IN THE SET TO BE OBSERVED.

It will probably be noted that the dorsal surface is quite smooth although the minority will have many tubercles (warts - bumps); other traits may be noted that will naturally segregate the sow bugs into two sets.

These sets are really general; there are only a few genera of sow bugs in North America, including Armadillidium (a type which rolls itself up like an armadillo) and Porcellio.

Instruct the class that in the future it is Porcellio which they ought to bring in when sow bugs are needed for experimental *work. Furthermore, there are two kinds of Porcellio (species): when mature Porcellio laevis is larger and less tuberculate than Porcellio scaber.*

1) *They have 2 antennae*
2) *They have 7 pairs of legs*
3) *Body is jointed*
4) *Three regions: head, middle, tail*
5) *Some have 2 projections on tail*
6) *Edge may be smooth or saw-toothed*
7) *Legs are jointed*
8) *Some of them roll up in a ball when bothered*
9) *Flat ones are faster*
10) *Some are domed; others nearly flat*
11) *Some have a faint pattern of color on the back*

Keep this section moving.

The student has observed the sow bug. One purpose of the following exercises and experiments is to point out that our senses used in observing are not always reliable. Environmental factors and preconceptions or "mind-set" will affect the way we perceive. We also have biological and physical limitations. Another purpose is to show that although people perceive somewhat similarly, they also perceive differently in many instances. A third

B. OPTICAL ILLUSIONS

You have noticed the use of your senses in observing and describing a sow bug. How reliable are your senses and the observations you make by means of those senses? See Figures B.1, B.2 and B.3.

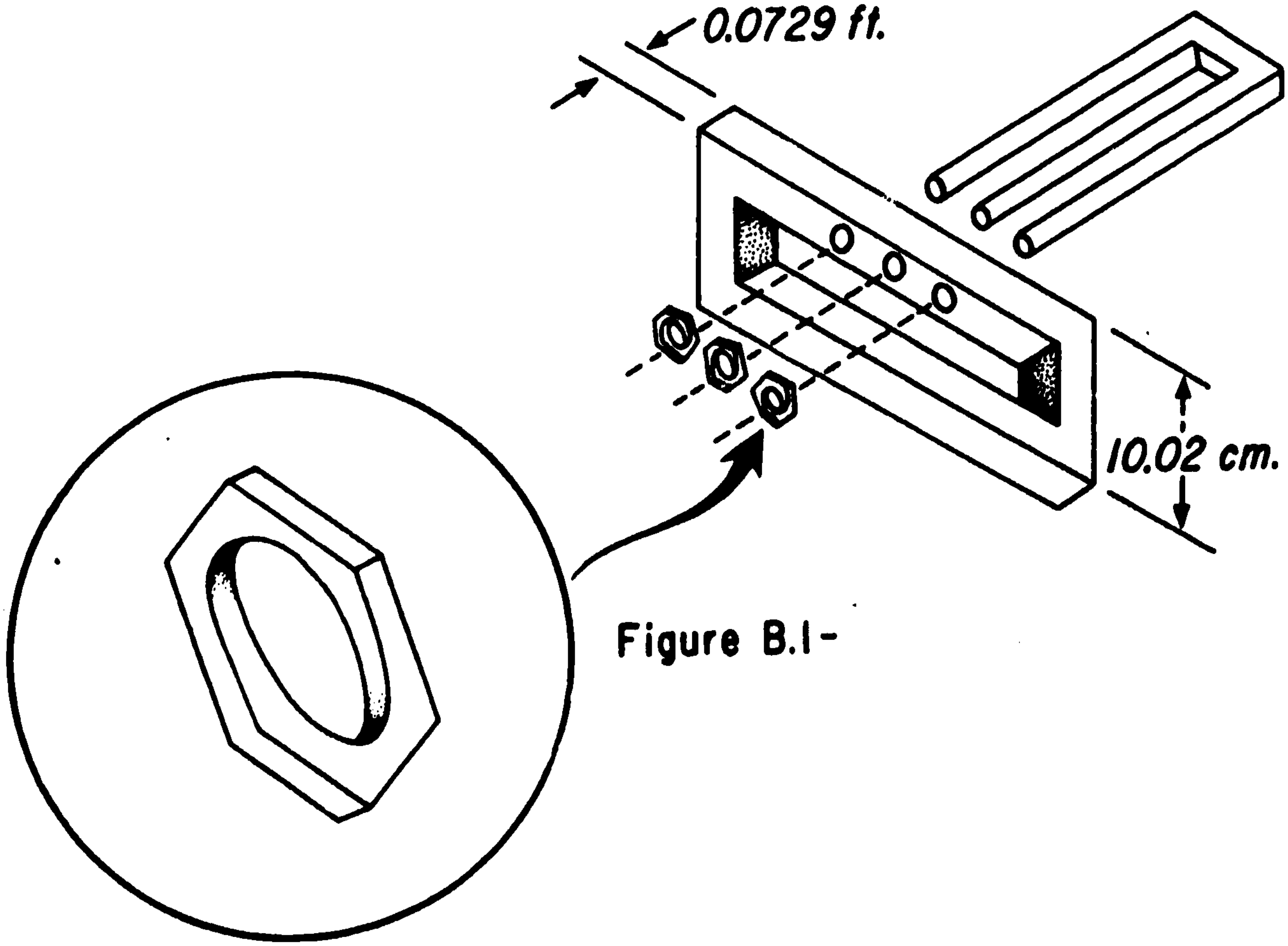


Figure B.1-

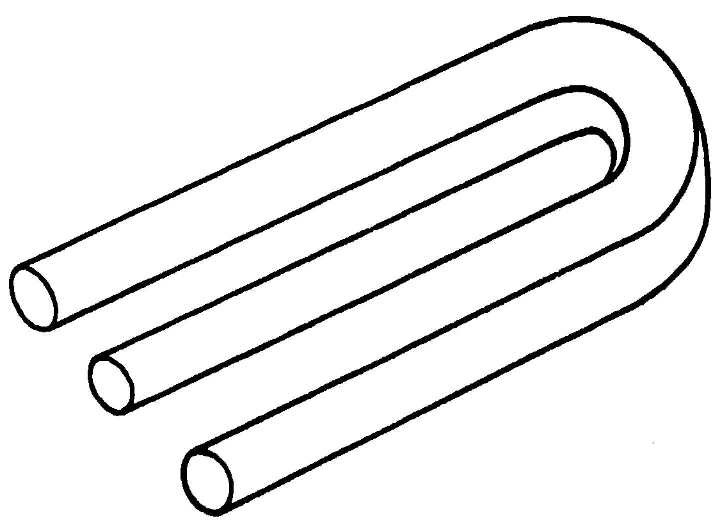


Figure B.2 -

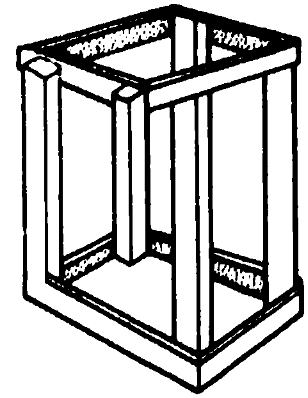


Figure B.3-

purpose is to lead the student to realize that he needs tools to extend his senses and that he needs to use measurement and quantification in order to communicate to others comparative descriptions of what he perceives.

There is a large number of examples of optical illusions available. Student science magazines, psychology and physiology books are usually good sources. Suggested books: The Mind (Life Science Library, Time Inc., N.Y., 1964); D. Krech and R. S. Crutchfield, Elements of Psychology, (Alfred A. Knopf Publishing Co., N.Y., 1961); and N. Beeler and F.M. Branley, Experiments in Optical Illusion, (Thomas Y. Crowell Co., N.Y., 1951). There are also some commercially prepared transparencies available (3 M Company). The teacher could use more examples of optical illusions as he sees fit -- depending upon time and materials available and on the interest of the class.

A useful and interesting pamphlet is The Color Tree by Interchem. For information send to Interchemical Corporation, 67 West 44th St., New York, New York 10036.

The following gives directions for preparing three illusions that should be of interest. Students who wish to do so could make these for themselves or the class.

Color After-Image

We have not dealt here with interesting color illusions or color after-image.

One good example is a drawing of the American flag with black stars on yellow background and alternating green or blue-green and black stripes. The colors must be vivid. The student stares at the center of the flag for about 30 seconds and then looks at a white paper for about 10 seconds. An after-image appears of a red, white, and blue flag. (Squinting the eyes a little sometimes makes the after-image clearer.)

The Pendulum

Tie an object such as a small metal weight on the end of a string. Tie the other end of the string to any kind of a hook (a nail, light fixture, etc.) attached to the wall or ceiling. This will allow the object to swing freely as a type of pendulum. It should wing parallel to the wall. Hold a piece (about 2" square) of colored filter paper (or cellophane or colored glass) over one eye. Look at the swinging object (pendulum) with both eyes open. Although the pendulum is swinging parallel to the wall, it will appear to swing in an ellipse. It will appear to swing counter clockwise if the right eye is covered and clockwise if the left eye is covered.

The color of the filter paper used is not important as long as it is dark. Dark blue, green, or red is effective.

An attempt should be made to explain the illusion. (Cutting down the light intensity to one eye is responsible for the effect.)

Test such hypotheses as these:

(a) The illusion is due to certain colors. (Not so; different colors give the same result.)

(b) The illusion is due to the filter paper or the glass. Clear paper or glass would not produce the illusion. Colored paper and colored glass give the same illusion.

(c) Light is bent. (Not so. Try a clear convex or concave lens. The illusion will not occur.)

The Trapezoid

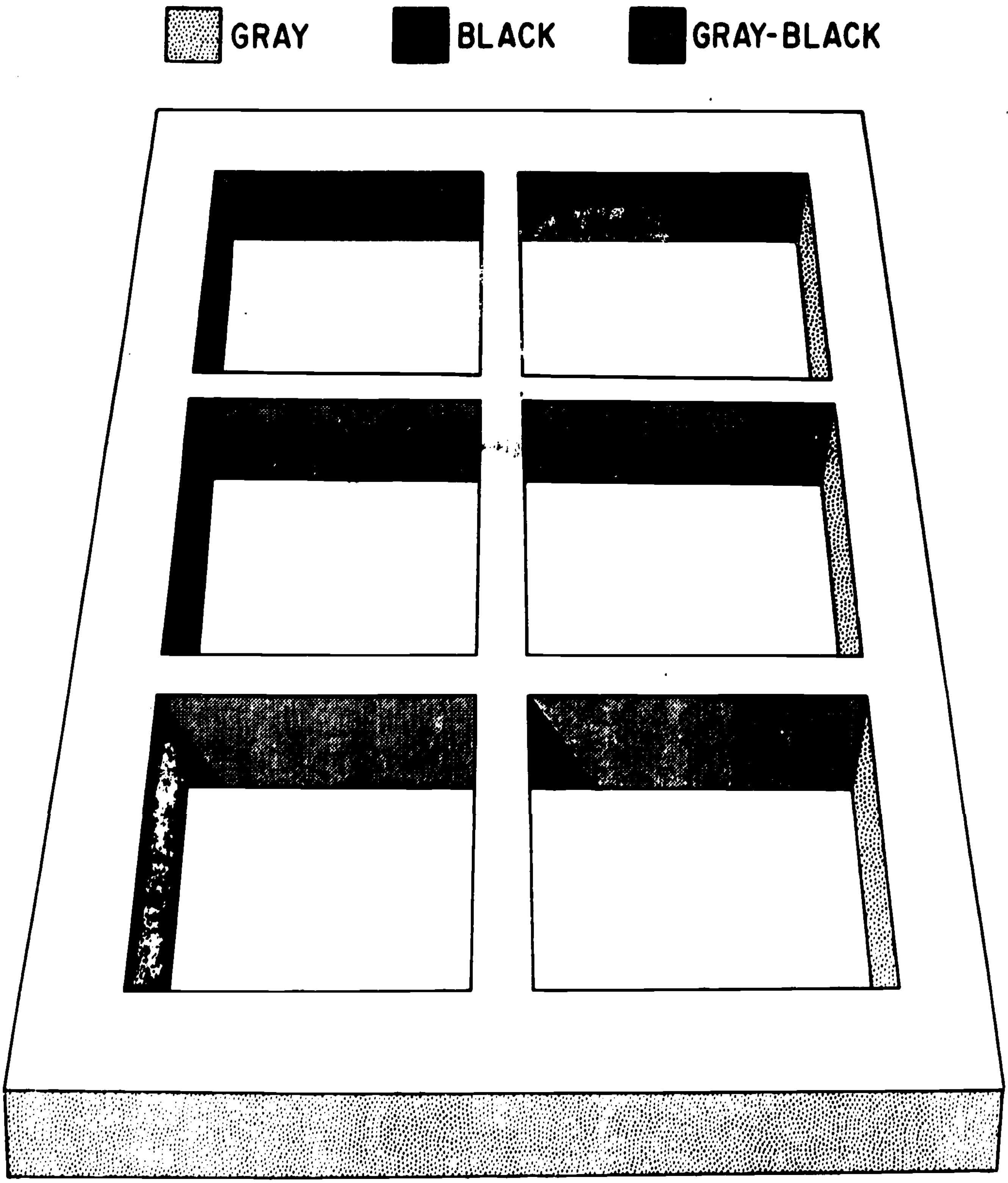
Build a trapezoid according to the pattern given. As shown on the pattern, shade both sides exactly the same.

Attach the trapezoid to a hand drill. This can be done by using a paper clip. Straighten one of the bends in the paper clip and glue this to the trapezoid. Put the other end (still bent) in the hand drill and tighten the hand drill in order to hold it.

Turn the hand drill to rotate the trapezoid. Because of its shape and its coloring, the trapezoid will appear to oscillate rather than to rotate.

It will be necessary to experiment somewhat to find the proper speed of rotation to get the illusion, but about one or two turns per second should work.

The illusion is easier to see if one eye is closed.


GRAY
BLACK
GRAY-BLACK

It would be better if a variable speed motor or turntable could be used in order to turn it more evenly. It would also be more effective to conceal the device used to turn the trapezoid.

For further illusion, place a half of (colored) kleenex through one of the windows (or use a small pencil held by a wire) and turn the trapezoid.

WARNING TO TEACHERS:

Prepare for Experiments C.1 through C.6.

B.1 Experiment: SIZE ILLUSION

Look at the following figures and record in your lab book which is larger, A or B? Do not be influenced by what you may know to be the right answer.

Which one do you think looks larger?

Estimate how much larger. (Do not measure.)

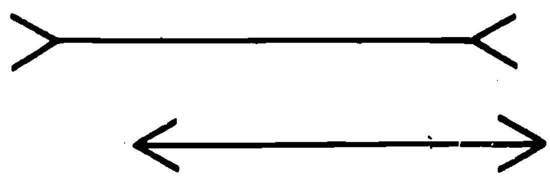


Figure B.4 - Which is longer?

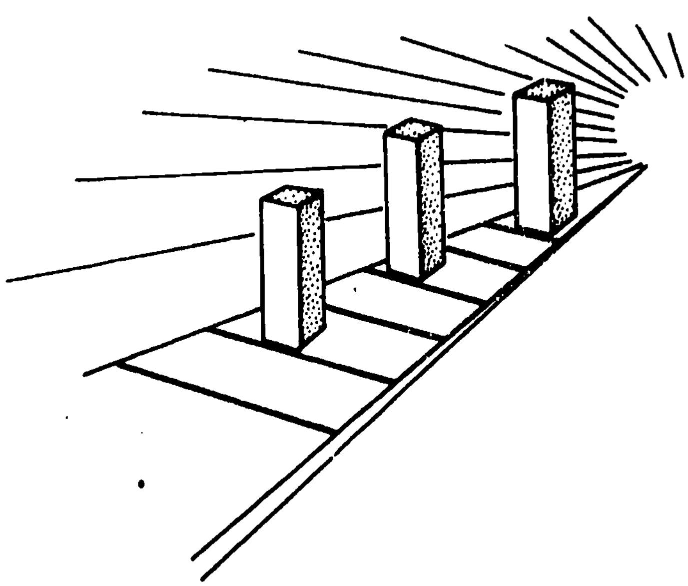


Figure B.5 - Front post is A, back post is B; which is taller?

Equipment and Materials

30 metric rulers or meter sticks

In looking at these optical illusions, the student should notice that the surroundings, the position, and the color (light and dark) have an effect on our visual perception.

It is also hoped that the student will realize a need for measurement. The ideas of uncertainty, significant figures, and averaging can be introduced here, but they will be treated in more detail later.

You are asking the students to estimate "how much larger" but not allowing them to measure. The idea of ratio could be introduced with these types of questions:

Does one figure appear to be twice as large (expressed 1:2)? Half again as large (expressed 1:1.5)? One-tenth again as large (expressed 1:1.1)?

Some students will have seen these and know that in each case they are the same size. Some others might give what they think will be the right answer and not what they actually see.

They are not to make measurements of any kind at this time. When time for measurement arrives, be sure the metric system is used.

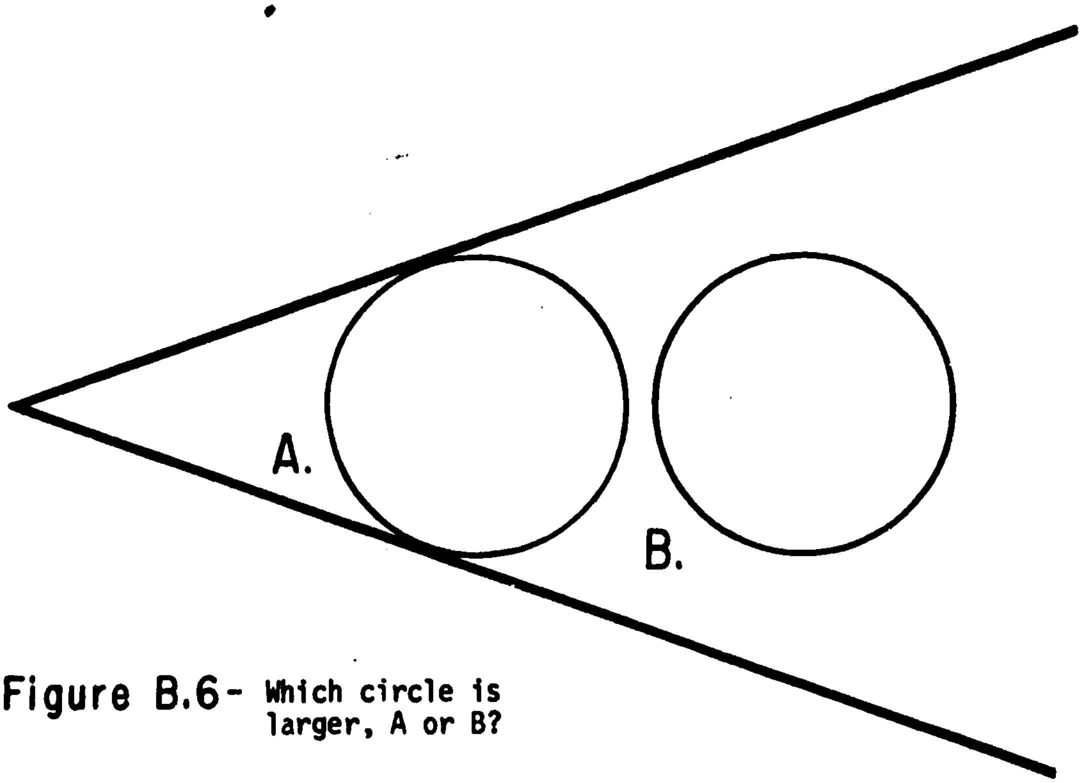


Figure B.6 - Which circle is larger, A or B?

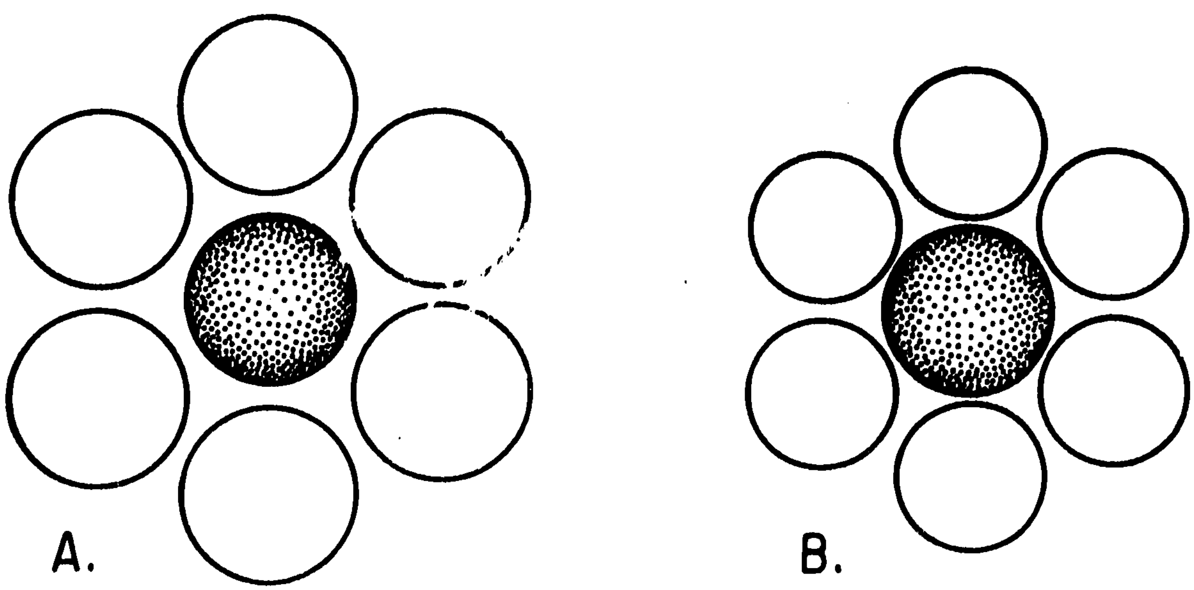


Figure B.7 - Look at the center circle. Is the center circle in A the same size as the center circle in B?

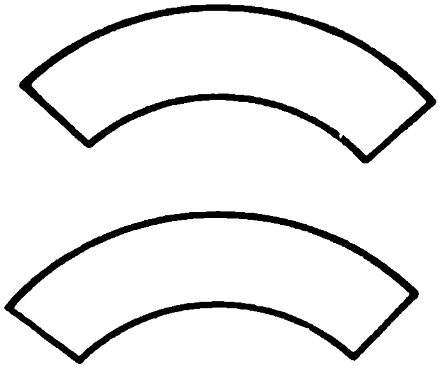


Figure B.8 - Which is larger?

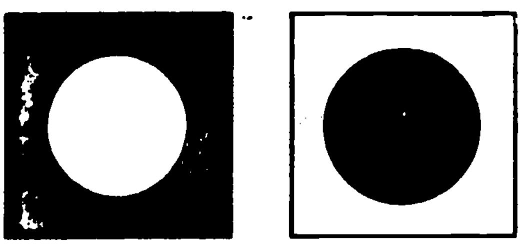


Figure B.9 - Which circle is larger?

Now that you have recorded your answers, check to see if you are right. Which one in each case is actually larger? Record the answers in your lab book.

For helpful hints in writing laboratory reports see Appendix A.

It is hoped that at this point students will see the need for a measuring instrument. They should be encouraged to devise their own units of measurements, even if they use a pencil or a similar object as a measuring instrument to make comparisons.

Now ask for the actual figures so that you can put them on the board. When this is done, students should see the need for a common standard of measurement. If one student gives his answer in inches, another ½ of a pencil, another the distance from his knuckle to the end of his finger, they should see that comparisons of results cannot be made and also that the length of a finger would not be the same for all. A common standard is needed. Discuss this in class.

Pass out meter sticks or rulers that are marked in the metric system. Have them measure in cm the length of the two lines in Figure B.4. (They may do more measurements if so desired, but one example should be adequate.) It may be necessary to take some time here to help those who are not familiar with the metric system, but a lengthy treatment is not necessary. An understanding of what a cm is and how to read the ruler is probably sufficient.

After the class has completed measuring (and recording) the length of the lines in Figure B.4, ask for the results of ten to fifteen students for line A. Put these on the board. It is expected that the answers *will vary slightly. These variations could introduce the idea of uncertainty, human and instrumental error, significant figures, and averaging.*

At the conclusion of B.1 show the film "Visual Perception" (19 minutes), 1959, Educational Testing Service.

B.2 USING ILLUSIONS

In Figure B.5 do you get the illusion of depth? Artists often make use of this illusion (which they call perspective). Have you seen examples in which "pop" artists use lines and colors to create illusions?

Figure B.10

In the picture above the lighter vase looks larger. The next time you go to a grocery store, notice how many packaged foods are in light colored containers.

Dress designers also make use of illusions. A black dress makes you appear thinner. What effect would a light dress have? Designers must also consider how lines affect your appearance. Which of the identical girls below looks thinner?

The one wearing the dress with vertical lines looks thinner.

Figure B. 11

Can you think of other examples of using optical illusions?

Equipment and Material:
blindfold
8" x 12" cardboard
4" x 6" cardboard

The film "Blind as a Bat" (MIS, 1954, 7 min.), available at Portland Administration Building, can be shown immediately preceding the "SEEING THROUGH HEARING" demonstration, which will be much more effective if the film is shown. Ask the students if they could do as well as the bats.

Blindfold a student and seat him on a chair in front of the class. Tell the blindfolded student that two pieces of cardboard will be successively passed before his face.

One piece of cardboard is 8 x 12 inches. The other is 4 x 6 inches. The blindfolded student should hiss while the teacher holds the cardboard about 8 inches from the student's mouth. Most students will have no difficulty identifying the cards. Repeat the demonstration with several students as time allows.

In addition to size differentiation by sound, blindfolded students may also locate direction by sound. Have a blindfolded student seated in a chair plug his ears with his fingers while you move to some position in a 180° arc in front of the student. After counting to 10 while his fingers are in his ears, the blindfolded student should remove his fingers from his ears and begin hissing. You will hold the 8 x 12 inch cardboard about 8 inches from his face as he hisses and swivels his head from side to side. The

B.3 - Demonstration: SEEING THROUGH HEARING

You have heard of bats flying at dusk and you know that airplanes fly at night. Submarines navigate under water. How can they see to follow their courses? What are your "seeing" powers when blindfolded? Your teacher will show you how to "see" with your ears.

For optional experiments related to perception, see Appendix B.

blindfolded student should have no difficulty in locating the card and pointing to your position. Perhaps your students have read reports on teaching blind humans Sonar navigation.

Lab instructions for Experiments C.1 - C.8.

In these five experiments students should recognize some limitations of the human senses. Because quantification is used, students can compare results and find some similarities and differences in human perception. They should begin to see a need to use tools to extend their senses.

The techniques of recording data, averaging and graphing are emphasized.

All five experiments should be set up in one room at one time. Student lab groups made up of three students do each experiment, but each group does them in a different order.

It is suggested that you give general instructions for the whole lab block before dividing into small groups.

After instructions are given, assign lab groups and the order in which each group is to proceed.

There are five experiments and three students in a lab group. Therefore, if you have more students, you will need to prepare two sets of equipment for some of the experiments. The Reaction Time, Touch, and Visual and Auditory Reaction Time experiments require the least amount of equipment, so use two lab "set-ups" for these as needed.

Toward the end of this lab block, students may have to wait for the use of the

C. LIMITATIONS OF OUR SENSES

In Experiment B.1 - SIZE ILLUSIONS, probably most of you chose the same figure as being the larger. But when you observe things, do you all perceive (see, feel, smell, hear, taste) the same things in the same way?

You know that some people like the taste of olives, some do not. Is this because they taste different to some? You know that your environment and learning have an effect on how you perceive and on your choice of what you like or don't like. But do you actually know whether or not all people taste the same thing in the same way?

When you see something that is blue, does it look exactly the same blue to someone else? Since there is no way to measure or quantify your perception of blue, there is no way of comparing and communicating with others as to what you actually are perceiving. Therefore, there is no way to tell whether or not the blue looks exactly the same to someone else.

equipment for Depth Perception, Peripheral Vision, and Response Time of the Eye. By then, however, they should have enough data to compile and questions to answer that they can work on these while waiting. Also, most of the experiments are open-ended and have suggestions for further study and experimentation for students who have the time.

With this many lab groups and experiments, it is suggested that you use student help or lab assistants. They could help set up the equipment and keep it working and could help students with general instructions and procedures.

The formula for finding an average or mean is used quite often. It is

$$\bar{X} = \frac{\sum x}{N} \quad \text{where}$$

$\bar{X}$ is the average or mean; Σ, the sum of; x, the individual scores; and N, the number of trials.

You might want to discuss this formula with them now by putting it on the board and seeing if they can figure out what it means.

Your senses are limited in several important ways. You will conduct a series of experiments to determine the nature of some of these limitations. Since in these experiments you will be making some measurements, you will be able to make some comparisons as to similarities and differences among sense perceptions.

There are five experiments to be done:

Touch

Depth Perception

Peripheral Vision

Visual Reaction Time

Auditory Reaction Time

The teacher will assign lab groups and give directions. He will also assign the order in which each group is to do the experiments.

Read carefully these instructions:

(1) Read the directions and background material for the experiment you will be doing before you come to class (time is limited).

(2) In class you should work quickly but carefully. You will be expected to do one experiment, collecting and recording all of the necessary data in about one lab period.

(3) You will be expected to do some of the data compiling, mathematics, graphing and questions at home. (The teacher will need to

Instructions for the students are as follows: (read them with the students for emphasis):

(1) Read the directions and background material for the experiment you will be doing before you come to class (time is limited).

(2) In class work quickly but carefully. You will be expected to do one

take some time in class for those who need help and for general instructions and discussion.)

(4) If the equipment you need to use is busy, while you are waiting, use the time to compile data and answer questions. If you have time, work on some of the suggestions for further study and experimentation.

experiment, collecting and recording all of the necessary data in about one lab period.

(3) You will be expected to do some of the data compiling, mathematics, graphing, and questions at home. (The teacher will need to take some time in class for those who need help and for general instructions and discussion.)

(4) If the equipment you need to use is busy, while you are waiting, use the time to compile data and answer questions. If you have time, work on some of the suggestions for further study and experimentation.

It is expected that this lab block will take two-and-one-half weeks. Some of the questions involving comparisons to the whole class cannot be answered until all of the students have finished, so allow two or three days for discussion of these questions.

At the end of this lab block be sure to discuss

Questions 2 and 3 (Depth Perception)

Questions 3 and 4 (Peripheral Vision)

Questions 2, 3, 4, 5, 6, 7, and 8 (Visual and Auditory Reaction Time)

C.1-Experiment: TOUCH

Equipment and Materials
compass, divider, or other sharp instrument
blindfold
metric ruler

Ideally you should file the sharp metal point of the compass to a slightly rounded point more like the pencil point. Students will find that their finger tips will have a touch threshold about ten times more sensitive than their forearm (3 mm vs. 3 cm). It makes no difference if the front or rear of the forearm is touched. The most important instruction is that great care be taken to have both points of the compass touch simultaneously. The student being "touched" may be blindfolded or he may simply look away from his arm. There should be time for each student to be "touched."

Spread the points of a compass (divider) to 4 cm. Touch the points of the compass to the forearm of a blindfolded lab partner. Ask if there are two points or one point touching his arm. Record the distances and the student responses. Move the points of the compass closer together. Record the distance that your lab partner reports as a single touch when two points are actually touching his arm. Remember to use an occasional one-point touch as a control or otherwise he will know that he is being touched with two points every time. Repeat this process on the tip of a finger. What do you find about the sense of touch for a finger compared to the forearm?

The finger is much more sensitive than the forearm.

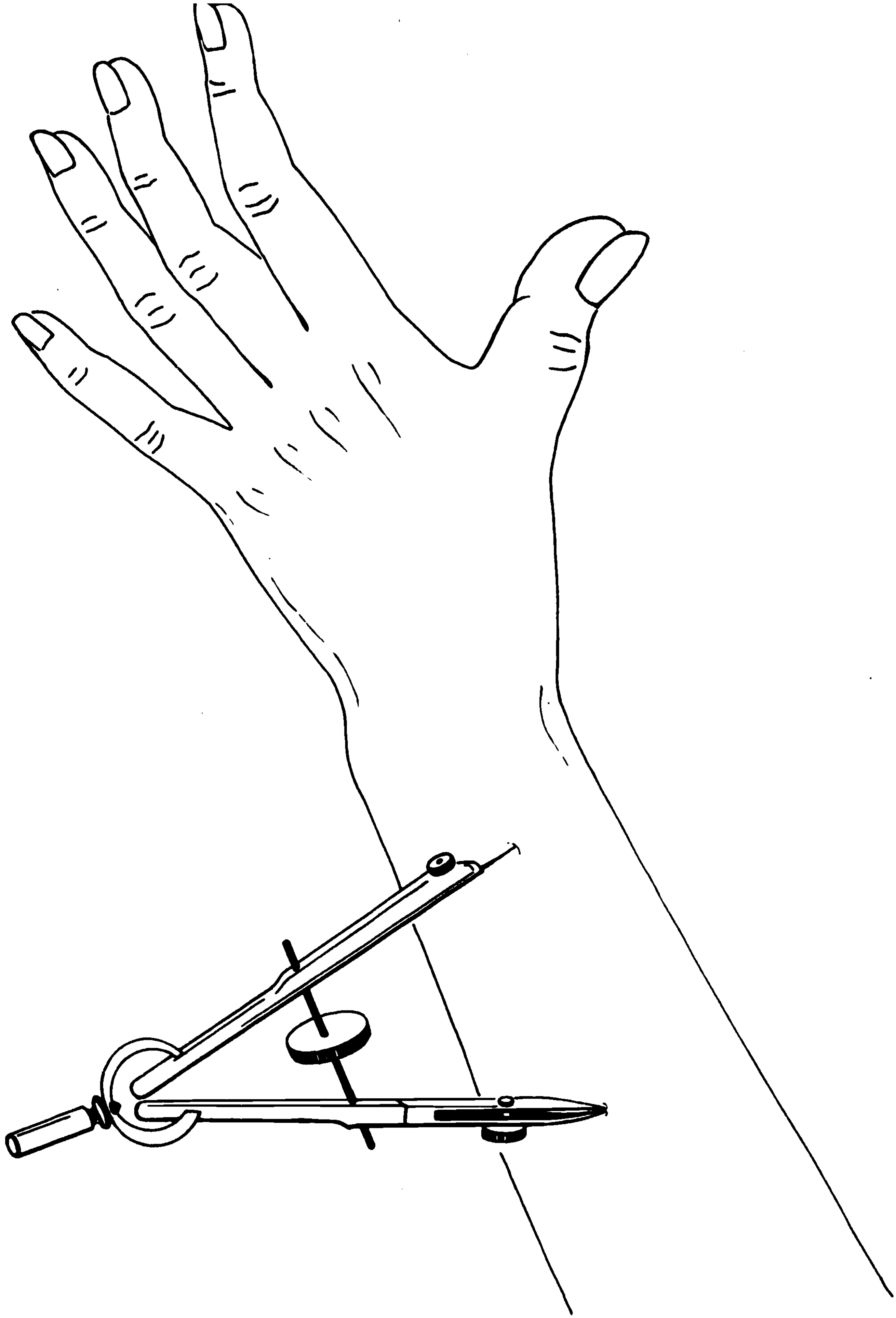
Does your sense of touch differ from that of your lab partners? Does the alignment (parallel or perpendicular) of touching upon the forearm change the measurement?

We don't think alignment makes a difference, but it depends upon experience.

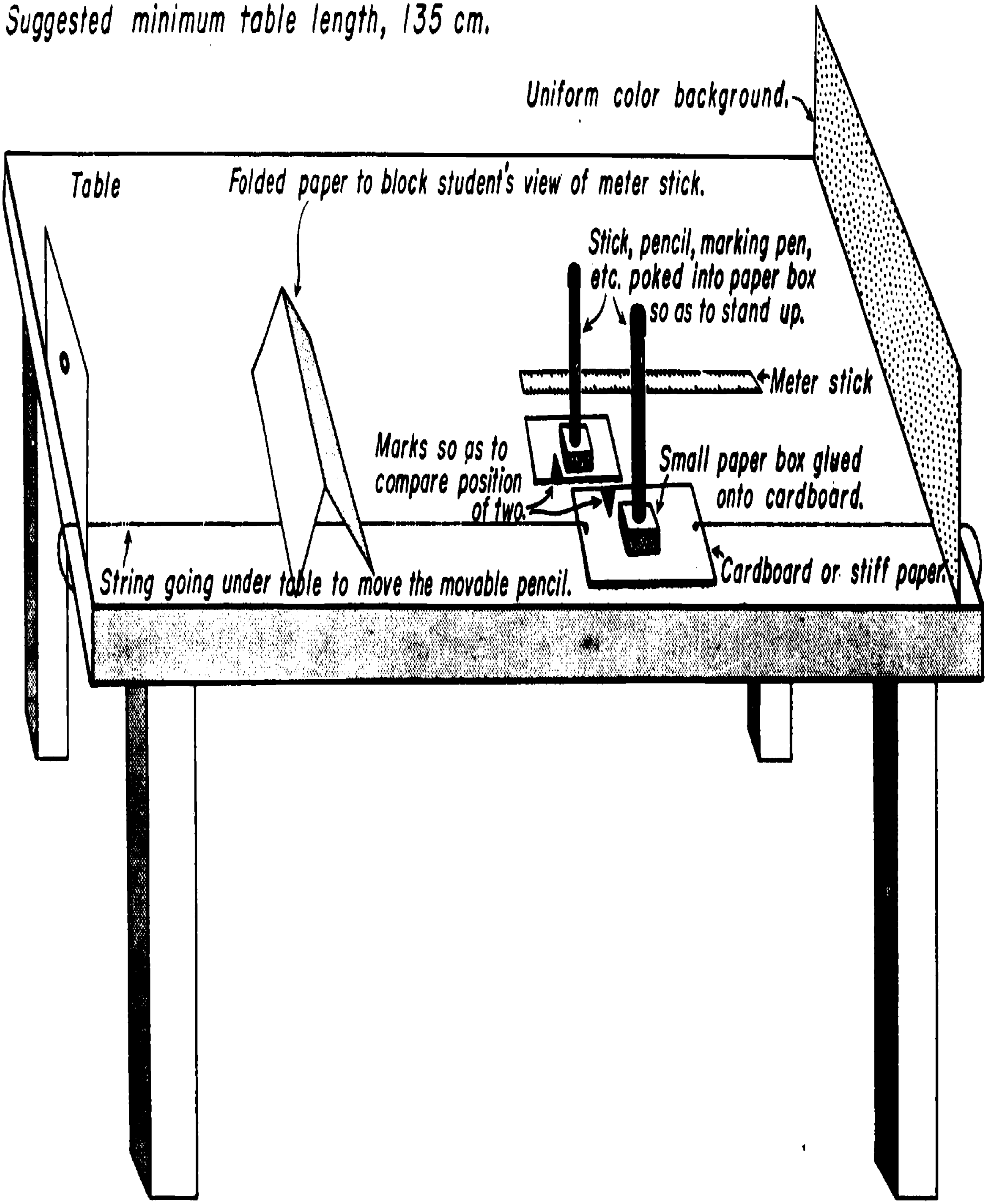
C.2-Experiment: DEPTH PERCEPTION

Equipment and Materials
Heavy string (one about 200 cm long, another about 600 cm long).
2 pens or pencils, same color and size, with clips.
Cardboard for shielding and screens, neutral color.
Meter stick.

The object of this experiment is to try to line up the two pens by moving one of them. You will need three people in your lab group. One student is the subject (S), one is the experimenter (E), and one is the recorder (R). After twelve trials change roles and repeat the pro-



Suggested minimum table length, 135 cm.



cedure for twelve trials. Then again change positions. Each of you will then have performed each of the roles of S, E, and R.

As S, you will sit at the table and look at the pens either (1) through a hole in the cardboard screen that allows you to use only one eye (either the left or right) with no head motion (monocular condition), (2) through a wide hole in the cardboard screen that allows you to use both eyes and no head motion (binocular condition), or (3) with the cardboard removed allowing you to use both eyes and head movement (motion parallax condition). Keep your head low enough so that the meter stick is not visible to you.

R will tell you the proper condition to use. Take the string and adjust the movable pen to and fro until you think you have it lined up with the stationary pen. You have then judged them to be the same distance from you.

As E, between each trial you will change the standard pen (the one that cannot be moved by S) to a new position and adjust the movable pen to the front or back of the meter stick. Why should this be done?

When S informs you that he has the pens lined up, give the error score to the recorder.

2 small boxes to support pens or pencils.

In this experiment students are to assess the advantages of binocular distance perception as compared to monocular distance perception. They are also to evaluate the addition of motion parallax as an aid in distance perception.

The experiments show similarities (binocular distance perception will be better) and differences (individual scores will differ) in visual perception.

There will be a need to find an average or mean error score.

In order to have a standard with which to compare, $\bar{X}$ can be found for the class by a few students.

Assemble equipment as shown in the diagram. Distances are approximate and can be varied.

Instruct the students to use the same eye throughout all the monocular tests.

Notice that the experimenter moves the pens between trials, and that the conditions are varied. Learning takes place and the subject makes adjustments if this is not done. For example, if he is consistently getting a negative score, he will compensate for it. He may also find other clues to use.

This error score is the number of centimeters (to the nearest 0.1 cm) that the movable pen is from the standard pen. If the movable pen is too far from S, give the direction of error as minus (-); if it is too near, give it as positive (+).

As R, you record for S. Make a chart as follows:

Trial	Condition	Error Score	Direction of Error (too near +) (too far -)
1	Monocular		
2	Monocular		
3	Binocular		
4	Binocular		
5	Motion Parallax		
6	Motion Parallax		
7	Motion Parallax		
8	Motion Parallax		
9	Binocular		
10	Binocular		
11	Monocular		
12	Monocular		

Why are the conditions varied? You give

the condition to be used for each trial to S. As R, record the error score and direction of error as given to you by E.

Exercises for Home, Desk, and Lab (HDL)

(1) What were your average scores for each condition? Why are you asked to find the average rather than to choose one score? What is your average when you disregard the + and - signs? What is your average when you consider the + and - signs? Which is more meaningful? Compare your averages with others in the class.

(1) In measuring we will have a range of values. This range of error shows up in a frequency distribution curve:

By averaging we should come closer to the more probable answer. It should be pointed out to the student that it would be possible, if + and - signs are considered, to get an average score of 0. This would not be very meaningful if one time he got 20 cm too far, the next time 20 cm too near.

(2) Write a conclusion concerning the effects of the three different conditions on depth perception according to the data taken on you.

(2) Most students will have a very small error with motion parallax, a slightly larger error with the binocular and quite a large error with the monocular condition.

(3) Is there any pattern in your data of + or - errors for any condition? Compare your findings with others in the class.

(3) Often for any one condition the errors will all be in the same direction. However, the next subject may have his errors for the same condition in the opposite direction. This would seem to point out individual differences and limitations.

Students who are interested and have the time may do these. They may think of questions of their own that they would like to investigate.

In most of these cases accept the student's results from his experiments. Question his degree of confidence in his results based on the number of tests done and number of people tested.

Questions for Further Study or Experimentation

(1) With the monocular condition you used only one eye. Will you get the same approximate results using the other eye?

(1) It depends on the condition of the eyes.

(2) Will you have better scores on the monocular condition if you are allowed to move your head?

(2) Yes, you should.

(3) Some of you wear prescription glasses. Do you get better scores with or without your glasses?

(3) It would depend on the type of correction made by the glasses.

(4) A quarterback on a football team would need to have good depth perception. Would a person who had lost an eye ever be able to become a good quarterback?

(4) Yes. There are many examples of people who have lost an eye who have become experts in jobs that require good depth perception. They learn; they adjust and compensate and find new clues with which to judge depth.

C.3 - RELIABILITY AND VALIDITY

You may wonder at this point if a good score in depth perception in this experiment will mean that you will be a good driver. Of course the answer is no. There are too many factors involved in driving a car to expect that one thing would determine whether or not you are a good driver. You might argue, however, that depth perception would be an ability you could have that would improve your driving. You will indeed need to judge depth while driving. But don't be misled. This experiment is reliable but it is not valid for all situations involving depth perception. By reliable we mean that if the experiment is repeated you will get the same scores as before. This experiment is reliable. By valid we mean that there is a useful relationship between results of this experiment and some other related performance. This experiment is not valid for measuring the ability for depth perception in all situations.

It may not be reliable based on what has been done in class, but thousands of tests have been made.

A very similar experiment was used to test airplane pilots. It was found that some of those who did very poorly in the experiment had very good depth perception as pilots.

So you may have a much better score than your lab partner in this experiment, but while driving, he may be able to judge the distance to two approaching cars more accurately than you.

C.4 - Experiment: PERIPHERAL VISION

How far can you see to the side if you keep your eyes focused straight ahead? Can some people see farther to the side (peripheral vision) than others?

Does color have any effect on your peripheral vision?

You will need three people in your lab group. One student is the subject (S), one is the experimenter (E), and one is the recorder (R). After twelve trials change roles and repeat the procedure for twelve trials. Then again change positions. Each of you will then have performed each of the roles of S, E, and R.

As S, you sit in a chair in front of the equipment. Make a loose fist with your hand and place it on the table in front of you. By resting your chin on your fist, you keep yourself as much as possible from moving your head. If this is too uncomfortable, use books under your fist. Also, the white X mark on the card-

Equipment and Materials

- *Black cardboard or cardboard covered with black construction paper, 180 cm x 25 cm (thickness should be about 1 mm so that it can be bent into a smooth semi-circle); if necessary, tape two or three smaller pieces of cardboard together to get the required length.*
- *2 C clamps (optional)*
- *Masking tape*
- *3 pieces of black construction paper about 14 x 6 cm*
- *Small squares (about 1½ sq. cm) of red, blue-green, and yellow construction paper.*
- *2 blindfolds, one for the right eye, one for the left (optional)*

In this experiment students observe one of the limitations of visual perception. This also shows similarities in visual perception (they will all find yellow the easiest to identify) and differences (they will have different average response positions).

They should see the need to find the average or mean response position and be able board and the colored dots on the movable cards should be at eye level, so make adjustments by using books.

Choose the eye you wish to use and cover the other with your hand (or blindfold that eye). Stare straight ahead at the white X mark.

There will be a great tendency to move your eyes. If you give in to this temptation, you should inform E so that trial can be disregarded. Your results will not be reliable unless this is done.

As E, you place one of the movable cards over the cardboard on S's preferred side. Hold it so that it is flat against the inside of the cardboard. Place it at the farthest lateral position (90) and move toward the center (0) until S identifies the <u>color</u> of the dot, not the motion or the card. Give directions that S is not to guess but to report only when he is certain he can identify the color. When S identifies the color, report the color and proper response position (actually the number of cm from 0) to the recorder. Be sure to read from the mark on the card each time and not the edges of the card. Why?

Each of the three colors (red, blue-green, and yellow) should be presented about four

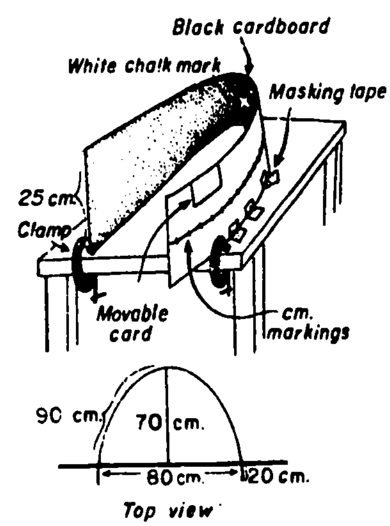
to do the necessary mathematics involved.

So that they will have <u>some</u> standard to compare to, $\overline{X}$ should be found for the whole class. A couple of volunteers could do this. Do not use individual averages but all of the individual scores.

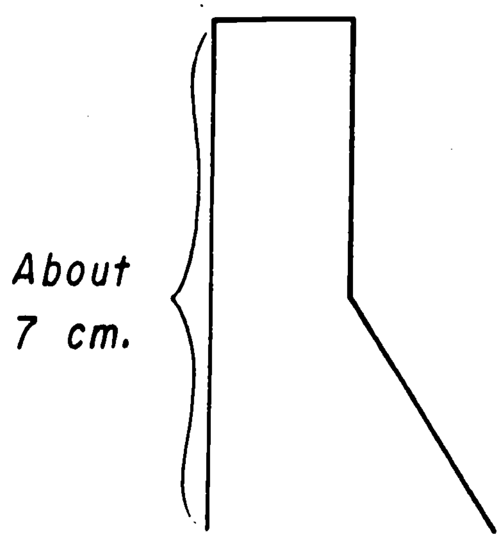
A histogram or frequency distribution curve could be done by an interested student.

A 10¢ pair of sun glasses with one lens removed and the other covered with black paper will do; they can, however, just cover their eyes with their hands.

Mark the cardboard off in centimeters on the outside, starting with 0 at the middle and going to 90 on both sides. Make these marks about 7 cm from the top of the cardboard. Place the cardboard on the table as shown in the diagram. Use masking tape to hold it in position by taping the outside of the cardboard to the table. The C clamps may be used but are not necessary if enough tape is used.

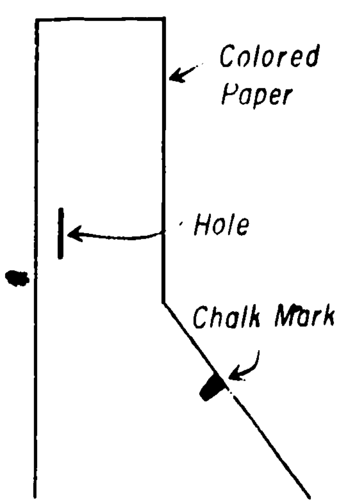


The three movable cards are made by folding the black construction paper as shown in this edge-on view:



In the middle of the card on the straight edge about 2 cm from the bottom, use a hole punch to punch out a small circle. Paste the colored paper behind this so that a dot of color shows through. Slip this over the cardboard semi-circle so that the colored dot is in the inside. The experimenter can then move it from the outside.

Make a chalk mark in the middle of the card so that the experimenter reads the response position from the same place each time.



times. The order in which you present the different colors should be randomly selected--for example, red, red, yellow, blue-green, yellow, etc. Why should the colors be presented randomly?

Also be sure that you give no clues to S as to what the color might be. For example, do not take a longer period of time, make a different sound, or move in a different way when changing colors. Move each color at about the same speed.

As R, you are to record the data for S.

For example:

Trial	Color	Response Position
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

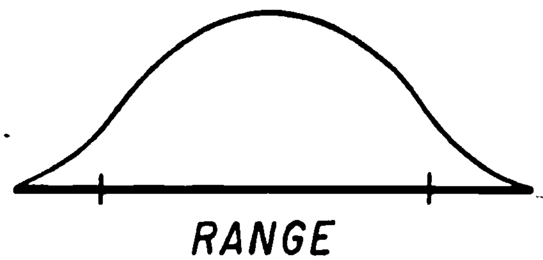
The color and response position is given to you by E.

Random selection of colors by E is very important. He should give no clues as to what the color is going to be. If S knows what is to be presented, he cannot be completely objective in his judgment. He will usually have a larger response position. This can be demonstrated by comparing the average response position of one of the colors when it was moved from 90 to 0 (and randomly selected) to the average response position moving it from 0 to 90 (or from 90 to 0 telling S which color it is). Lab groups having the time and interest could do this experiment, collect the data, and present it to the class.

Actually this is a good time to emphasize that in any experiment variables should not be introduced that might interfere with the variable (this time, color) you are trying to test. This variable you are testing is called the experimental factor. Each experiment or trial should be done in the same way except for changing the colors.

(1) $\overline{X} = \frac{\Sigma X}{N}$

(2) In measuring we will have a range of values (this can be shown by a frequency distribution curve):



By averaging we should come closer to the more probable answer.

(3) Yellow should give the longest and red the shortest response position for all. Also they will notice motion before being able to identify color. They will, however, have different individual response positions. We all have limitations but these vary slightly in individuals.

(4) If you were to map the eye, you would find different color receptors in different positions. The receptors for yellow are most widely distributed and found farther to the side. Red is nearer the center. The physical make-up of the eye, therefore, determines our similarities, differences, and limitations.

Brightness is also a factor, yellow usually being brighter than red.

Exercises for Home, Desk, and Lab (HDL)

(1) What is your average response position for each of the three colors?

(2) You had four response position numbers for each color. Why were you asked to give the average (also called the mean) instead of the highest or lowest number?

(3) Compare your results with other members of the class. What similarities do you find? What differences?

(4) What is your explanation for seeing one color before you can see the other colors?

<u>Questions for Further Study and Experimentation</u>

(1) As E, you were instructed to select the colors randomly and to give no clues as to what the color was to be. Would it make any difference in the data if the subject knew what color was to be presented? Check your hypothesis by experimentation.

(2) If you use the other eye do you get the same results?

(3) If you are allowed to move the eye, will you get substantially better results?

(4) If you wear glasses, would this have an effect on your results?

(5) White is a mixture of colors. What results would you get in using white?

(6) Do you know of any animals that have independent eyes? What does this mean?

There is evidence that this experiment is reliable, but there is no evidence that it is valid for the driving situation (refer to I.12). You may have received a very low average response position as compared to others, but in driving a car you might be just as quick or quicker than others to notice another car coming up beside you or approaching from a side street.

Students who have the time and interest could do these. They may also have questions of their own that they would like to investigate.

(1) If the subject knows what color is to be presented, he cannot be completely objective in his judgment and will very probably get larger response positions.

(2) It depends on the eye condition. Accept the student's experimental results.

(3) Yes.

(4) Accept the student's experimental results. It might depend on the correction. It is more likely that the rims of the glasses will interfere.

(5) Since white reflects a mixture of all of the colors, white will be detected at about the same position as yellow. Often it will be seen as yellow in that position.

(6) Examples are flounders and chameleons. Their eyes move independently.

Equipment and Materials
(for two lab groups of three)

- *2 meter sticks*
- *2 toy mechanical crickets (one about 3 inches long by 1 3/4 inches wide is a good size)*
- *60 sheets of graph paper*

In this experiment students are to compare their reaction times to a visual stimulus to their reaction times to an auditory stimulus.

Students should see the need to find an average or mean

$$\overline{X} = \frac{\sum X}{N}$$

Similarities and differences among students as well as limitations should be apparent in these two experiments.

The techniques of making a histogram and frequency distribution curve are introduced here. These will be covered in more detail later.

Make two Pieron sticks by taping a strip of calibrated paper to each of two meter sticks. The paper is calibrated in hundredths of seconds by using $D = \frac{1}{2}gT^2$. D is the distance in cm; g is the acceleration due to gravity (980 cm/sec²); T is time in seconds.

C.5 - Experiment: VISUAL REACTION TIME

You have done or will do several experiments on visual perception. This experiment will also involve auditory perception. You are to determine your reaction time to a visual stimulus and compare it to your reaction time to an auditory stimulus.

You will need three people in your lab group. One student is the subject (S), one is the experimenter (E), and one is the recorder (R). After fifteen trials for the visual reaction time, change roles and repeat the procedure for fifteen trials. Then again change positions. Each of you will have then performed each of the roles of S, E, and R. Follow the same procedure for the auditory reaction time experiment. It is suggested that when you change roles, R becomes S, S becomes E, and E becomes R. As E and S, you may become tired and fatigue could affect your reaction time.

Use the Pieron sticks, which are meter sticks with calibrated strips of paper attached to them. These strips of paper are calibrated in hundredths of seconds. Can you explain how this calibration was done?

Choose a smooth-surfaced wall where you will have plenty of room to work. The edge of a cabinet, a door casing, or an outside corner may be easier to use.

E places the stick against the wall at a height where the .00 mark is convenient for S. E holds the stick to the wall by the pressure of his thumb. He aligns the stick vertically at each trial.

S places his thumb about 1 cm away from the stick with the .00 mark in line with the top of his thumb. He supports his hand against the wall.

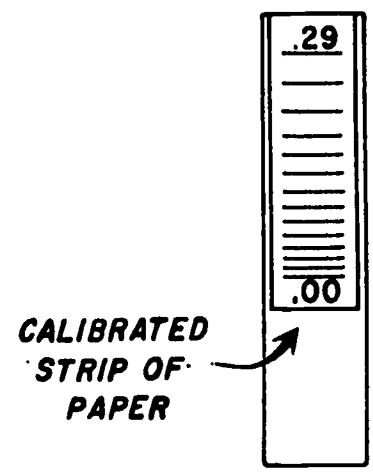
E should say "Ready" about 1 to 4 seconds before suddenly jerking back his thumb to allow the stick to fall freely.

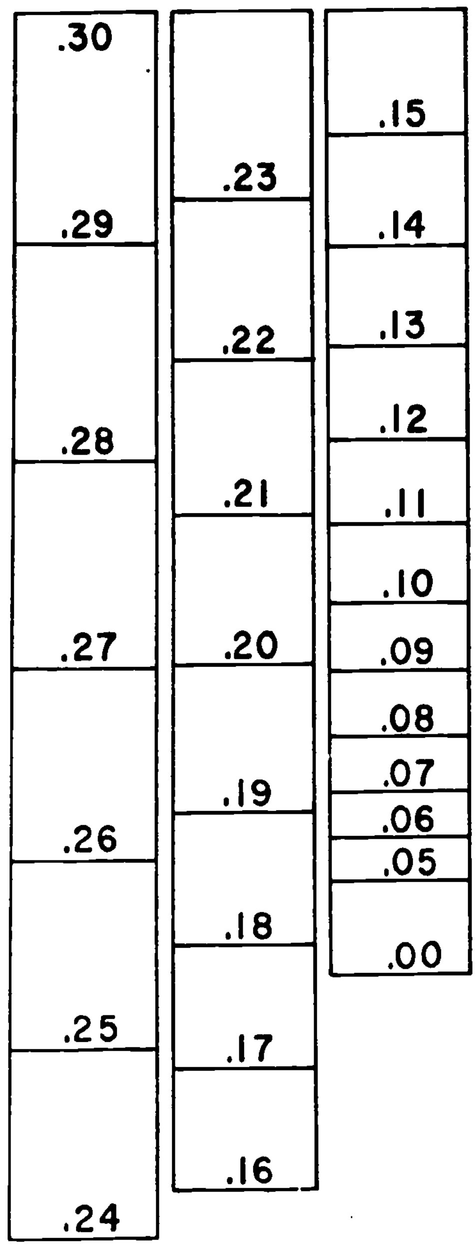
S watches E's thumb or the stick. When he sees the thumb move or the stick start to fall, he applies pressure with his own thumb to stop the fall of the stick.

Some students may know this formula and be able to figure out how the calibration was done. If not, explain it to them so they can understand how we arrive at the time figures given on the paper.

The following pattern when put together will give you the proper calibration.

Copy this onto a strip of paper and scotch tape it to the meter stick as shown with the highest time at the end of the stick.





The reaction time should be read that is in line with the top of the thumb since S started with the .00 mark in that position. The time should be read from the same reference point each time.

The experimenter should vary the time between the "ready" signal and release of the stick so that the subject cannot anticipate the time of release.

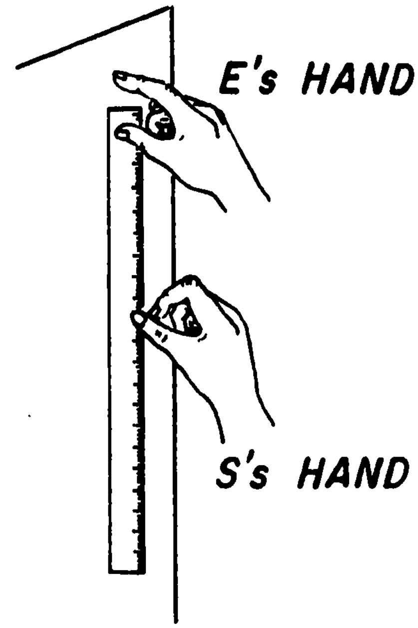


FIG. C.1

E reads the reaction time that is nearest in line with the top of S's thumb. Why should the time be read from the top of the thumb?

E should vary randomly the length of time between the "ready" signal and the release of the stick. Why?

R records for S. Record the visual reaction time for each of fifteen trials.

After each has recorded fifteen visual reaction times, find your auditory reaction times.

C.6 - Experiment: AUDITORY REACTION TIME

The procedure is exactly the same except the subject (S) is now blindfolded. E holds the stick against the wall with a toy mechanical cricket. E must place S's thumb in the proper place each time, or place the stick so S's thumb is in the proper place with the top of the thumb in line with the .00 mark. Again the thumb should be about 1 cm from the stick.

E presses the stick against the wall with the cricket. He should press hard enough to hold the stick with the cricket. That way the cricket clicks only once. E gives the "ready" signal and in from 1 to 4 seconds jerks the cricket away. This causes the second click to sound from the cricket and allows the stick to fall at the same time. E should practice this a few times to develop the technique before testing S (hold the cricket with the thumb on top and one finger under the side).

As soon as S hears the click, he moves his thumb to catch the stick.

E reads the auditory reaction time and R records it for S. Record the times for fifteen trials.

When you have completed the fifteen trials for all three students for both the visual and auditory reaction times, take your own data and

Equipment and Materials

Same as C.5, except add 3 blindfolds. These could be made by covering the eye holes of Halloween masks with black paper.

If more than one group is doing the auditory reaction time experiment, be sure that they are widely separated. One group might work in another room or the hall. The blindfolded student may not be able to distinguish the click that is meant for him from that which is meant for someone else.

If only two groups are working on this, one group could do the visual reaction time part while the other group is doing the auditory.

compile it as shown in the following example:

VISUAL		AUDITORY	
Seconds	Frequency	Seconds	Frequency
.04	0	.04	0
.05	0	.05	0
.06	0	.06	0
.07	0	.07	0
.08	1	.08	1
.09	0	.09	0
.10	0	.10	11
.11	11	.11	1
.12	1	.12	11
.13	1	.13	1111
.14	111	.14	11
.15	1111	.15	11
.16	11	.16	0
.17	0	.17	1
.18	1	.18	
.	.	.	.
.	.	.	.
.	.	.	.
.	.	.	.

By frequency we mean the number of trials in which you got a certain reaction time.

In the above example, for the visual, if you caught the stick in .15 seconds on four different trials, the frequency for .15 seconds is 4. If you caught the stick in .16 seconds two times, then the frequency for that time is 2.

On a large piece of paper, prepare a master sheet for the class as shown in this example:

Also add your data to the master sheet that the teacher has prepared for the class. Add the proper number of marks (frequency) to each time column. Put these marks about equal distances apart.

Vis. Reac. Time	*Freq.*	*Aud. Reac. Time*	*Freq.*
.04	/	.04	///
.05	/	.05	///
.06	//	.06	//////
.07	///	.07	///////
.08	///	.08	
.09	//////	.09	
.10	//////////	.10	
.11		.11	
.12		.12	
.13		.13	
.14		.14	
.15		.15	
.16		.16	
.17		.17	
etc.	etc.	etc.	etc.

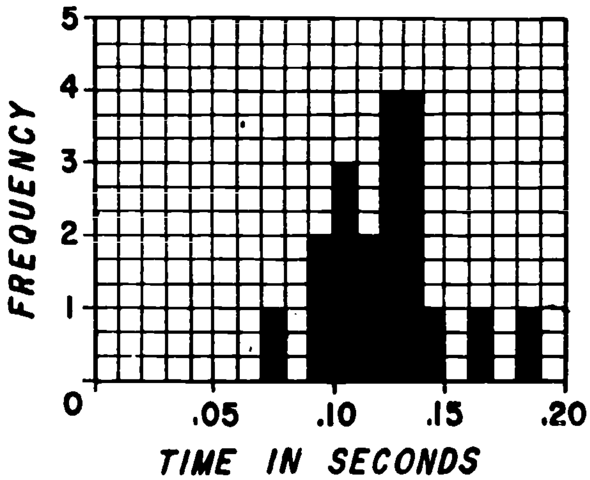
As students finish, have them add their data to this chart. The center times may have 50-100 marks. Allow plenty of room. Have them place the proper number of lines (frequency) to each time column for both the visual and auditory reaction times. Ask them to put the marks about equal distances apart.

When they have finished, you will have a histogram. It should show the distribution quite clearly.

Have volunteer students make graphs, one a histogram, the other a frequency distribution curve of the whole class.

Also have a student find the average or mean for the class from this information.

These can be used for reference, comparison, and discussion later.

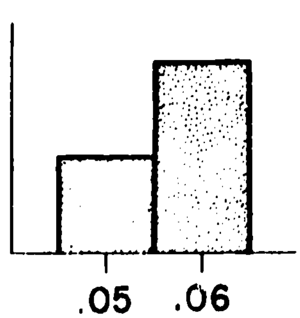


Students' graphs should come out something like the example above.

With only fifteen trials, however, the distribution may not be this good. They may only be able to see a good distribution when the scores of the whole class are graphed.

Also the curves, individual and class, may be skewed to the left. They usually will get higher reaction times in the beginning but practice will improve their scores. Then again, higher scores might appear as they become fatigued near the end of the set of trials. With only fifteen trials, fatigue may not be such a factor.

In a distribution curve each time is graphed even if the frequency is 0. The curve should not be rounded. In a histogram the center of the bar is placed at the proper time like this:



Graph your results for both visual and auditory reaction times. Label the X axis time in seconds, the Y axis, frequency. In graphing your data you will get what is called a frequency distribution curve. You may make two graphs on one sheet of graph paper, within the same area, by using a different color for each curve.

The experiments on reaction times are both reliable and valid. If your reaction time was faster than average in the experiment, it is very probable--if there is nothing to affect your reaction time--that you will react faster than average in other situations. While driving, if an emergency arises, you probably will be able to hit the brake faster than the average driver. Again, this will not make you a good driver. There are too many other factors to consider, but the point to be made here is that these experiments on reaction times are valid. There is a useful relationship between the results of the experiment and some related performance.

In this experiment students will find that they react more quickly to an auditory stimulus than to a visual stimulus. They may find this quite surprising. No questions have been asked of them as to why this is true so that results of the experiment would not be revealed. However, after they have all finished the experiments, some discussion as to why they got a faster auditory reaction time seems appropriate.

Since the two experiments were done the same way (except for the experimental factor) and since light travels faster than sound, the answer would seem to lie in the biological difference between the eye and the ear.

We should not try to give a simple answer to a very complex question. In fact, the full answer is not known. There is obviously a longer transmission time for the eye, but what part of the eye or neural system causes this lag in time is not known.

Exercises for Home, Desk, and Lab (HDL)

(1) Compare your graph for the auditory reaction time to the one for the visual reaction time.

a. Are the shapes of the curves similar?

b. Do they peak near the center?

c. Are they somewhat symmetrical?

d. How does the range (the amount of spread of values) of one differ from

(1) Individual graphs will differ but it is expected that the shapes will be similar, will peak near the center and will be somewhat symmetrical. Again, with such a small number of trials, this may not be evident until the graph for the class is completed.

The range for the visual will probably be greater than that for the auditory reaction *time. Most students will get a better reaction time for the auditory stimulus.*

(2) The shape of the graphs should be similar. The ranges and individual scores may differ slightly but there should be a similar general pattern.

(3) Students may want to report the average.

$$\overline{X} = \frac{\sum X}{N}$$

Since there is a range of values (which shows up in the distribution curve), the average should come closer to giving the most probable answer. However, range is also important since it indicates the limits within which you perform. The range gives important information--for example, two people may have the same average, but one a much larger range. This would show the one to be more erratic in behavior.

(4) Students should recognize similarities and differences here. The auditory reaction time scores should be smaller than the visual for all students. There will be different mean scores, but the differences will probably not be too great.

the other?

e. In which case would you think you would get a shorter reaction time?

(2) Compare your graphs with the graphs from the other members of the class and with the graphs from the entire class. What similarities and differences do you see?

(3)

a. What was your shortest reaction time for each stimulus?

b. What was your longest time for each stimulus?

c. What was your average reaction time for each stimulus?

d. Which ones should you report as your reaction times? Why?

(4) Are your mean or average scores the same for both the auditory reaction times and the visual reaction times? Check your results with others in the class.

a. Is the difference between your two scores (auditory and visual) about as great as that found by others in the class?

b. Are both your scores above the class

mean? below? one above and one below?

(5) Do you believe that one can, on the average, react faster when receiving a signal from one sense than he can if he receives a signal from another sense?

a. What evidence do you have to support your belief?

b. What degree of confidence do you place on your evidence?

(5) This experiment should demonstrate that we do react more quickly to an auditory stimulus than a visual stimulus. The evidence the student should have is the data collected in class. He should place confidence in this evidence only if a large number of people are tested and the same results are obtained in enough of these cases to justify the conclusion.

(6) What external factors might cause the reaction time scores to fluctuate? To what extent are these fluctuations predictable? Can you think of any ways to reduce the fluctuation?

(6) Some things that may cause the scores to fluctuate might be (a) attention may be diverted or someone watching may make you nervous, and (b) human errors in experimentation such as not dropping the stick correctly or allowing the students to anticipate the release of the stick by dropping it after the same interval of time from the "ready" signal for several trials. These fluctuations are somewhat predictable and can be reduced by careful experimentation. But there are, no doubt, some factors that are unpredictable and that we know nothing about.

(7) What are some internal factors that may affect your reaction time?

(7) Some factors that may affect reaction time are learning, fatigue, drugs, alcohol, lack of sleep, nervousness, age.

Some students may want to compare the girls' scores with those of the boys. Or they may want to experi-

ment to see if age seems to affect reaction times. Those who are interested and have time may experiment further.

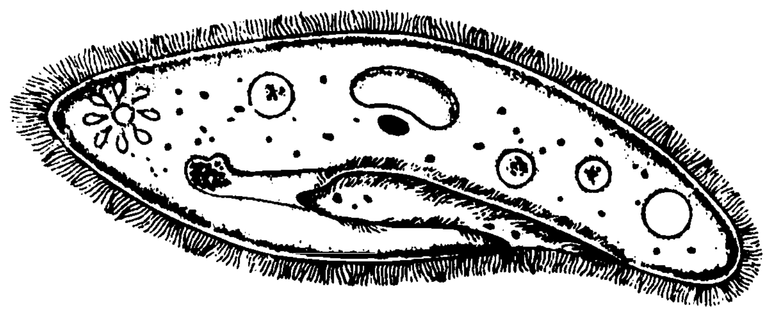
After completing the set of five experiments on the senses, use of the microscope may be introduced. Conceptually, work with the microscope fits the set of sensory experiments, but because of the detailed instruction required by the teacher, the microscope work is set aside as a separate experiment. An introduction to the use of the microscope like that given in the BSCS Green Version Exercise 1.4, "Use of the Microscope" (sections A through I), seems ideal at this time.

If the teacher uses the microprojector, so that C.7 is a demonstration, there is no need to introduce microscopes at this time.

When the students have completed BSCS Green Version Exercise 1.4, the experiment "Paramecia and Their Speed" will demonstrate a microscopic "illusion." The paramecia appear to move very rapidly across the microscope field, but an actual measurement of their speed will show this "illusion" is due to scaling. The paramecia actually travel a very short distance.

Note: this may be done as a demonstration using a micro-

From materials you have already studied, you have seen that your senses are subject to a sensitivity threshold, a time threshold, and illusions. You have also seen that various instruments or tools may help to overcome sensory limitations. Yet, even those instruments that are most used to extend the senses have limitations and lead to special illusions. We will illustrate these limitations and illusions using a microscope as a convenient sensory extender.



C.7 - Experiment: PARAMECIA AND THEIR SPEED

Using a medicine dropper, remove a small amount of liquid containing paramecia. Place one drop at the center of a clean glass slide and add a cover slip. Focus with low power and adjust to obtain good contrast. Move the slide around on the stage so that all areas under the cover slip are examined. Notice the movement of the organisms. When seen under high power, do the organisms appear to move more rapidly or more slowly than when seen under low power? Guess how rapidly the organisms are moving. Knowing the diameter of the circular field of view and approximately how long it takes a paramecium to cross that field, what is the speed of the paramecium? Contrast this speed with your speed of normal walking by expressing both values in the same units.

projector rather than as an activity of the entire class.

It is possible to grow your own culture of paramecia, but it is probably much easier to purchase them from Carolina Biological Supply, called Powell Laboratories, in Gladstone, Oregon. Powell Laboratories also sells a mixed bacterial culture which might be of interest because of the variety of sizes, shapes, and speeds. If you feel that there will be a shortage of organisms for your class, you might place a single drop of culture upon the student slides rather than have them do it.

C.8- Demonstration: SIZE AND WEIGHT

In this demonstration volunteers will be asked to judge relative weights and to make estimates of actual weights.

The purpose of this experiment is to demonstrate the size-weight illusion and to show the need for extending our senses in terms of measuring weight (mass). This will introduce the study of the equal-arm balance.

Poke holes in opposite sides of the cans near the top and attach the wire to make handles. The handles should be exactly the same on each can.

Add weights to two experimental cans until they are both exactly the same weight (300 grams or more). One can should be large, such as a 2 or 3 lb. coffee can and one should be small, such as a small vegetable or frozen juice can.

Since in the experiment on size illusions the lengths of the lines and diameters of the circles were all *equal, students might suspect that this will be true again and that the weights will be equal. It is suggested that you use, as a control, two other cans of different sizes and obviously different weights. For example, a 1 lb. coffee can with 350 grams of weight and a vegetable or fruit can with 50 grams of weight could be used. In the discussion the results and figures given for these may be disregarded, but the reason for using the control should be explained.*

Ask four or five students to judge the relative weights of the cans (both the two control cans and the two experimental cans). They are to decide which of the two cans is heavier and about how many times heavier. Also have them make estimates of the actual weights of each. In case the results do not show the size-weight illusion consistently, the estimates of weight will probably vary a great deal which will still demonstrate the need for a balance.

Be sure to give the following instructions to the students before they start:

(1) Lift two cans at a time (the two controls or the two experimental cans).

(2) Lift them the same way by hooking one finger under the wire.

(3) Watch the cans closely and do not allow them to swing. (Swinging the cans gives other clues.) Having them do this also keeps them looking at the

cans which is important in getting the size-weight illusion.

(4) Answer the following questions:

(a) Which can is heavier?

(b) How many times heavier (express as a ratio)?

(c) About how much does each can weigh?

(5) Write your decisions on a piece of paper. Do not make the answers known until all of the four or five students have made a judgment so that one student's decision will not be influenced by another.

Before making the decisions known, collect some data to try to answer the student questions.

Exercises for Home, Desk, and Lab (HDL)

(1) a. Do you think being able to see the cans will help or hinder the students in making their judgments of weight?

b. How would you test your hypothesis?

Repeat the experiment exactly except this time blindfold the four or five students.

(2) Do you think the students would make better judgments if they had a known weight with which to compare the unknown ones?

Again repeat the experiment with four or five students, but this time allow them to use a known weight as a comparison.

After all of the data are collected, put it on the board in some systematic form. For example:

DATA FOR 2 EXPERIMENTAL CANS

	Student	Heavier	Times Heavier	*Actual Estimates (grams)	
				Small Can	Large Can
Group 1					
	1	Small	$1\frac{1}{2}$ x		
	2	Small	2 x		
	3	Small	Slightly		
	4	Neither	Same		
Group 2	Blind-folded Student				
	1	Small			
	2	Large			
	3				
	4				
Group 3	Student Using Compar-ison				
	1				
	2				
	3				
	4				

*Since most students will give estimates in pounds and ounces, convert these to grams (454 g = 1 lb).

Place the cans on the platform balance to prove to the students that they are equal in weight. Give the actual weight.

Equipment and Materials

2 cans, one a large can such as a 3 lb. coffee can, the other a small one such as a frozen fruit juice or small vegetable can
2 cans, any sizes (to be used as the control)
4 pieces of wire about 30 cm long (for handles)
300 g (about) of weights to weight each can
Single beam platform balance
Blindfolds (Halloween masks with the eye holes covered with black paper)

(3) Examine the data on the board. Are there any conclusions you can draw from these data?

a. In the first trial did the volunteers consistently judge one of the cans heavier than the other?

b. If so, how might you account for this?

c. In the second and third trials, did the volunteers consistently judge one can heavier than the other?

d. Try to explain any similarities and differences in the judgments of the three as to which can was heavier.

e. Is there any consistency in the judgments as to how much heavier or in the actual estimates of weight?

f. Did one group definitely make better

(1-3) It is expected that the following conclusions can be drawn from the data:

(a) In the first trial the students will judge the smaller one to be heavier. This is the size-weight illusion, which seems to result from our experience with (if not knowledge of) density. A person, although asked to judge weight, seems to take density into account and the density of the smaller one is much greater.

(b) Because of the size-weight illusion, the blindfolded students should do better in their judgments of which is heavier. This will not necessarily be true for the third group, although the illusion will still exist.

(c) The estimates of "how many times heavier" and the actual estimates of weight will probably vary a great deal. Probably no pattern will be apparent although group three should do much better on the actual

estimates of weights. Our senses are much more accurate when we are allowed to make comparisons.

(4) If the students reach the conclusions that are listed here, they could find support for them in psychology books. But they should be reminded that psychologists have done thousands of experiments to support their conclusions. Here we have a very small sampling, not really enough to draw conclusions with any great degree of confidence.

Some errors may have been introduced. For example, some people, through experience, can make better judgments of weight. In using different students, it is possible that one group had more students capable of judging the weights more accurately.

Students may think of other errors that could have been introduced.

(5) The idea of weight and mass can be introduced. Mass is constant but weight is not. It depends on the pull of gravity which varies from place to place. For example, the cans would weigh more in Portland than they would if you were on top of Mount Hood. Because of the difference in elevation, Portland is nearer the center of gravity so the pull of gravity against the cans would be greater. On the moon the cans would weigh much less. (It should be pointed out that if you use an equal-arm balance, there would be no difference

judgments than the other groups? If so, try to explain why.

(4) What degree of confidence do you have in the conclusions you made?

a. What factors can you think of that might have caused you to draw a faulty conclusion?

(5) Are the weights of the cans constant? That is, would they weigh the same no matter where you are?

since the standard weights would be equally affected.)

(6) How accurate were the estimates of actual weight? Is there a need here to use a tool to extend our senses? What would be used?

(6) It is hoped that students will see a need to use a balance to extend their senses.

At this point, introduce the metric unit of force, the newton. A newton is an expression of Kg m/sec^2 as you can see when you use the formula, $F = mg$. F is a force (newton), m is a mass in Kg and g is meters/sec^2 (9.8).

It is not necessary to give a lengthy explanation of the formula to students, but since scientists would estimate "heft" in terms of newtons, have them get the feel of the amount of pull of a newton (they have estimated in grams and pounds).

If you have a newton spring scale, hang a Kg mass on it to show the relationship. (If you don't have the newton spring scale, calibrate a regular spring scale.) Then have students estimate the number of newtons in the cans.

<u>Questions for Further Study and Experimentation</u>

(1) Students were asked to lift the cans by hooking one finger under the handles. Was this really important? Lift the two cans by placing them on the palms of the hand. Lift them with one finger under the handles. How

(1) If the student lifts the cans with the palms of his hands, he will find that the smaller can seems to be much heavier than the larger as compared to lifting them with the fingers. This is because of the weight distribution. To eliminate this factor, he could place equal size

boards under the cans.

do you account for the difference? If you had no handles for the cans and had to lift them with the palms of the hand, what should you do?

(2) Students could experiment to see if their judgments are better when allowed to swing the cans. Their estimates should be better; they get some additional kinesthetic clues.

(2) Would you be able to make better judgments of relative weights if you were allowed to swing the cans back and forth?

D. Experiment: RESPONSES OF SOW BUGS

Equipment and Materials

sow bugs
pan or tray for each group
paper towelling
desk lamp for each group
colored cellophane--several colors
cardboard

A good resource would be "Amateur Scientist", Scientific American (May, 1967). The teacher may wish to have different groups of students doing different sections of this exercise and reporting back to the entire class. This is an excellent exercise for writing reports.

The little isopods called sow bugs or pill bugs, so common under boards and in moist litter, are organisms which respond demonstrably to their environment. They are cheap to maintain, require little attention, and are not odorous.

In gathering biological data, one sort which seems to be fairly interpretable is the either-or type. In this case an organism does something or it does not.

We have been studying human observation and its limitations. How do other organisms respond to external stimuli?

Sow bugs are crustaceans. They are one of the few branches of the family tree which now live on land. Like other crustaceans, they are gill breathers and require a fairly high level of moisture in the environment (air) to survive.

Into a large pan or enamel tray place a piece of paper towel which is moist. In some other part of the pan or tray, place a piece of paper towel which is not moist. The pieces should be some distance apart. Place the sow bugs allotted to you between the pieces of towel, and at approximately 30-second intervals record the number of sow bugs on the tray, the dry towel, and the wet towel.

Can the sow bugs find water? Must they touch it to know it is there?

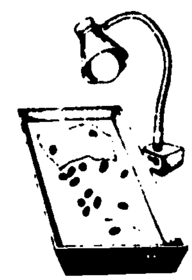
Set up a large tray with a desk lamp over it. Place the allotted sow bugs in the center of the tray and map their movements over the surface of the tray.

The culture may be maintained in a coffee can with some litter (dry leaves, soil, etc.); enough water to make it slightly moist (not wet enough to be able to squeeze water out of it like a sponge); and a little food (a slice of potato, apple, or carrot). Poke a few small holes in the lid of the coffee can for ventilation. If there is not enough moisture, the sow bugs will die in a few hours. Most school rooms are relatively dry, and this may present a problem.

Describe their placement on the tray at the end of 3 minutes. (Are they randomly distributed, bunched or other?)

Place one transparent and one opaque shelter (each 2" x 2" x 1/2") in the tray. Let the floor of the shelter be the preferred type (plain pan, dry towel, moist towel). Put the sow bugs on the tray between the two shelters and record their positions as in the earlier phase of this experiment.

There is a good opportunity to expand the exercise using other invertebrates and/or a battery of other possible stimuli.



If the students do not think of it, the teacher may suggest the use of differently colored cellophane shelters.

Can the sow bugs detect light? What is their response to light? How would you proceed to find out which color of light the sow bugs can see and which ones they cannot?

Discuss an experiment to test for responses to temperature. Do you think that temperature was an uncontrolled factor in the part of the experiment that tested their light responses? Explain. Describe the habitat you would expect sow bugs to favor.

Yes, the desk lamp gave off a great deal of heat.

Cool, moist, and dark.

TEXT SECTION	ROUGH TIME ESTI-MATES	EXPERIMENTS	DEMONSTRATIONS	TEACHING AIDS	OTHER STUDENT ACTIVITIES	OUTSIDE READING	PROBLEMS (pages 71-93)
Portland Project II-A Measuring and counting	8 Days						1
A.1 Systems and units of counting							2
A.2 Distance mass and time							3, 4, 5
		A.3 The scalene triangle					
A.4 Uncertainty associated with measurement							6,7
A.4.a Uncertainty associated with instruments							
A.4.b Human uncertainty							
A.4.c Uncertainty due to changes within the system							
A.5 Range of uncertainty							8, 9
A.6 Place of the uncertainty							10. 11
A.7 Rounding off to the correct place							12
A 8 Propaga- on of errors							

	ROUGH TIME ESTI-MATES	EXPERIMENTS	DEMONSTRATIONS	TEACHING AIDS	OTHER STUDENT ACTIVITIES	OUTSIDE READING	PROBLEMS
nificant							13
dding cant							
ub- g cant							
ulti- and g sig- t							
ienti- ation							14, 17
ck to lene e							
om events	3 Days	B.1 Mass of sow bugs					
		B.2 Coin flipping		Film - "Random Events" (PSSC)			
aniza-			C.1 Classi-fication and organi-zation				
			C.2 Classi-fication of leaves				

TEXT SECTION	ROUGH TIME ESTIMATES	EXPERIMENTS	DEMONSTRATIONS	TEACHING AIDS	OTHER STUDENT ACTIVITIES	OUTSIDE READING	PROBLEMS (pages 99-156)
D. Classification and organization							
		D.1 Visual observation		Collection of identified metals			
D.2 Prelude to density							
D.2.a Volume		D.2.b Volume of a solid					3, 8
D.2.c Mass	5 Days			Filmloop "Weighing with the triple beam balance"			
		D.2.d Mass					
D.3 Density		D.3.a Density by graphical method			H.D.L. 4,5, 13		1, 2, 6 7, 9, 10 11, 12

TEXT SECTION	ROUGH TIME ESTIMATES	EXPERIMENTS	DEMONSTRATIONS	TEACHING AIDS	OTHER STUDENT ACTIVITIES	OUTSIDE READING	PROBLEMS
D.4 Other physical properties							
D.4.a Freezing and melting							
		D.4.b Behavior of solids on warming					
	4 Days	D.4.c Freezing and melting curves					14, 15
		D.4.d Micromelting point					
		D.4.e Boiling point determination (optional)					
D.5 Solubility							

TEXT SECTION	ROUGH TIME ESTI-MATES	EXPERIMENTS	DEMONSTRATIONS	TEACHING AIDS	OTHER STUDENT ACTIVITIES	OUTSIDE READING	PROBLEMS
		D.5.a Classification by solubility					16, 17, 22
		D.5.b Temperature versus solubility					
		D.5.c Effect of temperature on solubility (optional)					18, 19
	5 Days	D.5.d Effect of temperature (optional)					
		D.6 Flame test for classification					19, 20
		D.6.a Analysis of colors					21

TEXT SECTION	ROUGH TIME ESTIMATES	EXPERIMENTS	DEMONSTRATIONS	TEACHING AIDS	OTHER STUDENT ACTIVITIES	OUTSIDE READING	PROBLEMS
D.7 Organizing and retrieving data							
D.7.a Building a punch card memory memory							
	3 Days	D.7.b Preparing a deck of cards					
		D.7.c Identifying unknown compounds					10. 11. 12

TEXT SECTION	ROUGH TIME ESTI-MATES	EXPERIMENTS	DEMONSTRATIONS	TEACHING AIDS	OTHER STUDENT ACTIVITIES	OUTSIDE READING	PROBLEMS
E. Communication		E.1 Oral communica-tion chain					
	3 Days	E.2 Communi-cating ideas					
E.3 Observing a system as a scientist							
					E.4 Test: The sow bug		

Chapter II: MEASUREMENT, DISTRIBUTION, ORGANIZATION AND COMMUNICATION

A. MEASURING AND COUNTING

We have stressed the use of instruments as aids in extending our senses, but is there a limit to our sensory aids just as there are limits to our senses? As we might expect, every measurement does indeed have some uncertainty.

To begin a study of the nature of measurement, a problem should be proposed that requires some kind of measurement for its solution.

Which of the shaded areas on the next page has more area? Even more specifically, what is the ratio of area B to area A?

A quantitative answer is needed. You should be able to say something like, "I think the ratio of B to A is 1.5/1.0.' What ratio did you get? What method did you use?

Suggested references for section A:

Woodruff, Bobby J., Terms, Tables, and Skills for the Physical Sciences, Silver Burdett Co., 1966, Chap. 1-3.

Tilbury, Glen, Problem Solving in Chemistry, Lyons and Carnahan, 1967, Chapter 5.

Cotton, F. Albert and Lawrence D. Lynch, Chemistry, An Investigative Approach, Houghton Mifflin Co., 1970, Chap. 2.

Toon, Ernest R., George L. Ellis and Jacob Brodkin, Foundations of Chemistry, Holt, Rinehart & Winston, 1968, Chap. 2.

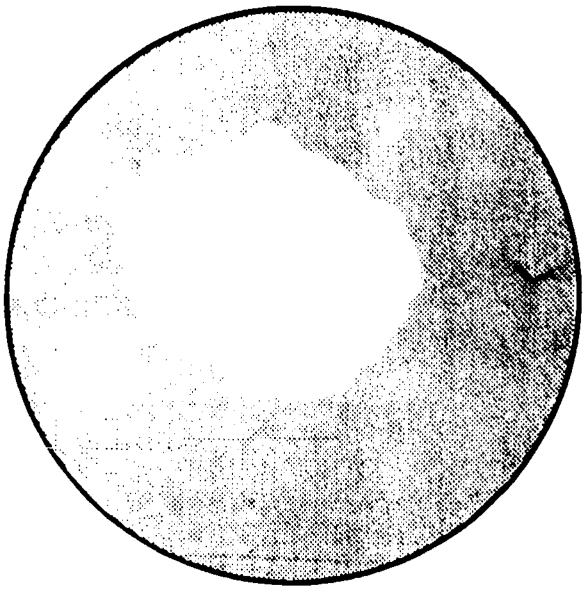


Figure A.1 - "A"

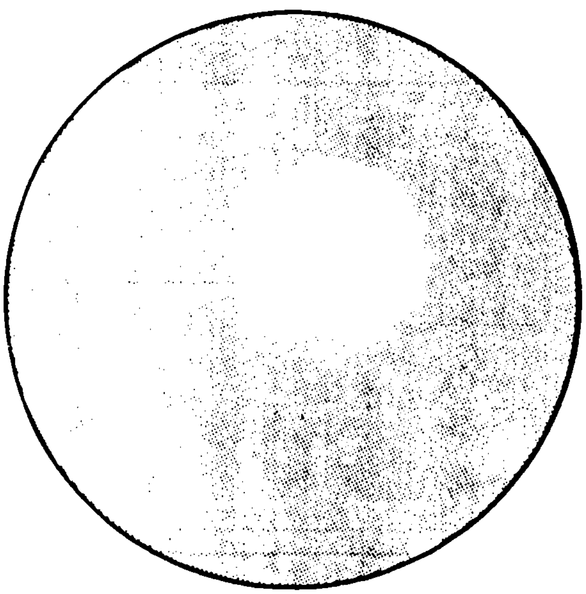


Figure A.2 - "B"

Students may want to find the area by weighing a piece of paper with a known area, [illegible] the shaded area.

HDL #[illegible] goes with this section.

One method that can be used is called square counting. Lay a piece of graph paper on top of the shaded figures and trace their outline. (We want the shaded area only.) Now count the squares within each. In this way we can find each of the areas. To get the ratio of area B to area A, divide the area of B by the area of A. Try it.

On graph paper with squares 1/10 of an inch on a side, there are 592 squares in A and 666 squares in B. This means the ratio of B/A is 1.13/1.00.

Now let's examine what we have done. We chose a certain sized square and counted how many fit into the odd-shaped areas. This leads to a very important principle: <u>all measurement is counting</u>. In measuring anything, we choose a basic unit and ask how many of the basic units will fit into the object being measured.

A.1 - SYSTEMS AND UNITS OF COUNTING

Suppose we had used a kind of graph paper which had larger squares. What difference would this have made? We could have found a lower count for both A and B, but they would have been lower by the same factor. For example, if the squares had been twice the area, the count for both A and B would have been one-half the original count. The actual ratio of the areas would be the same no matter what size squares were used. However, different ratios may appear in instances where the squares differ in size, especially if some people count squares which are partially filled while others count only those completely filled. We could have employed a different system of measurement with a different basic unit, but our conclusion would remain unchanged. Unfortunately, several systems of measurement such as the metric system and the English system are in use today. This makes the job of understanding the universe a bit more complicated than it might otherwise be.

Perhaps students would enjoy looking for other "historical" systems of measurement.

If time is available, they might create their own system.

In computer usage, numbers ending in 5 are rounded to the closest even number.

A.2 - DISTANCE, MASS, AND TIME

Although man has made many sophisticated measuring instruments, he is still basically able to make only three measurements. These measurements are:

HCL #3, 4 and 5 go with this section.

(1) measurements of distance [L],

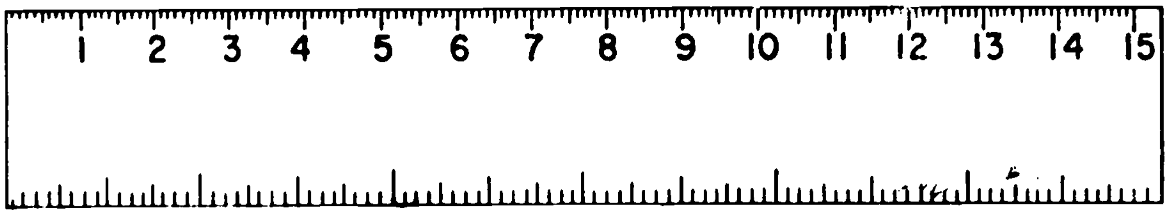
(2) measurements of mass [M], and

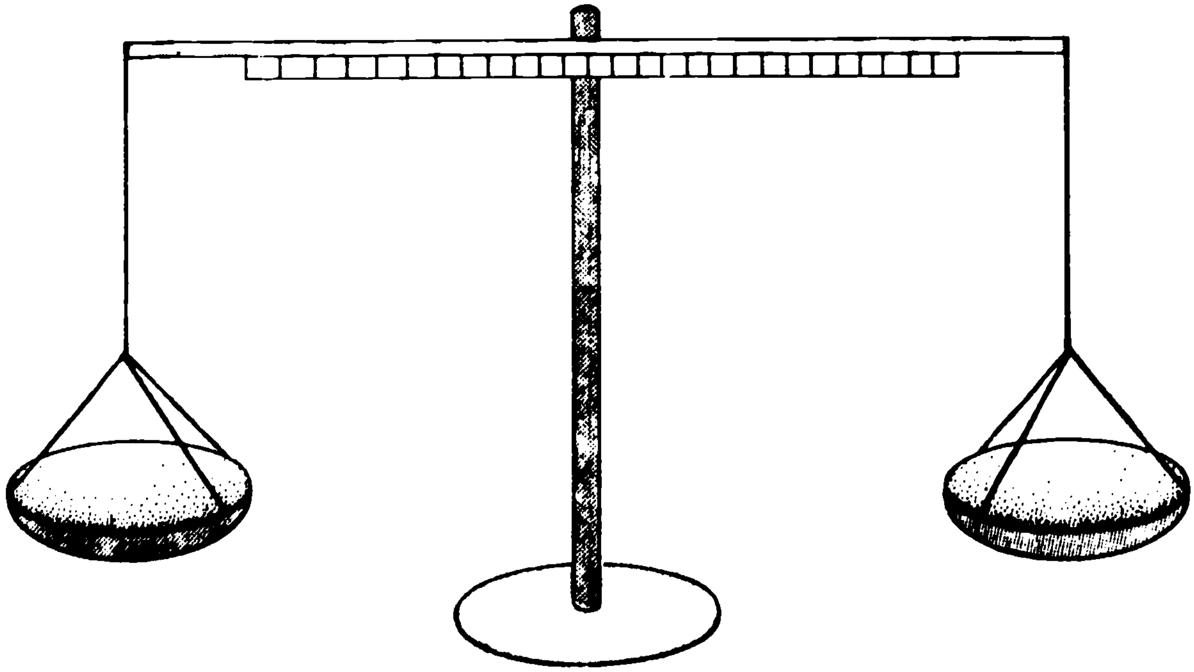
(3) measurements of time [T] .

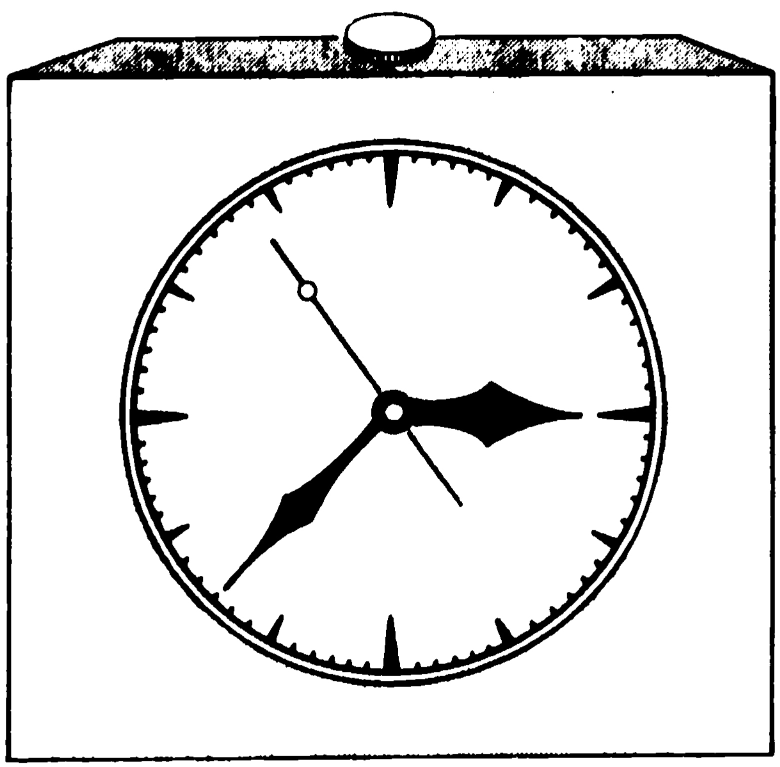
All other measurements are combinations of these three.

Temperature is special; it is basically a measure of the motion of molecules. Its derivation in terms of mass, time, and distance is much too complicated for the student at this time.

For example, the measurement of area that we just described is a combination of measurements. Area is length multiplied by length,


1 2 3 4 5 6 7 8 9 10 11 12 13 14 15





therefore expressed as L^2. In fact, area is always some factor multiplied by length times length. The area of a triangle is equal to the factor "1/2" multiplied by length (the base) multiplied by length (the height), or, in equation form, 1/2b x h. What is the factor in the equaticn for finding the area of a circle?

The factor is "π".

If we analyze the arrangement of these three basic measurements, we say we are doing a dimensional analysis. For instance, you have found that the dimensions of area are L^2. What are the dimensions of volume? As you know, the room you are in has three measurements. They are height, length, and width. But all of these are really one dimension -- i.e., distance.

The dimensions of volume are L^3.

The analysis of dimensions can be a powerful tool in problem solving. If you are trying to determine volume and your answer does not have the dimensions of volume, L^3, your answer is obviously wrong.

In the metric system, the basic units are seconds for time, meters for distance, and kilograms for mass. This system is often referred to as the MKS system.

A.3 - Experiment: THE SCALENE TRIANGLE

Carefully trace around the aluminum triangle given your group by the teacher.

Equipment and Material

2 or 3 aluminum (or other rigid material) patterns of a scalene triangle - all alike.

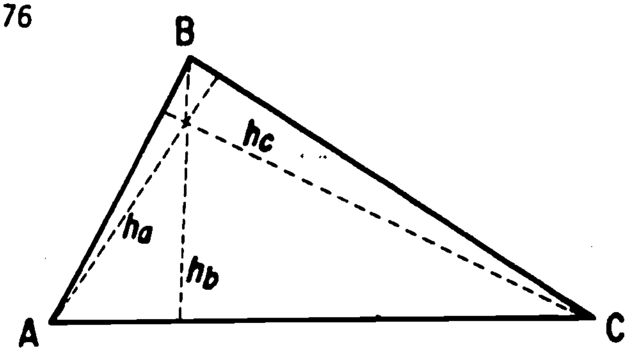


Figure A.3

To avoid confusion, be certain to use a triangle whose altitudes all fall within the triangle as in the sample above.

An easy way to construct altitudes on their tracings of the scalene triangle is by sliding a sheet of paper (anything with a right angle) along each base until its perpendicular bisects the opposing apex.

The student probably will not get the same answer because he is not careful about his measuring technique and will give his answer to a ridiculous number of significant figures.

It is called a scalene triangle because it has three different bases and heights. Label the three points of your drawing A, B, and C and consider the heights to be h_a, h_b, and h_c, as in the adjoining figure. Calculate the area of the tracing using base AB and h_c. Make your distance measurements and give your answers using the basic units of the MKS system. Calculate the area of the triangle using the base AC and the height h_b. Finally calculate the area of the triangle using base BC and h_a. Did you get the same answer all three times? Why? Perhaps the trouble lies in the way you made your measurements. Keep your data and tracing for the scalene triangle for later; you will want to refer to it.

A.4 - UNCERTAINTY ASSOCIATED WITH MEASUREMENT

You have made many measurements while doing the exercises and experiments associated with this course. After working with the scalene triangle, you very likely realized as you did in section I.4a that there was some uncertainty associated with every measurement you made. You have discovered one of the major problems all scientists have: no measurement is exact. There is some uncertainty associated with every measurement. It follows that science is, to some extent, uncertain. It is the extent of this uncertainty that is of interest to us now.

A.4.a - UNCERTAINTY ASSOCIATED WITH INSTRUMENTS

We can begin our search to find out why our answers for the area of the scalene triangle varied by analyzing a linear measurement. Imagine that a professional scientist is interested in determining the area of a scalene triangle similar to the one we worked with. The picture below is a representation of what the scientist sees as he measures the base of his triangle:

HDL #6 and 7 go with this section. You may want to assign "parts" of 6 and 7 as the student proceeds from here to the section, "Range of Uncertainty."

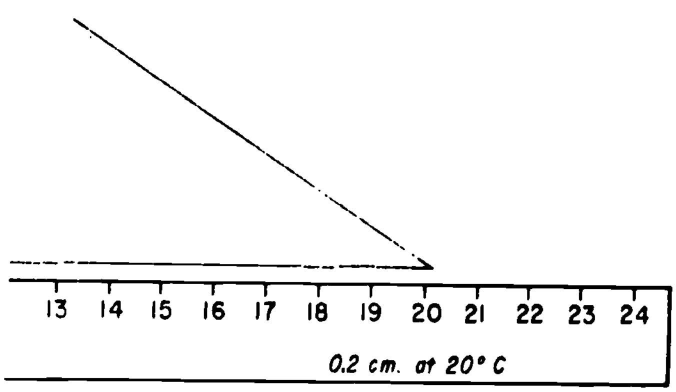


Figure A.4

Notice that the rule is marked plus or minus 0.2 cm when the temperature is 20°C. This means the rule may be longer or shorter than we think it is. Any reading may be 0.2 cm longer or it may be 0.2 cm shorter. The manufacturer of the rule guarantees the rule is never off more than 0.2 cm in either direction if the temperature is 20° C. Here then is a clear indication of one of the major sources of uncertainty -- instrumental error. Every instrument has some error associated with it. Unless the instrument is quite expensive, it usually does not have the plus or minus (±) engraved on it. Some of the typical uncertainties associated with instruments found in most science laboratories are listed in the following table:

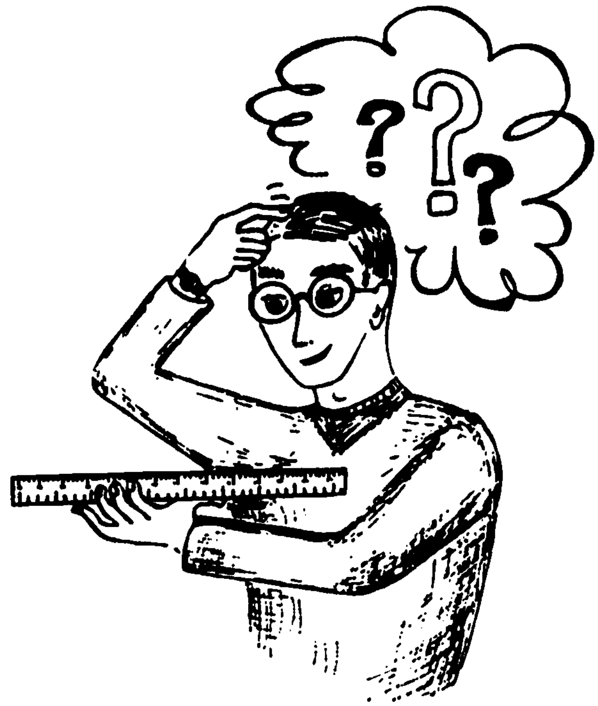
Instrument	Typical Uncertainty
Triple-beam centigram balance	± 0.01 g
50 ml graduated cylinder	± 0.2 ml
Platform balance	± 0.5 g
50 ml gas measuring tube	± 0.02 ml
50 ml buret	± 0.02 ml

A survey of "like" instruments will give a range of deviation. Also, manufacturers' catalogues often give tolerances.

In some cases if you cannot find the uncertainty of the instrument you wish to use, you will have to make an intelligent guess. Your teacher may be able to help you make this guess.

A.4.b. - HUMAN UNCERTAINTY

If the scientist knows how to read his rule, he will begin by mentally dividing the smallest marked division into tenths. This means he will read this particular rule (FIG. A.4) to the nearest 0.1 cm although it is marked to the nearest centimeter. Keeping alert to anything that might deceive his senses, the scientist makes his reading. He reads the length of the object as 20.3 cm. He would not stop there, however, because he is not finished with the measurement. He would say to himself, "I may be off as much as 0.1 cm in my reading because I mentally divided the smallest division on my rule into tenths. Therefore, my human uncertainty may be as much as ±0.1 cm." This type of uncertainty associated with measurement is called human error.



A.4.c - UNCERTAINTY DUE TO CHANGES WITHIN THE SYSTEM

Can you think of any way the triangle might be changed because of the measurement? Perhaps the scientist holds the aluminum triangle in his hand and, as the result of a heat exchange, the triangle changes size. Perhaps the rule is much warmer than the object; as a result of contact, the object changes. In this particular measurement the error due to a change within the system would be very small--so small, in fact, that the

The Heisenberg Uncertainty principle becomes important when objects are very small and energies are very great. For example, to determine the size of an electron, one might try to bombard electrons with photons of proper wavelength. Very small wavelengths mean very high energy photons. The result would be analogous to trying to get a picture of a small sports car by bouncing a large truck off of it. Many attempts at measurements on living systems are subject to this type of error. Polygraph tests are another example. The use of the polygraph on the subject may excite him as much as any incriminating question.

HDL #8 and 9 go with this section.

scientist would say it was negligible. He would assign ± 0.0 cm for this error.

You might think this category of error is not a major category and should itself be neglected. If we make measurements of ordinary objects, this category usually can be neglected. There are systems, however, where the process of measurement disturbs the system sufficiently to cause sizable errors in measurement.

A.5 - RANGE OF UNCERTAINTY

The three categories of error, then, are human error, instrumental error, and error due to change within the system. In the example used, the scientist assigned a ± 0.1 cm uncertainty as his human error. He assigned a ± 0.2 cm for the instrumental error and a ± 0.0 cm for the error due to change within the system. The scientist's reading was 20.3 cm. What final uncertainty should he assign to his reading? Before we can answer this question, we must think about the maximum amount the reading may be off. It is obvious that the scientist must add the human error, the instrumental error, and the error due to change within the system. Therefore, the scientist tabulates his reading as 20.3 ± 0.3 cm. The range of uncertainty is 0.6 cm, because the scientist is saying the actual length of the object lies somewhere between 20.0 cm and 20.6 cm.

Measurements within this range have a high level of confidence. Conversely, measurements outside this range are very dubious.

A.6 - PLACE OF THE UNCERTAINTY

As you probably recall, we have names for the positions digits occupy in numbers. For example:

HUNDREDS	TENS	ONES		TENTHS	HUNDREDTHS
___	___	___	•	___	___

HDL #10 and 11 go with this section.

In our previous example, 20.3 ± 0.3, the place of the uncertainty is the tenths place.

As another example, 168.9 ± 0.3 cm poses an interesting problem. The number 168.9 plus 0.3 is 169.2. Does this mean the place of the uncertainty is the ones place? Not at all. The place of the uncertainty is still in the tenths place.

A.7 - ROUNDING OFF TO THE CORRECT PLACE

When scientists communicate quantitatively, it is generally accepted that the uncertainty is rounded off to the largest place having a digit. In this case zero is not considered a digit. For example, in the measurement 102.73

HDL #12 goes with this section.

± 1.68, the uncertainty (1.68) is rounded off to the ones place and therefore becomes 2. It is also generally accepted that the part of the measurement that comes before the uncertainty is rounded off to the same place as the uncertainty. The measurement 102.73 ± 1.68 becomes 103 ± 2 when rounded off properly. Before you read any further, round off the following measurements to the proper place.

(1) 420±20 miles
(2) 6590±10 m.
(3) 1.27±0.07 cm.
(4) 500±100 sec.
(5) 50,000±100 Kg.

(1) 421 ± 22 miles

(2) 6591.2 ± 12 meters

(3) 1.269 ± 0.068 centimeters

(4) 500 ± 100 seconds

(5) 50,000 ± 100 kilograms

Check with your teacher to be certain of your answers before you continue.

A.8 - PROPAGATION OF ERRORS

What happens to this "plus or minus" when you add, subtract, multiply or divide? The propagation of errors is too large a topic for exhaustive coverage here. We will learn a simple method accepted by most scientists called "significant figures."

A.9 - SIGNIFICANT FIGURES

HDL #13 goes along with this section.

Significant figures are the digits that are certain plus one more. The measurement 20.3±0.3 has three significant figures. We are certain of the tens place and the ones place, but we are not certain of the tenths place. The uncertainty lies in the tenths place. Expressing this number using significant figures, we write 20.3 Determine the number of significant figures in the following measurements and express them using the proper number of significant figures. You may have to round off some of the measurements first.

(1) 251 ± 1 kilograms

(2) 6532.00 ± 0.04 grams

(3) 500 ± 10 seconds

(4) 500 ± 1 centimeter

(5) 4.0002 ± 0.00149 square meters

(1) 251
(2) 6532.00
(3) 500 (this should bother the "good" student. How do you write 500 using significant figures when it is "good" only to the tens place? Scientific notation comes later.)
(4) 500
(5) 4.000

A.9.a - ADDING SIGNIFICANT FIGURES

When you add or subtract measurements, the number of significant figures in your answer is determined by the largest place where there is uncertainty. In the following example, the digit that is uncertain is enclosed in a box.

```
 112.23
 100.0
 519.1698
   2.000
 -------
 733.3998
```

Keeping in mind that significant figures are the digits that are certain plus one more, it is evident there are four significant figures in the answer. The answer rounded off and expressed in significant figures is 733.4.

Try the following problems and check them with your teacher before you continue. Round off your answers and express them in significant figures.

*(1) 16^*

(1) 569.321 ± 0.01
2.0009 ± 0.0001
1030 ± 2

(2) 50.80

(2) 49.80 ± 0.03
1.000 ± 0.001

A.9.b - SUBTRACTING SIGNIFICANT FIGURES

As in addition, the number of significant figures in the answer is determined by the largest place that has any uncertainty. For example,

```
  32.5
- 8.598
  23.9
```

The proper answer, rounded off, is 23.9. Try the following problems and check with your teacher before you continue.

(1) 903.005

(2) 489.00

(1) 973.009
- 70.004

(2) 523.0013 ± 0.0235
- 34.00298 ± 0.00069

A.9.c - MULTIPLYING AND DIVIDING SIGNIFICANT FIGURES

HDL #16 and 17 go along with this section.

When you multiply or divide, your answer should have no more significant figures than the smallest number of significant figures originally available. For example,

```
  156  (three sig. figs.)        89453  (five sig. figs.)
  365  (three sig. figs.)          111  (three sig. figs.)
  780                            89453
 936                            89453
468                            89453
56940                          9929283

56,900 (three sig. figs)      9,930,000 (three sig. figs.)
```

$\frac{1943.1}{2.1}$ $\frac{\text{(five sig. figs.)}}{\text{(two sig. figs.)}}$ = ~~925.3~~ 930 (two sig. figs.)

Try the following problems and check with your teacher before continuing.

Multiply:

(1) 269.4 ± 0.1 × 16.2 ± 0.1 (2) 1000.0 ± 0.1 × 1.0 ± 0.1

(1) 4360 three sig. figs.
(2) 1000 two sig. figs.

Divide:

(1) $\frac{569.129 \pm .02}{69.001 \pm .005}$ = (2) $\frac{4834.2 \pm .1}{1.0 \pm .1}$ =

(1) 8.2481 (five sig. figs.)
(2) 4800 (two sig. figs.)

A.10 - SCIENTIFIC NOTATION

HDL #14-17 go with this section.

Unless we always attach the uncertainty to the measurements we make, it is difficult to convey to another investigator just where the uncertainty lies. For example, if we see the number 46,000,000 we cannot tell whether the uncertainty lies in the ones, tens, hundreds or thousands place.

To eliminate the confusion, we use a simple method which leaves no doubt as to the proper number of significant figures. This simple method is called scientific notation. We all know the decimal point moves one place to the right every time you multiply by ten. We also know the decimal point moves one place to the left when you divide by ten. To express a measurement using scientific notation, the recorder simply writes the proper number of significant figures, puts the decimal between the first and second digit, then multiplies or divides by the proper number of "tens" to make the measurement as large or small as it actually is.

For instance, if the recorder wishes to tell the person who reads his report that the measurement is 46,000 good to three significant figures, he simply writes 460, then puts the decimal point between the first two digits (4.60) and multiplies by the proper number of "tens" to make the number as large as it actually is (4.60×10^4).

How can we express the measurement 0.0000549, showing only three significant figures? Write 549 and then put a decimal between the first and second digit (5.49). Finally, we would divide by the proper number of "tens" (5.49×10^{-5}). Write the following measurements using scientific notation. (You may have to round off to the correct place first.)

(1) 1028 ± 1 cm

(2) 10,000 ± 10 miles

(3) 0.0261 ± .01

(4) 0.000018 ± 0.000002

(5) 1.25 ± 0.01

(1) 1.028×10^{3}
(2) 1.000×10^{4}
(3) 3×10^{-2}
(4) 1.8×10^{-5}
(5) 1.25×10^{0}

A.11 - BACK TO THE SCALENE TRIANGLE

By now you probably realize some of the inadequacies of significant figures. One that is very apparent is the lack of a range of uncertainty. When measurements are expressed using scientific notation, we are never certain about the range of the uncertainty. Nevertheless, significant figures are very useful in communicating the place of the uncertainty, and knowing the place of the uncertainty is usually satisfactory.

Notice there is no attempt to explain the "best" answer at this time. Interested students might refer to a paperback, by W. J. Youden, <u>Experimentation and Measurement</u> (Scholastic Book Services, 1962 NSTA).

Refer back to the data you collected when you tried to calculate the area of the scalene triangle. Refer back to the section on instrumental and human error and error due to changes within the system. Assign a range of uncertainty to each of your measurements, then round them off to the proper place. Now express them using scientific notation. Finally, recalculate the area of the triangle from the three sets of bases and heights using only

List the students' results on the blackboard.

The digits that are certain will be the same in all cases. The variance in the uncertain place is understandable because the last place written <u>is</u> uncertain.

significant figures. Are those digits that are certain the same in all three cases? If there is some variance in the uncertain place, is this understandable? Remember, significant figures are all the certain digits plus one more.

<u>Exercises for Home, Desk, and Lab (HDL)</u>

(1) Statements (c) and (d) are quantitative descriptions.

(1) Observation is made of a burning candle. Which of the following can be considered quantitative descriptions?

(a) The candle gives off light and heat as it burns.

(b) The top of the candle becomes wet with a colorless liquid.

(c) The wick is made of strands of string which are 9.8 cm long.

(d) The candle becomes shorter at a rate of 1 cm/minute.

(e) The top of the candle becomes bowl-shaped.

(2) No, his friend is not correct, because the relation of their heights remains the same no matter what system of measurement is applied. Therefore, the ratio of their heights would be the same.

(2) A student designs his own system of measurement. Using his system, he measures his height and a friend's height. He finds the ratio of his height to his friend's is 1.2/1.0. His friend argues that the ratio would be different if they used the metric system. Is the friend correct? Why?

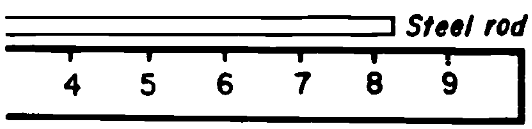
In the following problems use L for length, M for mass, and T for time.

(3) If you multiply length times length times length, what are the dimensions of your answer?

(4) What are the dimensions associated with the speed of your family car?

(5) If you multiply mass times length per time squared, then multiply by length, what are the dimensions of your answer?

(6) A steel rod has to be measured. The picture drawn below is what you see while making the measurement. The steel rod is at room temperature and so is the ruler.



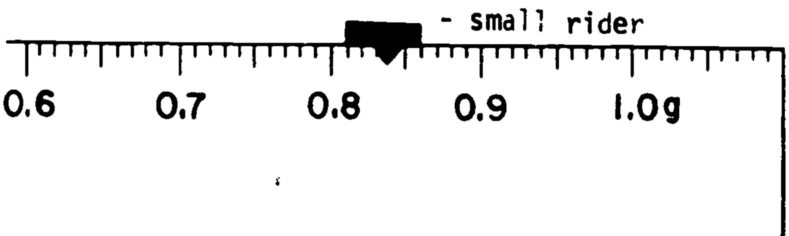
0.1 cm. at 25° C

(a) What uncertainty would you associate with the measurement?

(b) Write the measurement with the total uncertainty.

(c) What is the range of the uncertainty?

(7) A student sees the following while making a measurement using a typical triple-beam centigram balance. The large "riders" are at zero.



(3) L^3, which is the dimension of volume, is the correct answer.

(4) $\frac{L}{T}$ is the correct answer.

(5) $M\left(\frac{L^2}{T^2}\right)$ is the correct answer. $(M)\left(\frac{L}{T}\right)^2$ is mass times velocity squared which are the dimensions of E_k

(6) human error ± 0.2 cm
instrumental error ± 0.1 cm
other error ± 0.0 cm
± 0.3 cm

(a) Total uncertainty would be ± 0.3 cm.

(b) 8.2 ± 0.3 cm

(c) The range would be 0.6 cm.

(7)

(a) ±0.005 g

(b) ±0.01 g

(c) ±0.015 g

(a) What human error would you associate with this measurement?

(b) What instrumental error would you associate with this measurement?

(c) Assuming the error due to change in the system is zero, what total uncertainty would you associate with the measurement?

(8) The range is 0.4 grams.

(8) What is the range of the uncertainty in the measurement 6.2 ± 0.2 grams?

(9) The range is 0.16 seconds.

(9) What is the range of the uncertainty in the measurement 100.02 ± 0.08 seconds?

(10) The tenths place.

(10) What is the place of the uncertainty in the measurement 6.02 ± 0.2 grams?

(11) The hundredths place.

(11) What is the place of the uncertainty in the measurement 100.02 ± 0.08 seconds?

(12)

(a) 1.07 ± 0.03

(b) 0.006 ± 0.005

(c) 1600 ± 100

(12) Round the following off to the correct place:

(a) 1.065 ± 0.0295

(b) 0.0059 ± 0.005

(c) 1649 ± 100

(13)

(a) 649.2

(b) 0.0006

(13) Express the following using significant figures:

(a) 649.2 ± 0.5

(b) 0.00059 ± 0.00015

(c) 5649 ± 29.5

(14) Add the following and express your answer using scientific notation:

(a) 649.2 ± 0.5
29.26 ± 0.01
1.269 ± 0.001

(b) 527.8 ± 0.1
61.39 ± 0.01

(15) Subtract the following, expressing your answers in scientific notation:

(a) 32.50 ± 0.01
$- 8.902 \pm 0.001$

(b) 657.89 ± 0.06
$- 549.01 \pm 0.01$

(16) Multiply the following, expressing your answers in scientific notation:

(a) 156 ± 2
365 ± 6

(b) 1.009 ± 0.001
41 ± 1

(17) Divide the following, expressing your answers in scientific notation:

(a) $\dfrac{654.298 \pm 0.001}{2.0 \pm 0.1}$

(b) $\dfrac{54.07 \pm 0.05}{1.68 \pm 0.01}$

B. RANDOM EVENTS

B.1 - Experiment: MASS OF SOW BUGS

You observed sow bugs earlier in the course. Weigh your sow bug individually and record its mass on the board. Prepare a class histogram or bar graph showing the number of sow bugs at a given mass on the y axis and the mass of the sow bugs on the x axis.

(13) (c) 5650

You may first assign the problems that follow without asking students to express their answers using scientific notation. Then, after they have studied scientific notation, they can re-work the problems, expressing their answers using scientific notation.

(14)
(a) 6.797×10^2
(b) 5.892×10^2

(15)
(a) 2.360×10^1
(b) 1.0888×10^2

(16)
(a) 5.69×10^4
(b) 4.1×10^1

(17)
(a) 3.3×10^2
(b) 3.22×10^1

Equipment and Materials
sow bugs, 100 or more
balances

This experiment gives students weighing (massing) experience and data is collected that should show another distribution curve. If no two isopods have the same mass, instruct the students to use mass ranges on the x axis. Look at their data on the board and see if rounding off the masses will give a better distribution *curve. This will have to be decided after they have written the sow bug masses on the board. Use at least one hundred animals.*

You have already determined your reaction times in Experiments C.5 and C.6, Chapter I. Refer to the graph of your results. Does the sow bug mass graph resemble your reaction time graph? Graphs are used to present experimental data in an easily understood fashion. In addition, the shape of the resulting curve often leads to important insights.

For use of balances see D.2.c.

Yes, the two graphs should be similar.

WARNING TO TEACHER: Ask students to bring ten coins for B.2.

Distribution curves seem to be related to living systems because both of your graphs were obtained from observations on living systems -- sow bugs and humans. Perhaps distributions also occur in non-living events and are a fundamental property of nature.

B.2 - Experiment: COIN FLIPPING

Equipment and Materials
small boxes - optional
10 coins/student group
graph paper

Shake ten coins in a box, remove the lid, and count the heads. Record the number of heads after each shake. Repeat this operation twenty times. Graph the results by placing the number of trials with the same number of heads on the Y axis and the number of heads in each trial on the X axis.

This experiment may be done in groups or may be done individually if you have enough boxes and coins. If boxes are not available, the coins may be shaken by hand and spread on the table for counting.

Show the PSSC film, "Random Events" (30 min. running time) after this experiment. This film is very well produced; it should be seen by the students even if you may dislike films yourself.

Is this graph similar to the sow bug mass and human reaction time graphs? Does it appear that distributions due to random events are a general occurrence in nature?

Yes, the graphs should be similar.

Yes.

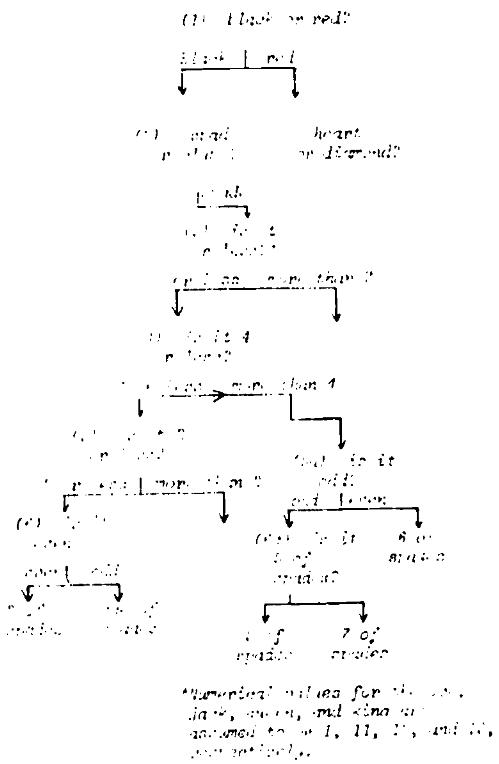
C. ORGANIZATION

C.1 - Demonstration: CLASSIFICATION AND ORGANIZATION

We live in a world where most objects and events have names. And names, in part at least, are a way of classifying and organizing information according to the scheme of language. What holds our attention best is something new. Our interest is immediately directed towards placing the new thing in its proper place in the world of things we already know. Often the shape and direction of your investigation of the new thing is strongly influenced by your first guess as to what it is. Thus taste and smell are used to investigate a powdered breakfast drink but not usually a powdered detergent.

In science, classification and organization of information must be done as concisely as possible. It is important not only in communicating what you have learned to other people, but also in guiding your investigation as it proceeds. The game of Twenty Questions is a good example of how one uses information logically to obtain new information and eventu-

This should be done as a demonstration with volunteer students, allowing them to use their own classification schemes. From these trials a rational system may be evolved by the students themselves. The teacher should, in any case, finish up by drawing on the board a dichotomy flow sheet which provides an efficient route to the answer. An example follows:



**Numerical values for the ace, jack, queen, and king are assumed to be 1, 11, 12, 13, respectively.*

ally to identify the object in question.

A good example of how proper organization can lead more quickly to the answer than simple guessing is provided by a deck of cards. How many "yes or no" questions do you think necessary in order to identify positively a card chosen by someone else? Certainly you could do it with fifty-two questions, but what is the minimum number of questions that would be sufficient?

You have used a flow sheet in identifying one card out of fifty-two. You have probably noticed that this system of organizing and classifying provides a useful way of dividing up the possible alternatives into smaller and smaller groups--that is, a way of going from the general to the particular. At the same time it provides a roadmap or sequence of operations which lead you most quickly to the answer.

But the flow sheet has its limitations. It is most useful only when a great deal is known in advance about the collection of things which you want to analyze--that is, when you already know what characteristics there are and which are most important or general and which are trivial.

If necessary, the teacher can draw out the entire flow sheet and show the students that in every case it is possible to identify the chosen card by a maximum of six questions through this scheme. In the use of the dichotomy or mutually exclusive category system, the number of alternatives which can be resolved in n questions is equal to 2^n. Hence, with six questions, $2^6 = 64$ alternatives could be handled. This problem should be presented to the students by asking them if six questions would still suffice when an additional three cards were included in each suit.

The teacher should also make the point that the deck of cards is an artificial situation in that

(1) all of the relevant characteristics of the cards are known in advance;

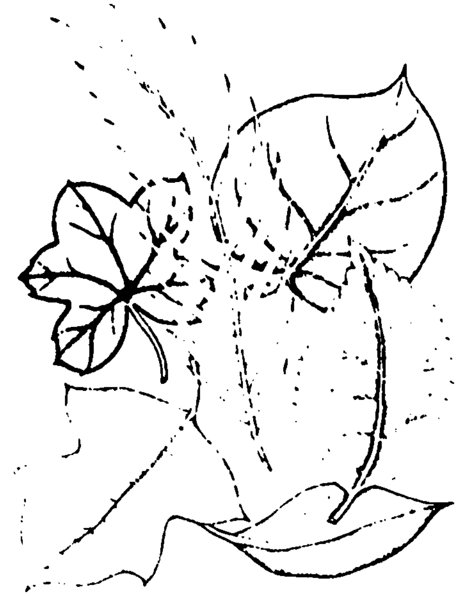
(2) the generality of each characteristic is known in advance (e.g., red cards are more common than aces);

(3) the total number of alternatives in the system is known in advance; and

(4) the relationships among the various characteristics is fixed and known (e.g., one card of each numerical value occurs in each suit).

The teacher may want to cite other uses of the flow sheet such as in chemical analysis, chains of command, responsibility in organizations, or genealogical tables.

WARNING TO TEACHER:
Ask the students to bring in an assortment of 7-10 leaves for C.2. Too many leaves lead to problems rather than solutions.



C.2 - Experiment: CLASSIFICATION OF LEAVES

Equipment and Materials

The leaf collection per student group should consist of about ten different types of leaves collected in any convenient garden or yard and numbered by means of small pieces of tape attached to the leaves.

A Roman Square is a device for correlating properties and/or objects. See Figure C.1 on the next page.

This writing group, which contained no botanists, collected fifty types and discovered thirty-five useful characteristics which were divided about equally among the general headings Shape; Veining; Border or Edge; Fuzz, Hair, or Spikes; Texture; Stem; and Odor.

Knowing very little about the collection of objects in question, what do you do then when you have to start from "scratch"? Try it now by observing the collection of leaves provided, noting as many characteristics as you can for each leaf. A useful device in this case is the Roman Square. This is a less organized and more open-ended way of handling observations.

The square can be expanded as you examine new leaves and find new characteristics. But it would be wise first to study the leaves for 15 to 20 minutes to determine as many characteristics as you can, and then to try to

	CHARACTERISTIC SHAPE				VEINING			
Leaf Number	Tear-drop	Heart	Blade	Round	Paral-lel un-branched	Net-work branches	Paral-lel branches	one main vein
1	yes	no	no	no	yes	no	no	no
2								
3								
4								
5								
6								
7								
8								

Figure C.1

arrange or group them under major headings as in the example above. As you proceed, you may find that some characteristics--such as the presence of veins--are true of all leaves and therefore not of much value in classification. Others--such as round shape--may be too vague. In your examination you may use any of your senses except taste, since some leaves contain poisonous substances. You may find that some pairs of characteristics usually go together, while others appear to be mutually exclusive. Probably the most difficult part of this study will be setting up the best characteristics. There is no easy solution to this; only trial and error can accomplish the job.

The main purposes of this exercise are to acquaint the student with the Roman Square method of handling observations or data; to contrast for him the relative difficulties in classification encountered in biological systems as compared to those of a simple man-made system like the deck of cards; and finally to force him to think and express himself precisely and concisely in his formulation of characteristics. It is anticipated that a considerable period of trial and error will be necessary before each student arrives at a satisfactory set of characteristics and organizes them into some system; two class periods may be necessary. If this is the case, the teacher should store the leaf collections overnight in damp newspaper or damp paper towels.

Once you are satisfied with your Roman Square, you may want to reorganize your characteristics into a flow sheet which would permit you to identify a leaf in your collection with as few "yes-no" questions as possible. Test your scheme of classification by having someone else in your group decide on a leaf which you then try to identify by means of these questions.

We think this test of the student's classification scheme is important. The teacher should require it.

It has proved meaningful to follow this exercise with another keying about 15 examples of evergreen or deciduous trees. Limbs or twigs may be used as samples.

D. CLASSIFICATION AND ORGANIZATION - EXTENDED

Classification and organization of playing cards and leaves can be accomplished using readily observed characteristics of the cards or leaves. In many cases visual observation will provide enough information to allow a classification scheme to be formulated. Since the ultimate use of classification and organization is the identification of individual members of the set, the problem is quite general and important. Manufacturers of household products must devote considerable attention to the design of the packages their products come in. Packages should "stand out" on the supermarket shelf and be quickly identified visually. Supermarket managers like to keep similar products shelved together (classified and organized) so one finds shelves of soap, for instance, with a multitude of garish boxes in living color assaulting the eyes. Advertising of new products is often as concerned with establishing the identity of the box as it is with telling about the new product. The design of automobiles is complicated by the fact that design features characteristic of a certain brand must remain constant enough to allow identification of the brand year after year. At the same time, however, the design must change each year so the public will believe the new model is different from the old one. Identification of automobiles is further extended by the necessity for each one to carry a permanent number attached to the frame and/or stamped on the engine in addition to the license plate. If we had to key automobiles we could also include body style and color in our key.

For the fastest possible identification of a given automobile one might go through the items on our key in order of ease of observation. A policeman would probably be trained to read licence plates fast and accurately while the average citizen would probably notice color or body style first. In either case the car might be tentatively identified by a fast visual observation but the ultimate identification would be by finding the frame and/or engine number.

The study of nature often starts with observation, classification and identification. Sometimes it is desirable to make a fast tentative identification (sometimes nothing more than a guess) while other times a very detailed analysis may be required (for example, samples of moon material are being studied in great detail). Now we are going to extend these ideas of classification and identification to include chemicals. The objective of the following experiment is to identify some unknown metals.

D.1 - Experiment: VISUAL OBSERVATION

Equipment and Material
Identified metals
Handbook of Chem. and Physics
Sets of unknown metals
Emery cloth or file
Table: "Selected Properties of Some Metals"

A fast tentative identification of some metals might be made on the basis of visual observation. A more complete identification can be made by measurement of a physical property. An absolutely positive identification could only be made by measurement of several physical properties.

The cheapest way to do this experiment is to have five pieces of each of three metals for the classroom. The pieces of each metal should be different sizes. The volumes should vary as widely as possible for the available graduated cylinders. All the pieces of a given metal could be color coded on one end for easy identification. They will be used in the next experiment also.

Look at the table "Selected Properties of Some Metals" on the next page. The column headed "Color" is blank. Using the identified metals in the lab, the Handbook, and your previous experiences, fill in the blank column. In order to observe the true color of the identified metals it may be necessary to remove the surface layer of corrosion with emery cloth or a file.

Have a Handbook and a collection of identified metals around the lab. Emery cloth or a file would also be helpful.

Obtain unknown metals from the teacher and attempt to identify the metals by color. This may be only a guess.

The table lists three other characteristic properties of the metals, melting point, boiling point and density. The temperature at which

Selected Properties of Some Metals[1].

Metal	Symbol[2]	Color[3]	Density Grams/cc.	Melting Point °C	Boiling Point °C
Aluminum	Al		2.7	660°	2467°
Cadmium	Cd		8.6	321°	765°
Chromium	Cr		7.2	1890°	2482°
Cobalt	Co		8.9	1495°	2900°
Copper	Cu		8.9	1083°	2595°
Gold	Au		19.3	1063°	2966°
Iron	Fe		7.9	1535°	3000°
Lead	Pb		11.3	327°	1744°
Magnesium	Mg		1.7	651°	1107°
Mercury	Hg		13.5	-39°	357°
Nickel	Ni		8.9	1453°	2732°
Osmium	Os		22.5	3000°	5000°
Palladium	Pd		12.0	1552°	2927°
Platinum	Pt		21.5	1709°	3827°
Silver	Ag		10.5	961°	2212°
Titanium	Ti		4.5	1075°	3260°
Zinc	Zn		7.1	419°	907°

1. Data taken from current handbooks.

2. Symbols are a convenient shorthand. Often the symbol for an element is an abbreviation of the name. Sometimes it is the abbreviation of an older name.

Common Name	Old Name	Symbol
Copper	Cuprum	Cu
Gold	Aurum	Au
Iron	Ferrum	Fe
Lead	Plumbum	Pb
Mercury	Hydrargyrum	Hg
Silver	Argentum	Ag
Tin	Stannum	Sn

3. Colors can be described in various ways. Use your imagination.

almost all metals melt are too high for us to determine in our laboratory. The boiling points are even higher. This leaves density as the property we can use.

HDL's 1-13 at the end of the chapter go with the section on density.

D.2 PRELUDE TO DENSITY

Quantity of Matter: "How much?" is a pretty fundamental question for the description of matter. There are several answers. One is how much space the matter occupies, that is, its volume. The second is the mass of the matter or its weight*. By tradition, volume is used as a measure of quantity for some things and mass for other things. Gasoline could be sold by the pound though, and the space occupied by a person might be more interesting than his poundage.

D.2.a VOLUME

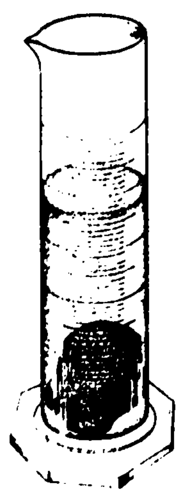
Liquids are most commonly measured by determining the space they occupy. This is easy because liquids assume the shape of their container. There are containers made for this purpose such as measuring cups and spoons. In the laboratory graduated cylinders are one kind

*Mass and weight are not synonomous. The distinction between them will require some physics.

of container used for volume determination. Scientific work commonly uses the cubic centimeter (cc. or cm^3) or the milliliter (ml.) as the unit of volume. The two units are equivalent and graduated cylinders may be found marked or calibrated in either cc., cm^3, or ml.

Equipment and Materials
Graduated cylinders
3 or 4 metals, 5 pieces of each

If the students drop the metal into a glass graduated cylinder there is a good chance the glass will crack. Either use plastic graduate cylinders or warn the students to tilt the cylinder and allow the metal to slide down the wall. Alternatively, the metal can be lowered into the cylinder with a piece of thread.



Demonstrate how the graduated cylinder is held at an angle and the piece of metal allowed to slowly slide down. With an old glass jar you could also demonstrate how easily glass can be broken by the metal.

D.2.b. Experiment: VOLUME OF A SOLID

The volume of a solid may be determined directly if its dimensions can be conveniently measured. If one of your unknown metals is a cube, for instance, you would have no difficulty obtaining its volume by direct measurement. Most regularly shaped objects such as spheres, cylinders, cones and rectangles can be handled similarly. Attempt to determine the volumes of some of your unknown metals by direct measurement. How many significant figures are justified in your answer?

Irregularly shaped objects present a different problem. Fill a graduated cylinder half full of water and record the volume. Carefully add one of your unknown metals and record the new volume. The difference between the original volume measurement and the new one should equal the volume of the metal. Determine the volume of each of your unknowns. How many significant figures are you allowed in your answer? Compare your results with the direct measurement results. Are they the same? If not, why is there a difference? Which is the most accurate method? Why? Which method would be best for sand? For wooden blocks? Does knowing the volume help you in deciding what your unknown is?

Warn students to record their data so that they will be able to use it later.

Knowing the volume won't identify the metal.

D.2.c. MASS

If this is the student's first experience with a graduated cylinder it might be wise to have them make several volume determinations of one piece of metal to develop their skill.

<u>Use of the Balance</u>: A balance is an instrument used for making comparisons of two masses. There are several types of balances in common use. One type is called an equal-arm balance. It consists of a beam suspended at its midpoint with a pan at each end. If an object on one pan has the same mass as an object on the other pan, the beam will be horizontal. Comparison of two masses is particularly valuable when one mass is standard.

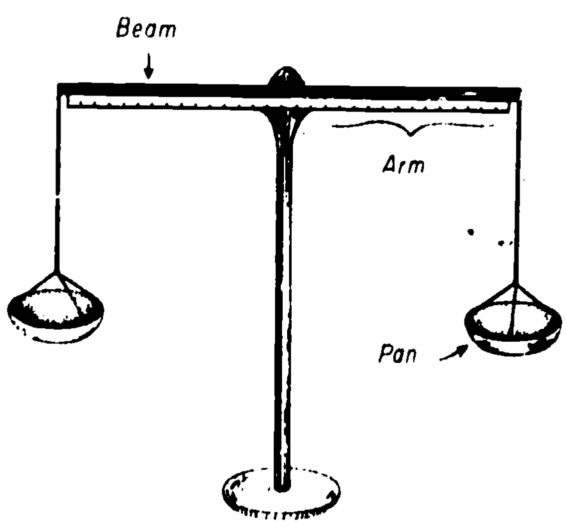


Figure D.1

A standard mass is any mass that we decide should be the basis for all comparisons. Scientists throughout the world use the same standard of mass, the kilogram. The international standard of mass in the metric system is a cylinder of platinum-iridium alloy kept at the International Bureau of Weight and Measures at Sevres, France. Our own National Bureau of Standards in Washington, D.C., has an accurate copy of the international standard. Accurate copies of this copy are used for comparison purposes. The gram is one one-thousandth the mass of the kilogram. It is very nearly equal to the mass of one cubic centimeter of water.

The triple-beam balance is in principle the same as an equal-arm balance. One pan has been replaced with a set of comparison masses in metric units, which slide along the beam.

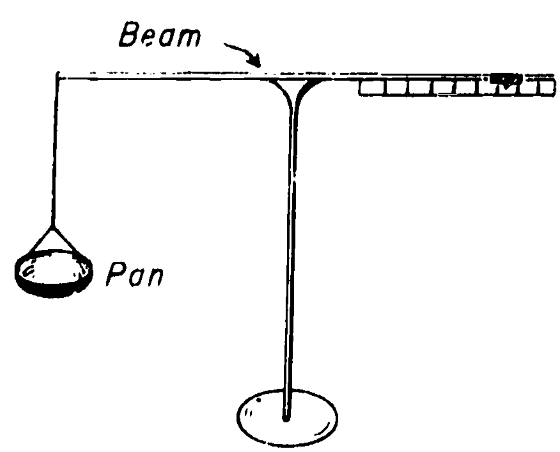


Figure D.2

D.2.d. Experiment: MASS

Determine the mass of each of your unknown metals with a balance.

Does knowing the masses of your unknowns help you to identify them?

It is likely that knowing the volume and the mass was not particularly valuable to you in identifying your unknowns. This is because both are properties of the particular sample in your hand and are not properties of any particular metal . They are very useful, however, in calculating a characteristic property of matter which will be helpful.

Equipment and Materials
- *3 or 4 metals, 5 pieces each*
- *triple beam balances*
- *platform balances*

There is a film loop on the use of the balance, "Weighing with the Triple Beam Balance", Ealing Company.

For the heavier pieces of metal a platform balance will be needed.

Knowing the masses will not identify the metal.

D.3 DENSITY: A CHARACTERISTIC PROPERTY OF MATTER

If we take an iron bar 1 cm. square and cut off 1 cm. sections we would have a number of identical iron cubes. Their volumes would all be one cubic centimeter. If we weighed them they would each weigh 7.9 grams. A 2 cm. section would have a volume of 2 cubic centimeters and certainly we would expect it to weigh 15.8 grams.

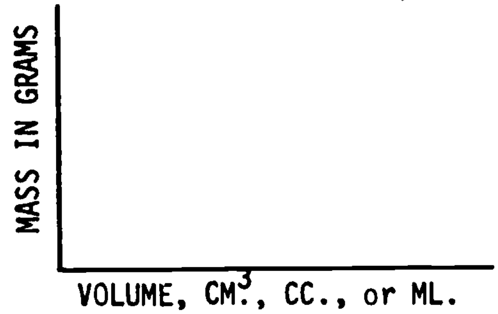
The laboratory exercise which follows is included as a review of graph-making and as a tool for teaching graph analysis.

D.3.a. An Experiment: DENSITY BY A GRAPHICAL METHOD

You have now determined the mass and volume of each piece of metal in the three

Equipment and Materials
- *3 or 4 metals, 5 pieces of each*
- *Balances, triple beam or platform*
- *Graph paper*

unknown sets. Plot a graph of the data.



If the balance is zeroed before the experiment is performed the origin can be considered as a data point. This should be discussed with the class.

Notes on graphing: Gather all the mass and volume data before setting up the scale division. Start the graph scale with zero grams and zero ml.

When the data points for one metal have been plotted, draw a straight line which appears to best fit through the points. Probably some points will not fall on the straight line. Why not?

From the graph you have plotted read the mass of 1 cm.^{3} (cc. or ml.) of your metal. Read the mass of 10 cm.^{3} (cc. or ml.) of your metal from the graph, divide the result by ten and compare this number with your direct reading of grams per one cm.^{3} (cc. or ml.).

Extend the line using dashes so that you can read the mass of a 100 cm.^{3} piece of metal.

How steep is your line? The "steepness" or slope of the line can be described quantitatively as the number of units the line extends vertically divided by the number of units the line extends horizontally.

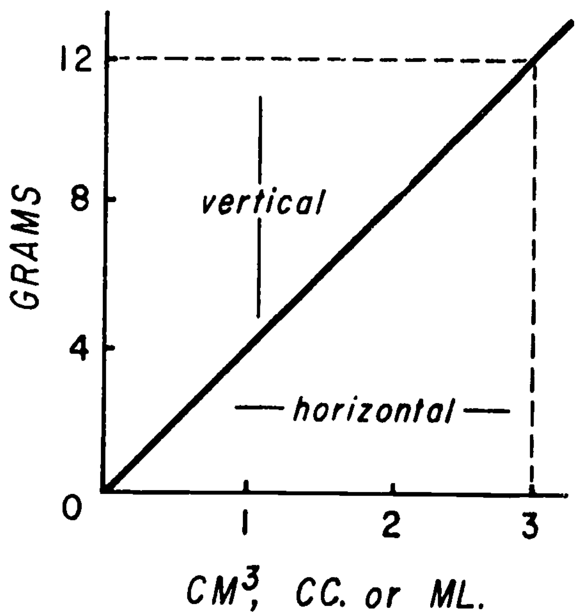


Figure D.3

By performing the actual arithmetic division we have the number of grams per cm.^{3} (cc. or ml.) of metal. This is the same as reading directly the number of grams on the Y-axis at the one cm.^{3} (cc. or ml.) horizontal division.

The quantity you have just calculated, the mass per one cm^3 or unit volume, is defined as density. For any substance (including of course, your unknown metals) the density is a characteristic physical property. It is independent of the size of the sample. It should be a very useful characteristic property to use for identification of your unknowns. Graph the data for your other two unknown metals and repeat the process used above. Identify each unknown.

Density could have been obtained by the determination of volume and mass of just one piece of each of the unknowns. However, by making several determinations on the same metal using different pieces, lab errors hopefully will tend to cancel each other. The graphing technique we used shows us when a data point is "out of line." If we did only one determination we would not have this extra information about the data. Would we get the same result if we connected the data points with straight lines as shown below?

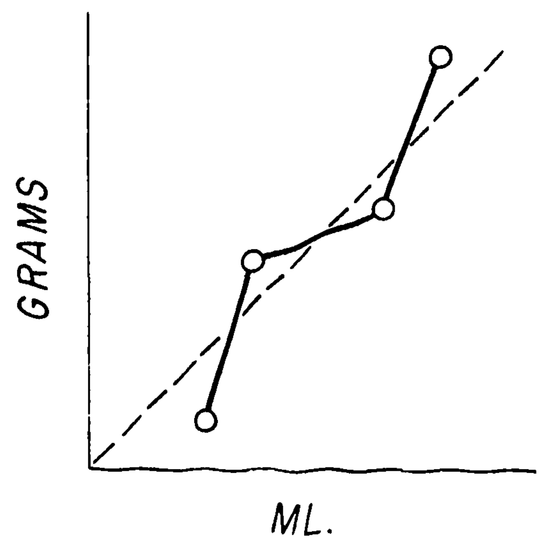


Figure D.4

D.4 OTHER CHARACTERISTIC PHYSICAL PROPERTIES

Density is a physical property used for identification. There are other physical properties which are also useful for this purpose. We will now learn about some of these and use them for identification.

D.4.a. FREEZING AND MELTING

We know that water freezes to form ice and that ice melts to form liquid water. The temperature at which this change takes place is known as the freezing point or melting point. Does ice melt at the same temperature that water freezes? It should, but how can we prove that it does? Plan an experiment which would demonstrate this.

If someone has a good idea on this let them try it. Perhaps a container of ice and water and a thermometer will be sufficiently suggestive.

For classification, organization and identification we can make use of freezing and melting. First, if a substance has a freezing point or melting point lower than room temperature it should exist ordinarily as a liquid. On the other hand, a substance that has a freezing point or melting point higher than room temperature should exist ordinarily as a solid. We can classify and organize substances on the basis of whether they are ordinarily liquids or solids. List six substances you would expect to be liquids ordinarily.

If we restrict the list to pure substances this is not an easy task for sophomores.

D.4.b. Experiment: BEHAVIOR OF SOLIDS ON WARMING

Careful observation of familiar objects around us usually reveals characteristics and properties that were not obvious to us before. In this experiment you will compare the behavior of several solids when heated.

Equipment and Materials (for thirty students)
- *15 candles*
- *15 Bunsen burners*
- *15 ring stands, ring, wire gauze*
- *15 250 ml beaker*
- *15 tin can lids*
- *Small pieces of sulfur, lead, tin, copper, and steel wool*

Small tin cans from home or school kitchens could replace beakers, avoiding the need to clean wax-coated beakers.

This experiment involves a careful observation and comparison of several substances and how they behave under varying temperature ranges.

This will give rise to making some generalizations as to the melting point of a substance being a characteristic property of matter.

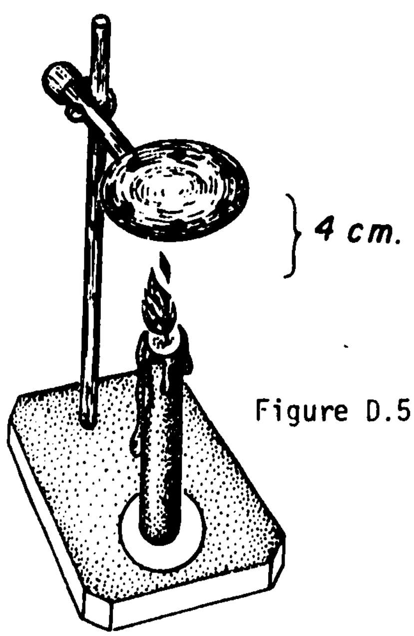


Figure D.5

The copper and the iron do not melt by this particular process. After comparing class results, it may be desirable to refer the student to a chemistry handbook to compare his findings with the accepted melting point values as listed.

Some classes have found the sulfur an irritant to eyes and throat when heated over the bunsen burner. It is suggested that this may be carried out under a hood.

Place a lid from a tin can on an iron ring stand as shown in Figure D.5. The lid should have some depressions made in it to hold the substances to be tested. Adjust the height of the ring so that it is about 8 cm above the tip of your candle. Place on the lid, equally spaced near the edge, small equal volumes of candle wax, steel wool, sulfur, lead, tin and copper wire or turnings.

Light your candle and adjust the ring height until the tip of the flame is about 4 cm directly below the center of the lid. Heat the lid for about three minutes. Record your observations paying particular attention to the melting process. Replace the candle with a bunsen burner and adjust the iron ring about 8 cm above the bunsen burner. Now adjust the burner flame to about 5 cm and heat for about 3 minutes. Increase the size of the flame and heat for another 2 minutes. Record all observations.

In the burning of a candle you will observe that there is a pool of liquid at the base of the candle wick.

The question then arises as to whether the solidified liquid from the bowl of the candle will behave in the same way as the original candle wax when heated.

Remove your tin can lid from the ring stand and replace it with a wire gauze and a 250 ml beaker about 1/3 full of water. Pour a few drops of the liquid from the bowl of the burning candle onto a piece of paper. Break off a piece of the solid formed and place it in the beaker of cold water. Obtain a piece of the unmelted candle wax by cutting a chip out of the bottom of your candle. Both pieces should be about the same size. Place the second piece in the beaker apart from the first piece.

Heat the beaker and its contents with the bunsen burner and note when each substance starts to melt. Allow the beaker and its contents to cool and discard the solid material. (Do not put it in the sink.)

Careful observation will show that only the candle wax and the sulfur are melted by the candle -- in that order. The tin and then the lead are melted by using the bunsen burner.

How does your observed order of melting compare with the findings of other members of your class? Make a generalization based on the combined observation of the class. What statement can you make concerning the melted material in the bowl of your burning candle and the candle wax? Can you make any statements as to why the substances on the tin can lid began to melt at different temperatures?

When the student observes that the solidified liquid from the bowl of the candle melts at the same temperature as the solid piece cut from the candle, he will conclude that they are probably the same substance.

It will be important later to be able to tell if a chemical melts in a bunsen burner flame or not. Remember, I told you so.

Make sure that the student understands that solids do melt and that they do have characteristic melting points peculiar to themselves, and also that a particular substance always melts at the same temperature.

Equipment and Materials

- [illegible] test tubes
- [illegible] centigrade thermometers
- [illegible] ring stands
- [illegible] rings
- [illegible] wire gauze
- [illegible] bunsen burners
- [illegible] timing devices
- [illegible] large beakers
  - [illegible] each of paradichlorobenzene, napthalene, and candle wax

Some teachers report better student results when the paradichlorobenzene is heated to about 90° C rather than 70°C.

In the first part of the experiment the student will not have many problems in establishing a cooling curve provided that the temperature of the water bath does not fall below [illegible].

In the second part of the experiment the temperature of 70° C is considerably more critical in order to get a satisfactory result. Heating the water in the beaker to 90° C should eliminate the need to rewarm it.

D.4.c. Experiment: FREEZING AND MELTING CURVES

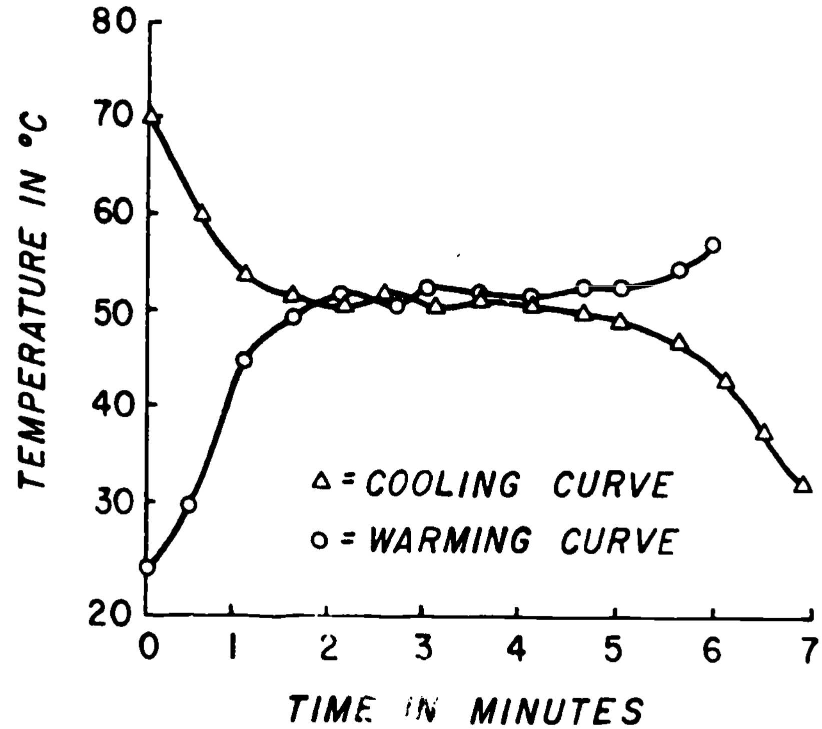
In this experiment we will attempt to show that the melting points and freezing points of a substance are the same.

In a clean, dry test tube place 10 grams of paradichlorobenzene and immerse in a water bath and warm gently until the substance in the test tube is completely melted. Continue heating until the temperature reaches about 70° C. Remove the test tube from the hot water bath and place in a beaker of cold water at about 30° C. Measure and record the temperature of the melted substance every 30 seconds as it cools and begins to solidify. Continue to take data for about another 5 minutes. Note when the solidifying process starts and when it ends.

Using an entire sheet of graph paper, record your data in graphical form, plotting the temperature as a function of time. (Enter the time on the horizontal axis and the temperature on the vertical axis.) This is a cooling curve.

Heat a large beaker of water about 70° C. Read and record the temperature of the solid substance in the test tube and place it in the beaker of hot water. Record temperatures every thirty seconds noting when the melting begins and when it ends. (Note it may be necessary to warm up the water bath as the action continues.) Record the observed data and plot the data on the same graph used for the first part of the experiment. With a black pencil draw a smooth curve to represent the cooling behavior of the substance checked, and with a pencil of another color draw a smooth curve representing the warming behavior of the substance. This is a warming curve.

The following graph indicates one set of values for paradichlorobenzene.



Obtain other samples of different materials from your instructor and determine the cooling and warming curves for these using the same techniques that you have used previously. Note and discuss any differences that may appear in the different substances.

Is there any significance to the fact that one or more of the substances investigated may have little or no plateau, while others may present a relatively longer plateau as they are plotted on the graph? Explain the reasoning for the choice you make.

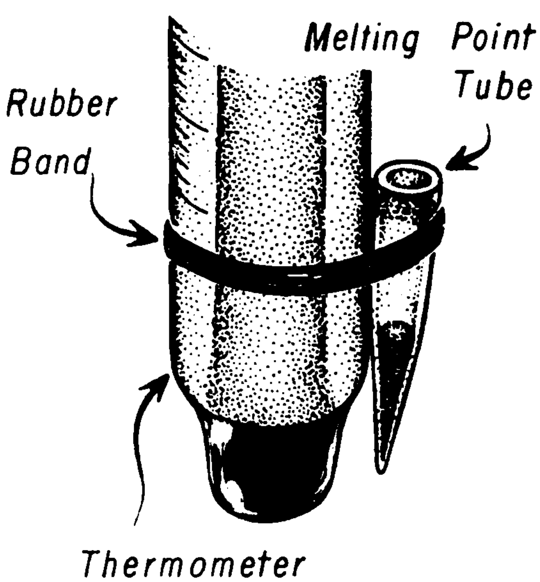
Do you think that there would be any marked changes in either the cooling curve or

Varying the number of grams of material would not cause any significant changes

116 *in the curve except that it may become more gradual. The length of the plateau (but not its height) would be affected because of the fact that a longer time would result from the greater amount of mass to be either melted or solidified.*

A cooling curve that has little or no plateau indicates that it has no freezing point within this temperature range.

Equipment and Materials
- *beakers*
- *thermometers*
- *capillary tubes*
- *chemicals*
- *rubber bands*
- *stirring rods*
- *clamps*
- *corks*
- *ring stands*



the warming curve if you were to vary the number of grams of material used in each case? Explain your choice.

D.4.d. Experiment: MICRO-MELTING POINT

For convenience, melting points are usually determined on very small quantities of sample. A melting point tube can be prepared from glass capillary tubing. Heat a capillary tube in the middle until it melts. Pull the two pieces apart and seal one end of each piece in the flame. Crush a small piece of paradichlorobenzene and scoop up the powder into the open end of one of the tubes. Carefully tap the sealed end of the tube against the desk top. The powder should fall to the bottom of the tube. A column of material about 3 to 5 millimeters high packed in the bottom of the tube serves as the melting point sample. Attach the packed tube to a thermometer with a rubber band so that the sample is next to the thermometer bulb.

Suspend the thermometer with the melting point tube attached to it in the center of a beaker half filled with water. Slowly heat and stir the water while observing the sample. Record the temperature at which liquid first appears and the temperature at which the last bit of solid disappears. These two temperature readings define a melting point range for paradichlorobenzene. We will use this micromelting point method to identify an unknown. Obtain an unknown from your teacher. The unknown will be one of the substances listed below. Identify it by its melting point. You will want to make several melting point range determinations. The most accurate results will be obtained when the water bath temperature is rising by about 2 degrees per minute while the sample is melting.

Camphene 42°
Paradichlorobenzene 53°
Maleic anhydride 56°
Naphthalene 80°
Acetamide 82°
Citraconic acid 91°
Citric acid hydrate 100°

Equipment and Materials

ring stand
clamps
test tube
thermometer
alcohol or bunsen burner
boiling chips
water

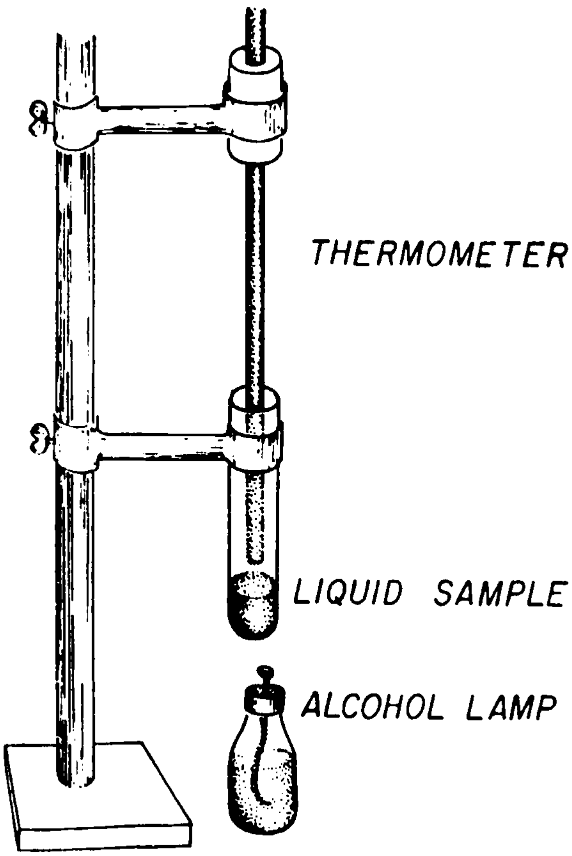


Figure D.6

There are precious few liquids besides water which are safe and boil at a convenient temperature.

D.4.e. Optional Experiment: BOILING POINT DETERMINATION

If a substance boils at a convenient temperature we can determine the boiling point with the simple apparatus shown. The boiling point temperature is another useful physical property.

Place approximately two cm.^{3} (ml.) of water in a test tube and suspend a thermometer so that the bulb is two to three centimeters (about one inch) above the surface of the liquid as shown. Add a few small chips of porcelain to insure even boiling. Now gently heat the liquid. The liquid will boil and you should be able to spot liquid on the wall of the tube formed by condensation. Gently heat so that the condensation takes place about 1 cm. above the thermometer bulb. When the temperature is no longer changing record the boiling point. Do not heat the tube so hot that vapor escapes from the tube.

D.5. SOLUBILITY: ANOTHER METHOD FOR CLASSIFYING

There are many times in our lives when we add a solid to a liquid and the solid seems to disappear. Sometimes there is no visible change other than the "disappearance" of the solid. If we mixed sugar and water in a glass the sugar would seem to disappear. However, if we tasted the water it would be sweet. Since water alone is not sweet, and sugar alone is sweet we could conclude that the sugar is mixed throughout the water giving it a sweet taste. If we mixed Kool-Aid and water we would actually see the coloring mix throughout the water. A solid mixing throughout a liquid in this manner is soluble and dissolves and the resulting combination of solid and liquid is called a solution. The solid is called the solute and the liquid is called the solvent. We could also obtain a solution by dissolving one liquid in another. In this case the liquid present in the least amount would be called the solute. Gases can also dissolve in liquids to form solutions.

There is often some limit as to how much solute can dissolve in a given amount of a particular solvent. It is possible to add more solute to a particular solvent than can dissolve. If no more solute can dissolve the solution is said to be saturated. Terms introduced so far:

dissolve

soluble

solution

solute

solvent

saturated solution

Substances can be classified according to how soluble they are in a particular solvent. If, for instance, a thousand grams of a substance dissolves in 100 ml. of water, we would classify the substance as very, very soluble in water. On the other hand if 0.0001 gram of a substance was all that would dissolve in 100 ml. of water we would classify the substance as insoluble. Of course, the substance is not totally insoluble, but for all practical purposes it is insoluble. We will arbitrarily call anything insoluble if no more than 0.1 gram will dissolve in 100 ml. of water.

Equipment and Materials
- *test tubes*
- *gummed paper labels or glass marking pencils*
- *balances*
- *sodium chloride*
- *sodium nitrate*
- *calcium carbonate*
- *ammonium sulfate*
- *potassium acetate*
- *paper to use on balance pans (5 pieces/student team)*

D.5.a. Experiment: CLASSIFICATION BY SOLUBILITY

Place one ml. of water in each of five test tubes. Label the tubes sodium chloride (NaCl), sodium nitrate ($NaNO_3$), calcium carbonate ($CaCO_3$), ammonium sulfate ($(NH_4)_2SO_4$), potassium acetate (KCH_3CO_2). First place a piece of paper on the balance pan and weigh it.

Record the weight. Add one-half gram to the weights and then place the chemical you are weighing on the paper until the beam balances. If you add too much chemical adjust the weights until the beam balances and record the weight. If you get more than one-half gram it will not matter. Use five pieces of paper to weigh the five chemicals in this manner. Be sure to label each of the five pieces of paper.

Add a small amount of sodium chloride to the water in the test tube labeled sodium chloride, using your scoopula. Repeat the procedure by adding a small amount of each chemical to the appropriately labeled test tube. Would you classify any of the chemicals as insoluble?

Continue adding small amounts of each chemical to the appropriate test tube until each solution is saturated. You may need more than one-half gram of some of the chemicals in order to make the solution saturated. Keep a record of the weight of each chemical needed to achieve a saturated solution.

Classify the five chemicals as insoluble, moderately soluble, very soluble and very very soluble.

If students are required to record solubilities in gm/100 ml, this experiment will be a more helpful prelude to D.5.b. From a series of such recordings they might establish some quantitative limits for "insoluble, moderately soluble," etc.

Their findings may be checked against values in the Handbook of Chemistry and Physics.

Equipment and Materials

Non-expendable:
- *1 evaporating dish per student*
- *1 250 ml pyrex beaker per student*
- *5 150 ml pyrex beakers for the saturated solutions*
- *1 wire screen with asbestos center per student*
- *1 tripod per student*
- *1 bunsen burner per student*
- *1 striker per student (or matches if you want to dig them out of the sinks)*
- *1 -10 to 110° centigrade thermometer per student.*

Expendable:
- *1 lb $K_2Cr_2O_7$ (assuming about 5 data points per class); technical grade is okay.*

If students do this experiment as a class, check the thermometer they use for accuracy.

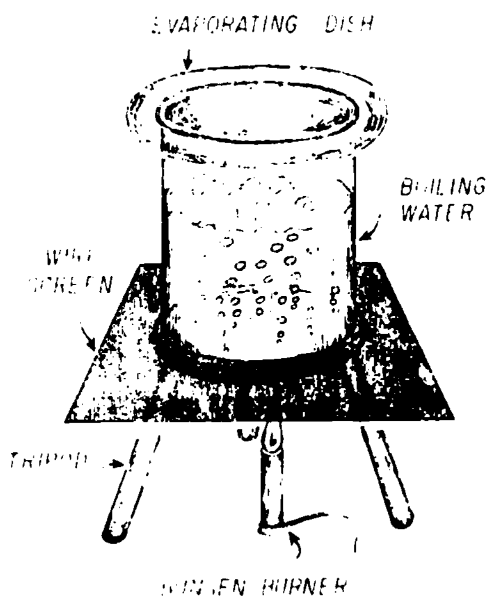


Figure D.7

D.5.b. Experiment: TEMPERATURE VERSUS SOLUBILITY

In this experiment, a saturated solution at a given temperature is evaporated to dryness. From the weight of the residue, the solubility in grams per 100 g of water can be calculated. Others in the class may be performing the same experiment at different temperatures. Share your data. You will need the solubility of a substance at many different temperatures to make a graph of solubility as a function of temperature. Such a graph is called a solubility curve.

Within a class, make several saturated solutions of potassium dichromate at temperatures ranging from 5° C to 90° C. Pour about 20 ml of one of the saturated solutions into a clean, dry evaporating dish. Carefully evaporate the solvent. Let the evaporating dish cool and then re-weigh it. Repeat this process until constant weighings are obtained.

Now pour about 20 ml of another saturated solution at a different temperature into a clean, dry evaporating dish and drive off the solvent. Continue using saturated solutions at different temperatures until you and your fellow students have enough data for at least five points on your graph. After you have made your graph, carefully discard the residue and wash the evaporating dishes and your hands. Potassium dichromate is poisonous.

Can you predict from your graph the solubility of potassium dichromate at a temperature you did not use? How many grams of potassium dichromate will dissolve in 1 ml of water at 60° C? Can you assume the same sort of graph is typical of the solubilities of all substances?

If you have additional time, your teacher will show you how to use The Handbook of Chemistry and Physics to make solubility curves for other substances.

Remind students always to be certain there is some solid in the bottom of their beakers to insure that the solution is saturated.

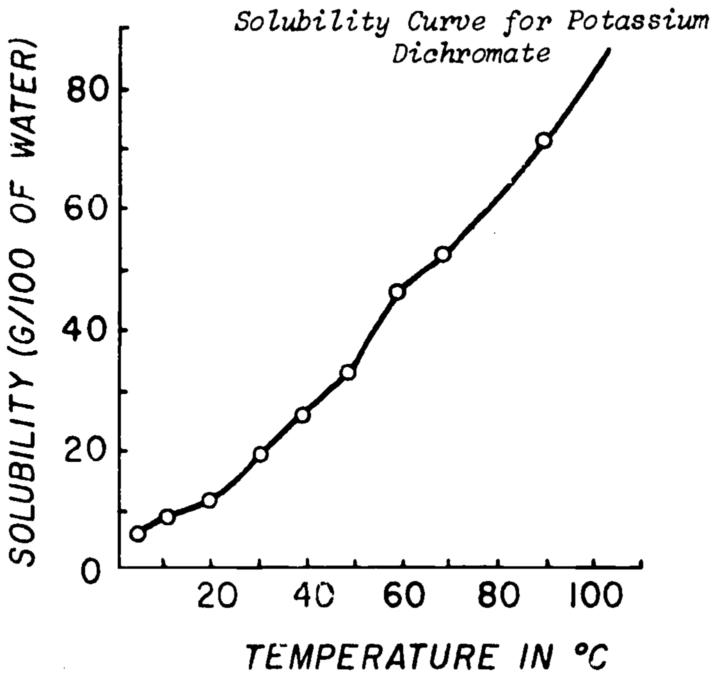
Caution students to weigh the evaporating dish itself first.

To save time, the teacher could have a series of solutions prepared for class use.

It is possible to predict the solubility of potassium dichromate at a temperature he or his fellow students do not use. It can be done by either interpolating or extrapolating. A "read-out" from the graph should show a solubility of 40 g of potassium dichromate per 100 ml of water at 60°C. It will be difficult for a student to answer the question, "Can you assume the same sort of graph is typical of the solubilities of all substances?" From the experiments he has already done and the solubility curves he has already seen, he may jump to the conclusion that solubility always increases with temperature. Experiments D.5.c, and D.5.d should prove to the student that not all substances increase in solubility as temperature increases.

Students can find data in the section "Solubility of Inorganic Compounds."

The student's graph should look similar to the one below.



Another alternative would be to use sodium chromate, which has a most unusual solubility curve, in place of potassium dichromate.

This experiment and the next are supplemental. Probably few students will have time to do them.

D.5.c. Experiment: THE EFFECT OF TEMPERATURE ON SOLUBILITY

In previous experiments, the substances you worked with were more soluble in hot water than in cool water. In other words, the solubility increased with an increase in temperature.

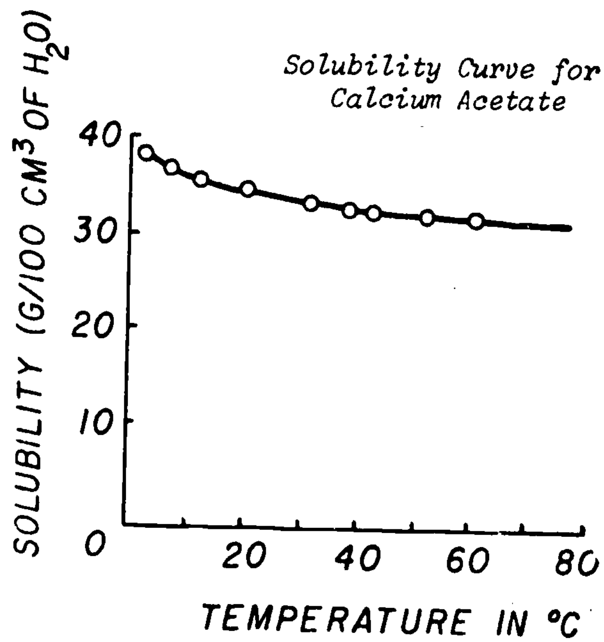
Prepare 20 ml of a saturated solution of calcium acetate at room temperature. Now heat the solution carefully. Do not let it boil. Do you think the solubility of calcium acetate increased with an increase in temperature? Could you make a solubility curve for calcium acetate? If you have time, do so, and note how it compares with the solubility curves you have already studied.

The solubility of Ca $(CH_3COO)_2$ *decreases with increasing temperature. It is an exception to the solubility patterns the student has observed in D.5.b.*

Answers to Questions

The solubility evidently decreases with increasing temperature, because a precipitate forms when the saturated solution is heated. It is possible to make a solubility curve by starting with a saturated solution at a low temperature and drawing off portions of the supernatant liquid at various higher temperatures.

The solubility curve your students make should be similar to the one on the next page.



Equipment and Materials

Non-expendable:
Same as D.5.b.

Expendable:
1 lb Ca $(CH_3COO)_2 \cdot H_2O$
(assuming about 5 data points/class); technical grade is okay.

D.5.d. Experiment: THE EFFECT OF TEMPERATURE ON SOLUBILITY

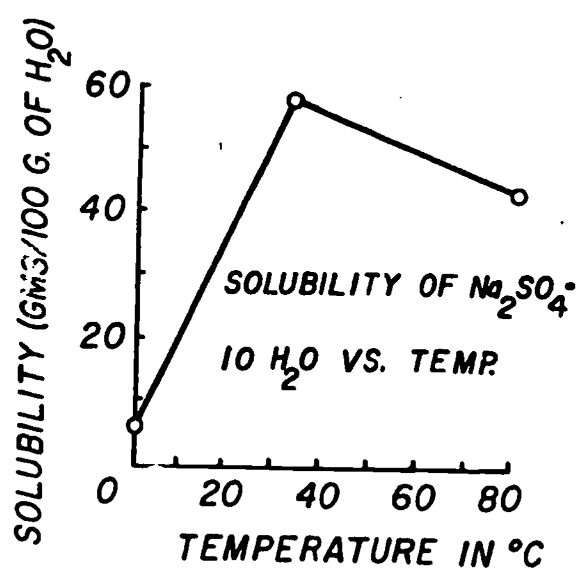
In previous experiments, the majority of the substances you worked with were more soluble in hot water than in cold water. In the case of calcium acetate, however, you discovered the solubility decreased with increasing temperature. Now let's investigate a "real strange one." Determine the solubility of sodium sulfate over a range of temperatures, 10° C to 80° C. Make a graph of your data. Use The Handbook of Chemistry and Physics and try to explain your graph.

Equipment and Materials

Non-expendable:
Same as D.5.b.

Expendable:
1 lb. $Na_2SO_4 . 10\ H_2O$ (assuming about 5 data points per class); technical grade is okay or $Na_2SO_4 . 7\ H_2O$.

The graph below should be similar to the ones produced by students.



We suggest the use of $Na_2SO_4 . 10\ H_2O$. $Na_2SO_4 . 7\ H_2O$ may be used but the results will not be as dramatic. The solubility curve for $Na_2SO_4 . 10\ H_2O$ presents a singular feature. It rises rapidly in a normal way, but above a certain point it falls. An examination of the solids above and below *this point shows they are not the same. Below this point the solid is $Na_2SO_4.10\ H_2O$, while above this point it is the anhydrous salt Na_2SO_4. Sharp breaks like this in a solubility curve always suggest some chemical change in the solute.*

Answers to Questions

If the students check in The Handbook of Chemistry and Physics, they may discover that the first part of the curve demonstrates the solubility of $Na_2SO_4.10\ H_2O$ and the second part of the curve demonstrates the solubility of Na_2SO_4.

D.6 Experiment: FLAME TESTS FOR CLASSIFICATION

When things burn, the flame often has pretty colors in it. These flame colors might be useful for classification. In order to determine how flame colors might be useful we will burn a number of different chemicals and look for significant tidbits of information.

Obtain a piece of nichrome wire with one end connected to a handle and a small loop in the other end. Heat the looped end in a flame and note any change in the flame color. If the flame is highly colored hold the wire in the flame until it is hot and then dip it into a small dish of hydrochloric acid. Heat again and note the color of the flame. If necessary repeat the process until the wire glows but does not give more than a faint yellow color to the flame.

Alternate Instructions: If the class is provided with a different piece of wire for each chemical it is not necessary to clean them. You must, however, be careful not to use a wire for more than one chemical.

Now dip the wire into some potassium acetate (KCH_3CO_2) and then hold it in the flame. Record the color. In describing

Equipment and Materials

Nichrome wires with loops
Bunsen burners
Calcium chloride
Copper chloride
Copper nitrate
Lithium chloride
Strontium chloride
Strontium nitrate
Sodium chloride

Alcohol burners do not provide enough heat for flame tests. Bunsen burners are necessary.

colors exercise your writing skill as well as your imagination. Repeat this procedure using potassium chloride (KCl) and again record the color. Can you make a guess about what was the direct cause of the color?

Repeat the process for the following chemicals and record the flame colors obtained.

Calcium chloride

Copper chloride

Copper nitrate

Lithium chloride

Strontium chloride

Strontium nitrate

Sodium chloride

Examine your data and state how flame tests may be used for classification.

Equipment and Materials
same as D.6 with addition of simple grating spectroscopes, plus pieces of blue and green glass

Students should be provided with a piece of blue glass and a piece of green glass.

Visible color of each chemical will depend upon its volatility. All substances will give the characteristic flame test if the temperature is high enough. There are limits to the number of chemicals that can be used to distinguish the characteristic color. Some chemicals will not give a characteristic

D.6.a. Experiment: ANALYSIS OF COLORS

The use of the flame tests is limited in some cases by our ability to describe the colors. Clearly, we need a method for analyzing mixtures of colors. There are several tools useful for the analysis of mixtures of colors. One simple device known as a grating spectroscope, spreads out the various colors in light so that the eye can readily see slight difference. A soap bubble or a glass prism can do the same thing.

Using a hand held simple grating spectroscope repeat the flame tests.

Try to reproduce the arrangement of lines obtained from each chemical. Also note the colors and their relative intensities. The arrangement of lines is called a spectrum (plural: spectra).

Examine your spectra reproduction now and state how flame tests with a grating spectroscope can be used for classification.

color in a Bunsen flame because the temperature is not high enough.

Violet

Potassium compounds -- Purple red through blue glass. Easily obscured by sodium flame. Bluish green through green glass.

Blues

Azure -- Copper chloride. Copper bromide gives azure blue followed by green. Other copper compounds give same colorization when moistened with hydrochloric acid.

Light blue -- Lead, arsenic, selenium.

Greens

Emerald -- Copper compounds except the halides, and when not moistened with hydrochloric acid.

Yellowish -- Barium compounds. Some molybdenum compounds. Borates, especially when treated with sulfuric acid or when burned with alcohol.

Pure Green -- Compounds of thallium and tellurium.

Bluish -- Phosphates with sulfuric acid.

Very faint -- Antimony compounds. Ammonium compounds.

Whitish -- Zinc.

Reds

Carmine -- Lithium compounds. Violet through blue glass. Invisible through green glass. Masked by barium flame.

Scarlet -- Strontium compounds. Violet through blue glass. Yellowish through green glass. Masked by barium flame.

Yellowish -- Calcium compounds. Greenish through blue glass. Green through green glass. Masked by barium flame.

Yellow

All sodium compounds. Invisible with blue glass.

A more sophisticated version of color analysis may be possible if you have access to gas discharge tubes.

D.7. - ORGANIZING AND RETRIEVING DATA

We have been learning how to study several physical characteristics of chemicals. Because we used only a few chemicals and determined only a few characteristics we were never overwhelmed with data. Even so, the data we obtained is now spread out over a number of pages of paper. Some of the data is home, some is in another room, and some has been covered with mustard and relish and been eaten. If we were going to gather any more data there would be a good chance we would also lose some of it or at least not have it around when we needed it. Even if we had it around it would take us a while to find exactly what we needed at any particular time. Clearly data needs to be organized and some attention must be given to the need for retrieving it at a later date.

There are over two million different chemicals known now. If we had several physical properties of each of them we would have around five million bits of information. Let's see how we could organize this mountain of data.

The first organization scheme to come to mind would probably be the handbook method. The compounds would each have a name, and we would list them alphabetically and record the data on each of them in columns following the name. If we wanted to locate data on a particular chemical we would only need to locate the chemical by name. However, if we had the melting point, density and/or solubility of an unknown chemical and wanted to identify the chemical, this organization scheme would not be very useful. We would have to go through pages and pages of data and would probably get ill long before we found what we were looking for.

In view of the above problem we might need to make a list of the chemicals in order of increasing melting point, a second list in order of increasing density and so forth. What a job! At this point someone might suggest that we really need some kind of computer.

We can build a small mechanical data processing machine to see how one works and how it could be of use. Our machine will have a memory (data storage) and will be able to answer yes or no to any question we ask it about the data in its memory. Using our machine will be like playing "twenty questions."

D.7.a. - BUILDING A PUNCH CARD MEMORY

Punch cards come in different sizes with a variety of arrangements of holes. They are all the same in principle, though. A typical card shown below has four sets of holes.

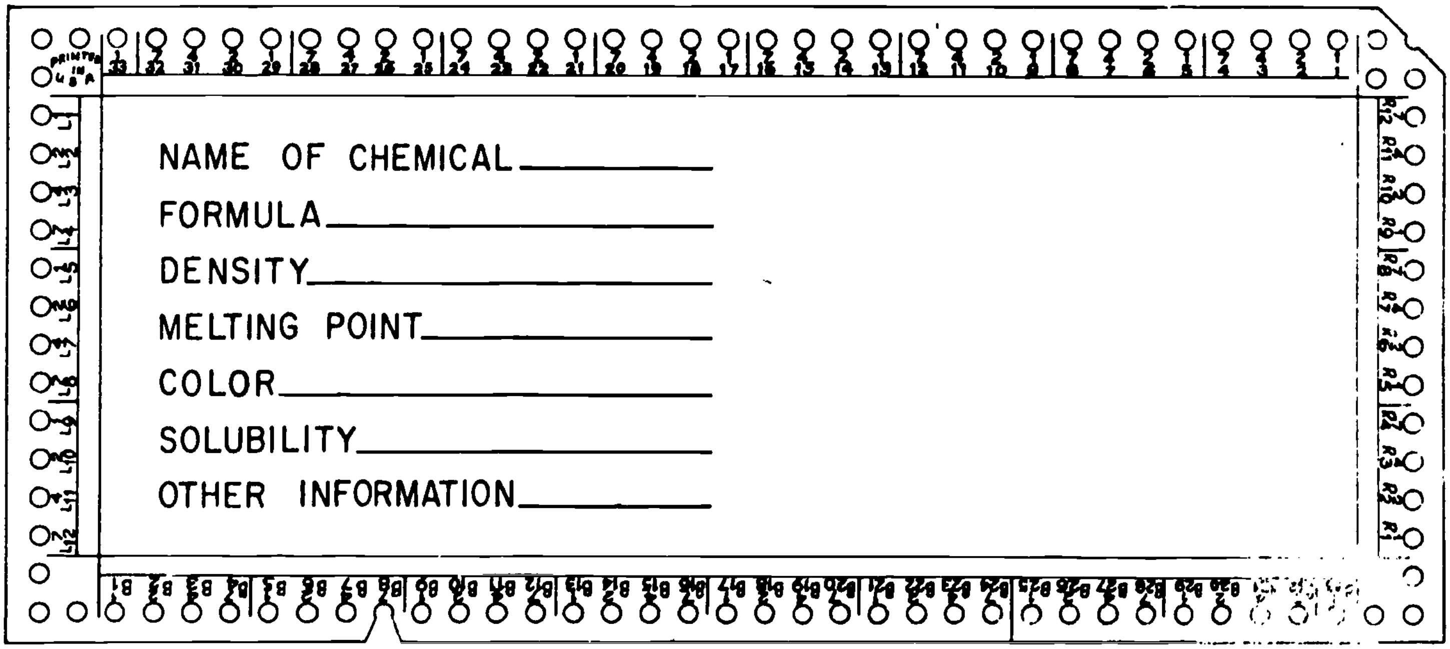


Figure D.8

The holes in the row across the top are simply numbered consecutively one to thirty-three. Along the left side of the card the holes are designated L_1 to L_{12}. Along the right side they are designated R_1 to R_{12} and the bottom holes are B_1 to B_{33}. The first task in using the card is to decide on a code so that each of the four rows of holes corresponds to a different physical characteristic. Then the holes themselves in each row are coded to correspond to some value for the physical characteristic designated by the row

For example, let's code the row of holes on the left (L_1 to L_{12}) solubility.

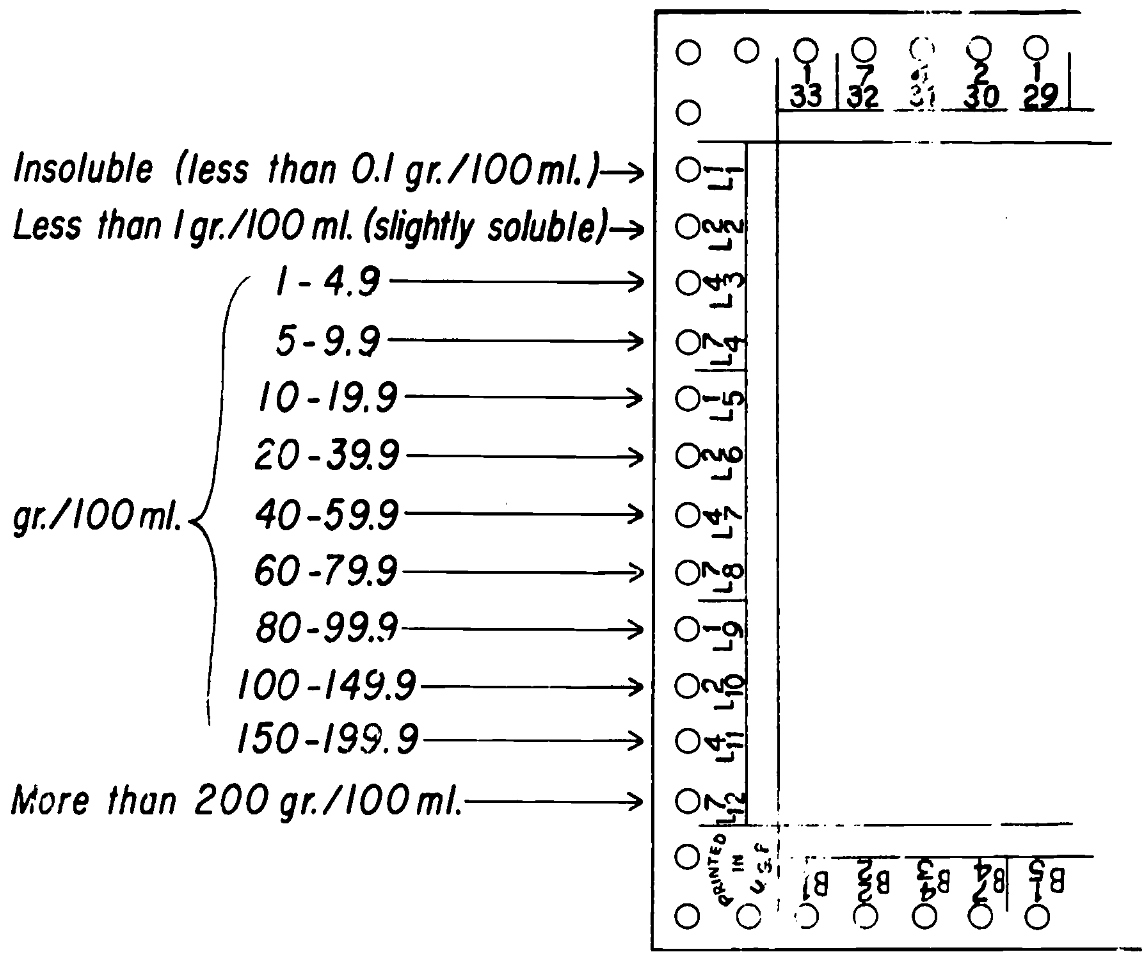


Figure D.9

If the particular chemical is soluble to the extent of 35 gr per 100 ml of water at 25 degrees centigrade we would store this data in L_6 (20-39.9 gr/100 ml). To store the data we cut a slot between the hole in the card and the edge of the card as shown on the following page.

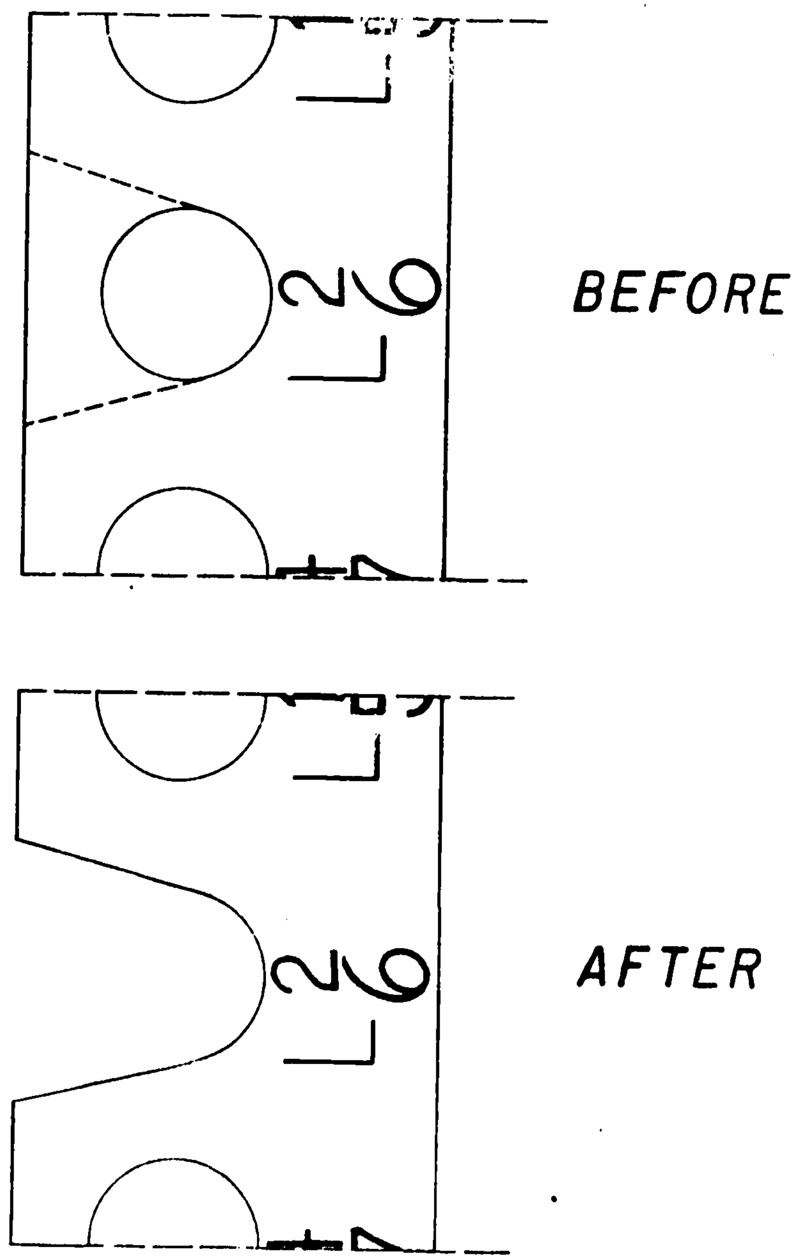


Figure D.10

How can a punch card answer yes or no to a question about the solubility of the corresponding chemical? We ask the question, "Is the chemical insoluble?" We do this by inserting a needle into the L_1 hole. The card is stuck on the needle and this means "no." Next we might ask, "Is the chemical slightly soluble, 1 gr/100 ml or less?" by inserting the needle in L_2. Again the card is stuck on the needle and the answer is "no." Eventually we would get to L_6 and ask, "Is the chemical soluble in the range 20-39.9 gr/100 ml?" The card would fall off the needle because of the slot we cut. This is a "yes" answer to our question. If we had a hundred cards, each corresponding to a different chemical, the method described above would allow us to simultaneously ask the same question about one hundred different compounds. Several cards might fall off the needle, indicating that more than one chemical has the solubility corresponding to L_6.

We could think up several different systems that would work. It will be easier if we all use the same system.

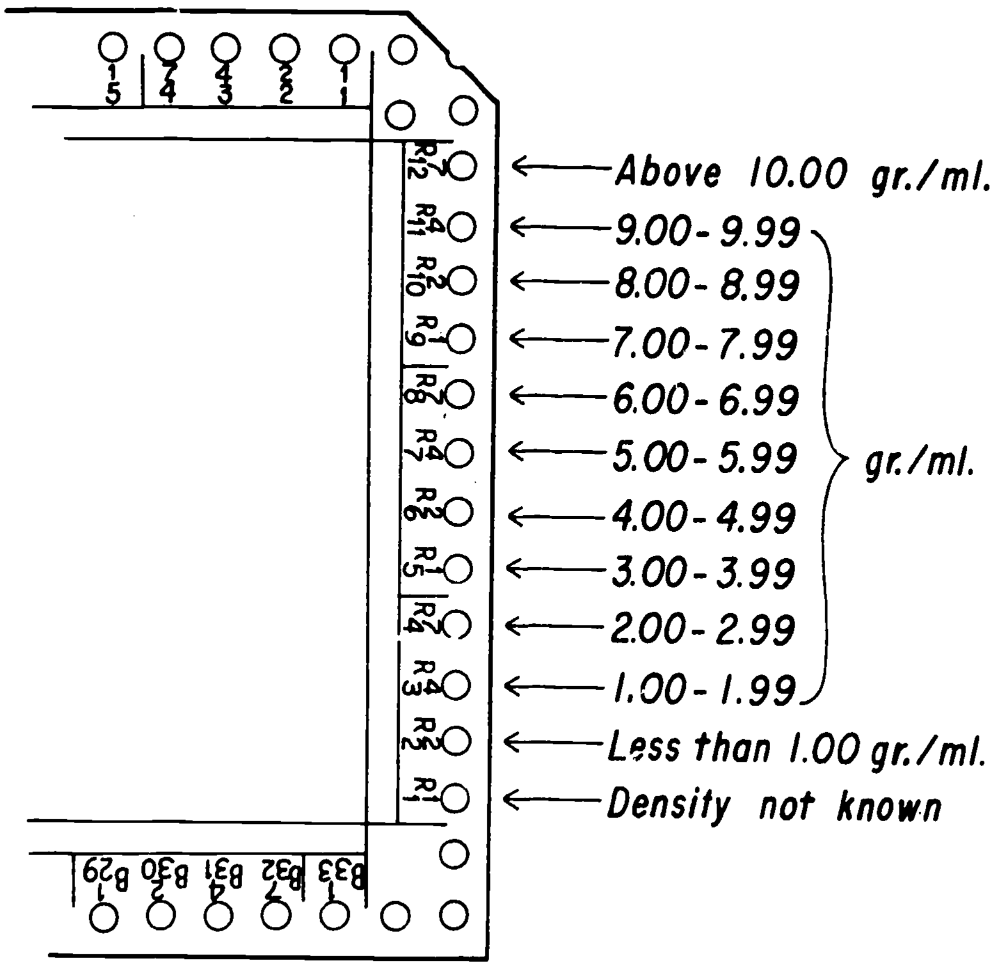


Figure D.11

The next physical property to tabulate will be density. Let's use the R holes as shown.

We could use some of the top holes for melting point data, but we actually do not need many holes for this purpose. The use of the bunsen flame temperature as a dividing line is a convenience just as the boiling point of water (100° C.) has become an arbitrary dividing line. The temperature of the bunsen flame is approximately 1100° C.

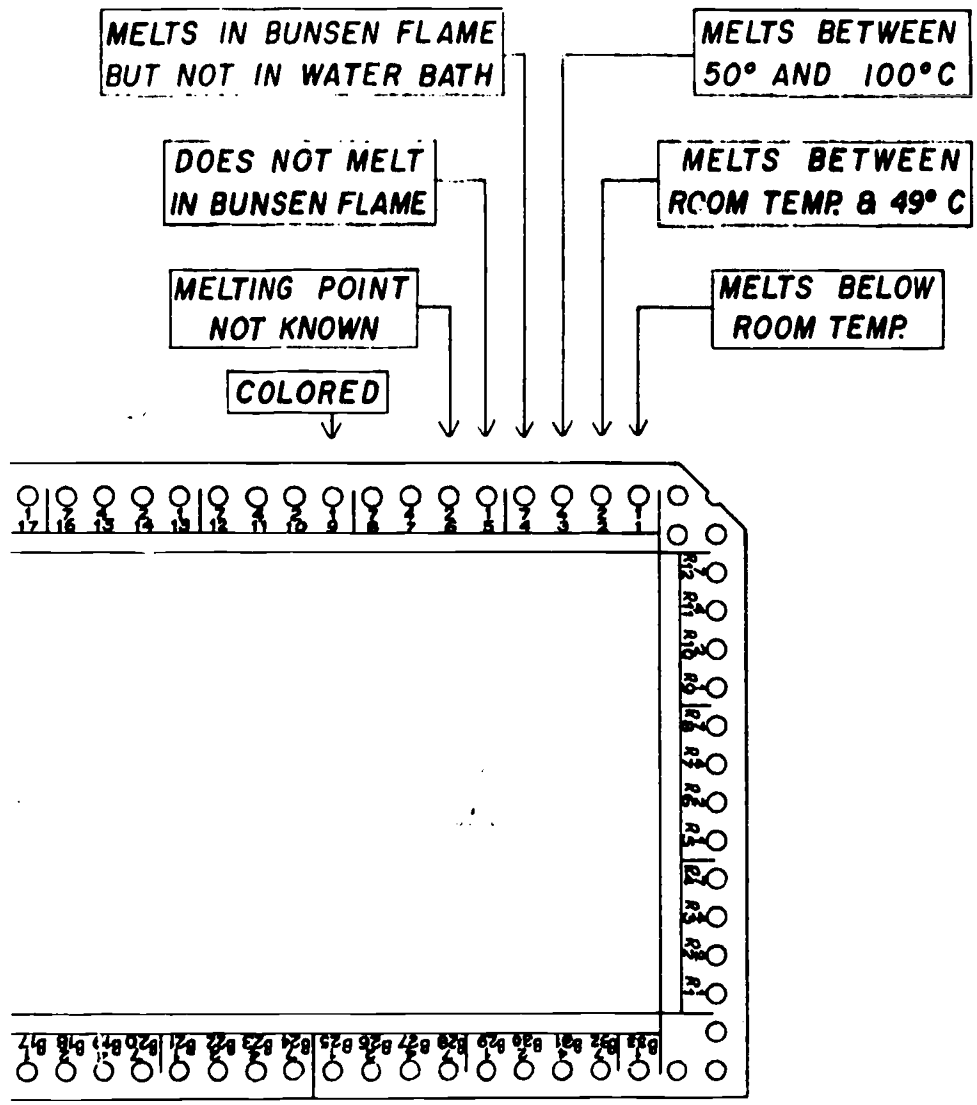


Figure D.12

We have lots of holes left to use for various purposes. If a chemical is not white or colorless we could indicate on the memory that it is colored and write the color on the card. This might be very useful. Let's use hole number 9 to answer yes or no to the question, "Is the chemical colored?" We can write many tidbits of information about the chemical on its card. These tidbits might be useful if we searched a deck of cards for a chemical with a particular set of properties and found two or more cards answered "yes" to all our questions.

CODE SUMMARY

TEMPLATE

Think about using the extra holes to code more information.
Hint: If everyone in the class is assigned a B number, then the coder of each card could be easily identified.

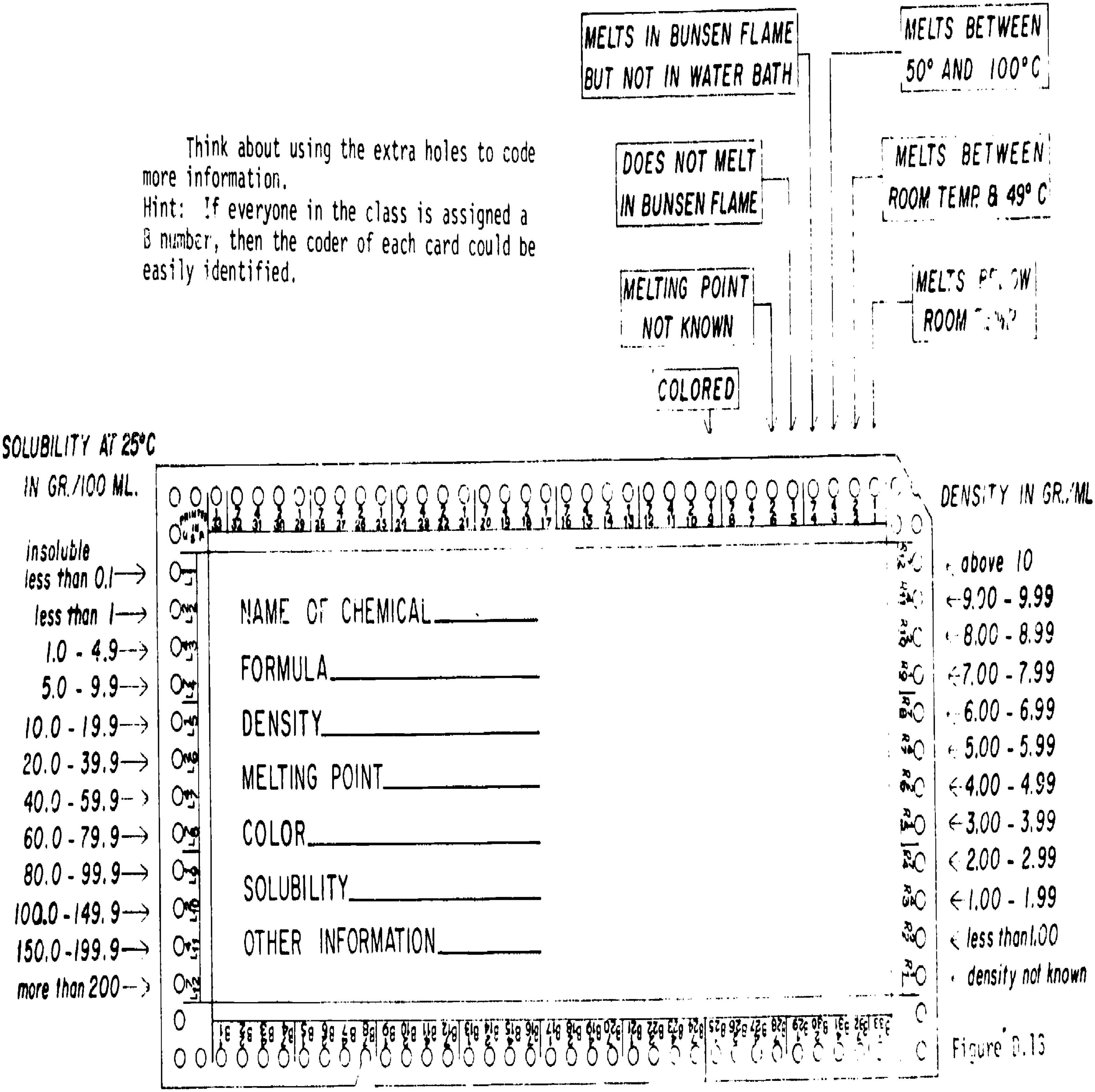


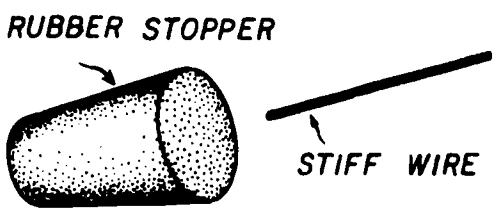
Figure D.13

You can lay your card over the summary card to identify the holes which are to be used.

D.7.b. - PREPARING A DECK OF CARDS

We are going to prepare a deck of punch cards containing the information given in a handbook type of data storage system. Use the handbook section for this experiment. The Code Summary we have developed in the preceding notes will serve as a template. The teacher will tell you how many decks the class will prepare. Each student will prepare some cards for the decks by cutting the appropriate slots for a chemical. Be sure to write the name of the chemical and the other data directly on the card.

When the deck is done make a sorting needle from stiff wire and a rubber stopper.



Jam a stiff wire into the rubber stopper. Now test the deck by inserting the wire into hole L_2 and fan the deck along the wire. Make sure all the cards are arranged with the notch in the upper right corner. One card, calcium sulfate, should fall from the deck. Now try hole number two along the top. Two cards should fall out, lanthanum nitrate and calcium iodide hexahydrate.

Equipment and Materials

scissors
punch cards
Handbook
stiff wire (like coat hangers)
rubber stoppers, no. 3

We have found McBee cards K5S371N satisfactory and economical. The cheapest key sort cards on the market are too flimsy to be practical for this use.

The classroom should have four or five decks of completed cards. Each class, however, need not prepare all five decks. For the experiments utilizing the decks, pool the decks from all the classes taking the course. You will have to decide in advance how many decks you want each class to prepare and therefore how many chemicals each student will prepare a card for. There are 56 chemicals in the Handbook. If a class prepares 2 decks, (2 x 56 = 112) 112 cards will have to be prepared.

A dissecting needle can be used for sorting the cards if you are willing to risk the danger involved with the sharp point.

Place the unknown chemicals about the room with the punch hole range of the density given.

The following is a suggested list of chemicals that can be used as unknowns. You may substitute any compound you want, provided a punch card has been prepared for the chemical.

Chemical A
Lead Chromate
Density >6 <7
Solubility - insoluble
M.P. - 844°C
Color - bright yellow
Silver bromide same specs except color is pale yellow

Chemical B
Paradichlorobenzene
Density >1 <2
Color - white
M.P. - 53°C
Solubility - insoluble
Naphthalene same specs except M.P. is 80°C

Chemical C
Strontium chloride
Density >3 <4
Color - white
M.P. - 873°C
Solubility - 55.8/g/100 ml.
Flame test crimson for Sr

Chemical D
Copper (I) chloride
Density >4 <5
M.P. - 430°C
Solubility - .52 g/100 ml.
Color - white

D.7.c. - IDENTIFYING UNKNOWN COMPOUNDS

In this experiment you will be given unknown chemicals. You are to identify the name of each chemical by using the punch cards and the characteristic tests of solubility, density, color, melting point and flame tests.

The density of each compound will be given within the range of the punch card. When you test for solubility determine if the substance is slightly soluble or very soluble. If slightly soluble, find the solubility in 100 ml of water. If very soluble, find solubility in 10 ml of water.

Write the name of the unknown compounds on a separate sheet of paper.

Chemical E

Calcium chloride

Density > 2 < 3
Color - white
M.P. - 773°C
Solubility 82 gr/100 ml.
Flame test - yellow - red
Sodium nitrate, lithium chloride, ammonium bromide, same specs except different flame tests

Chemical F

Lead Oxide

Density > 9 < 10
M.P. - 500°C
Solubility - insoluble
Color - red

Chemical G

Potassium acetate

Density > 1 < 2
M.P. - 292°C
Solubility - 269 gr/100 ml.
Color - white

Chemical H

Potassium chloride

Density > 1 < 2
M.P. - 776°C
Solubility - 35.6 gr/100ml.
Color - white

Chemical I

Sodium bicarbonate

Density > 2 < 3
M.P. - 270°C
Solubility - 10.2 gr/100ml.
Color - white
Flame test - yellow
Potassium sulfate same specs except flame test

Chemical J
Sodium chloride
Density > 2 < 3
M.P. - 801°C
Solubility - 35.9 gr/100ml.
Color - white
Flame test - yellow
Potassium dihydrogen phosphate same specs except flame test

There are many possible extensions of this experiment. If time permits you can add more chemicals. You could utilize the unused holes along the bottom to identify the student preparing the card. You could make up problems, like HDL number twelve, which are gamelike.

NAME	FORMULA	DENSITY (gr/ml)	MELTING POINT (°C)	25° SOLUBILITY (gr/100ml H_2O)	NOTES
Example: Dysprosium chromate	$Dy_2(CrO_4)_3.10\ H_2O$	not available (Notch hole R_1)	150° (Notch hole 4 on top)	1.002gr/100 ml H_2O (notch hole L_3)	Yellow (Notch hole 9 on top and write yellow on card)
Acetamide	C_2H_5NO	1.2	82°	100+	
Aluminum nitrate	$Al(NO_3)_3.9\ H_2O$	Not available	73.5°	63.7	
Aluminum oxide	Al_2O_3	3.965	2045°	insoluble	
Ammonium bromide	NH_4Br	2.429	not available (sublimes)	97	
Cadmium fluoride	CdF_2	6.64	1100°	4.35	
Cadmium hydroxide	$Cd(OH)_2$	4.79	300°	insoluble	
Cadmium iodide	CdI_2	5.67	387°	86.2	green-yellow
Calcium bromide	$CaBr_2$	3.33	180°	153	
Calcium carbonate	$CaCO_3$	2.93	520°	insoluble	

NAME	FORMULA	DENSITY (gr/ml)	MELTING POINT (°C)	SOLUBILITY (gr/100ml H_2O)	NOTES
Calcium chloride	$CaCl_2$	2.15	772°	82	
Calcium iodide hexahydrate	$CaI_2.6H_2O$	2.55	42°	757	yellow
Calcium sulfate	$CaSO_4$	2.96	1450°	0.2 approx.	
Cesium bromide	CsBr	4.43	636°	123	
Chromium chloride hexahydrate	$[Cr(H_2O)_4Cl_2].2H_2O$	1.76	83°	58.5	violet
Citric acid hydrate	$C_6H_8O_7.xH_2O$	1.5	70-75°	62+	
Cobalt fluoride	CoF_2	4.46	1200° approx.	1.5	pink
Copper (I) chloride	Cu_2Cl_2	4.14	430°	1.52	
Copper (II) sulfate	$CuSO_4$	3.60	650°	21.8	green
Iron (III) carbonate	$FeCO_3$	3.8	not available	insoluble	gray
Lanthanum nitrate	$La(NO_3)_3.6H_2O$	not available	40°	151	
Lead chromate	$PbCrO_4$	6.12	844°	insoluble	yellow

NAME	FORMULA	DENSITY (gr/ml)	MELTING POINT (0°C)	SOLUBILITY (gr/100ml H_2O)	NOTES
Lead oxide	Pb_3O_4	9.1	500°	insoluble	red
Lead sulfate	$PbSO_4$	6.2	112°	insoluble	
Lithium bromide	$LiBr$	3.46	547°	151	
Lithium chloride	$LiCl$	2.07	614°	84	
Maleic anhydride	$C_4H_2O_3$	1.5	56°	16	
Naphthalene	$C_{10}H_8$	1.15	80°	insoluble	
Neodymium bromate	$Nd_2(BrO_3).18H_2O$	not available	67°	146	red
Paradichlorobenzene	$C_6H_4Cl_2$	1.45	53°	insoluble	
Platinum tetrachloride	$PtCl_4$	4.3	370°	58.7	red
Potassium acetate	$K\ C_2H_3O_2$	1.57	292°	269	
Potassium bromide	KBr	2.75	730°	67.7	
Potassium chloride	KCl	1.98	776°	35.6	
Potassium dihydrogen phosphate	KH_2PO_4	2.34	253°	33	

NAME	FORMULA	DENSITY (gr/ml)	MELTING POINT (°C)	SOLUBILITY (gr/100ml H_2O)	NOTES
Potassium iodide	KI	3.13	686°	148	
Potassium molybdate	K_2MoO_4	2.91	919°	184.6	
Potassium phosphate	K_3PO_4	2.56	1340°	193	
Potassium sulfate	K_2SO_4	2.66	not available	12	
Silver bromide	AgBr	6.47	432°	insoluble	pale yellow
Silver chloride	AgCl	5.56	455°	insoluble	white, turns dark in light
Silver nitrate	$AgNO_3$	4.35	212°	245	
Silver trihydrogen paraperiodate	$Ag_2H_3IO_6$	5.68	60°	1.68	yellow
Sodium bicarbonate	$NaHCO_3$	2.16	270°	10.2	
Sodium chloride	NaCl	2.16	801°	35.9	
Sodium hydrogen sulfate	$NaHSO_4$	2.44	not available	28.6	
Sodium iodide	NaI	3.67	651°	184	

NAME	FORMULA	DENSITY (gr/ml)	MELTING POINT (°C)	SOLUBILITY (gr/100ml H_2O)	NOTES
Sodium nitrate	$NaNO_3$	2.26	307°	92.1	
Strontium bromide	$SrBr_2$	4.22	643°	107	
Strontium chloride	$SrCl_2$	3.05	873°	55.8	
Thallium aluminum sulfate	$TlAl(SO_4)_2 \cdot 12H_2O$	2.3	91°	11.8	
Thallium iron (III) sulfate	$TlFe(SO_4)_2 \cdot 12H_2O$	2.35	100°	36.2	pink
Thallium nitrite	$TlNO_2$	not available	182°	32.1	yellow
Tin (II) sulfate	$SnSO_4$	not available	not available	33	yellow
Zinc acetate dihydrate	$Zn(C_2H_3O_2)_2 \cdot 2H_2O$	1.74	100°	40	
Zinc chloride	$ZnCl_2$	2.91	283°	432	

E. COMMUNICATION

E.1 - Experiment: ORAL COMMUNICATION CHAIN

You have been introduced to instruments which, by extending your senses, can help you collect information. You have been introduced to two methods of organizing that gathered data into useful categories. Suppose you performed a laboratory experiment to find an answer to a question. How would you communicate the results you obtained to others interested in the same question? Would you keep a record of all your observations in your head until someone asked for your findings? Some people pride themselves on their good memories. Do you? You will perform a brief experiment with your classmates to see whether this method of communicating ideas is a useful technique for the scientist.

Equipment and Materials

Overhead projector
Prepared color transparency

Select four students to serve as "reporters" in this experiment. All four will step outside the room until called in. Reporter #1 will examine a picture supplied by the teacher. This reporter will pay close attention to detail and will try to remember as much as he can about the picture. Reporter #2 will be called into the room and will be given a full description of the picture by reporter #1. Neither reporter will be able to see the picture from where he stands; the description will be done completely from memory. When he is through, reporter #1 may take his seat. Reporter #3 is then called into the room to get a full description from reporter #2. The same procedure is repeated until reporter #4 is ready to pass on the description. He faces the whole class and describes what he remembers to all the students in the room.

This works best if, as each reporter is carrying out his task, the rest of the class is able to look at the picture projected on the screen.

While the four students are out of the room, instruct the class to keep a record of any changes in the description as they might occur. Omissions are as important as verbal errors.

To the question as to why these changes occur, students may bring in the ideas that preconceptions influence the descriptions and that, when details are hazy and the story-line gets rather thin, some people may embellish the description to make it worth listening to. Of course, stress the need to write down all significant lab observations on paper, preferably in a bound book to prevent future loss.

An alternate experiment which demonstrates the difficulty of oral communication, but not the pitfalls of the chain, would be to use the entire class. Working as partners, one looks at the picture on the overhead and describes it while the other draws what he heard described.

Equipment and Materials

- *1 3 x 5 envelope per student*
- *1 Communicating Ideas kit for each six-student team*

The kit is made up of one flat-fold cardboard box, about 4" x 5" x 6", and ten nonrecognizable objects obtainable as surplus or unusable parts from the electronics classroom in any school, electronics shops, local science and industry museum, etc. The assortment of objects in a kit should include look-alikes, thereby drawing the student's attention to significant differences in detail and creating a reason for some diagrams or measurements on the student's part.

Standard measuring devices such as meter sticks and balances should be available upon request.

Five teams of six students each will do. The teams should not be told beforehand that the winning team is the team that wrote the descriptions that made the most correct identifications possible.

It will undoubtedly save time if you read the students' instructions aloud in class.

Give them 10 to 15 minutes to examine the objects and write about them. Another 5 to 10 minutes may be needed as they try to identify them.

E.2 - Exercise: COMMUNICATING IDEAS

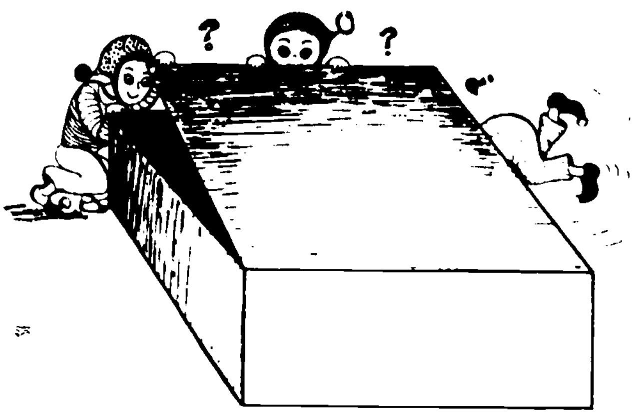
The purpose of this exercise is for you to write a description of one object in a group of objects in such a way that a reader can identify the object from your description.

Your team will be given a box containing ten small objects. Each of you is to examine all of them, then to choose one object and examine it more carefully (try not to let any of the students at the other tables see what you are handling). Now write down a description of this object using the face of the envelope handed to you for this purpose. Return the object to the box.

When each member on your team has finished, pass all your envelopes and the box of objects to the team your teacher designates.

Your table will then receive a pack of six envelopes with descriptions written on them, plus a box of objects from another table. Take one envelope apiece and try to match up the corresponding object. When you think you have the right one, place it inside the envelope, put all six filled envelopes together and take them back to the table that passed them to you.

Your table will get back its envelopes, also filled. Check them and tally up the number of correct identifications.



Suggested table (team) arrangement:

A	*A passes to C*
B	*B passes to D*
C	*C passes to E*
D	*D passes to A*
E	*E passes to B*

In doing this sort of exercise, the student should come to realize

(1) the need for a standard;

(2) the usefulness of conciseness in word description;

(3) the need for making measurements; and particularly

(4) the full use of his senses of sight, touch, feel (temperature), etc.

E.3 - OBSERVING A SYSTEM AS A SCIENTIST

When you conduct a laboratory experiment on a living thing, you have the advantage of being able to vary one condition in the environment in order to see how this change will affect the behavior of the organism. When you try to observe this organism in the field (its natural habitat), you may be able to learn more about its normal behavior. Here, however, you cannot regulate the conditions for your observations. For example, you may risk losing your specimen; while it is being observed, it may wander off into the brush and disappear. It is essential that any conclusions drawn about "normal" behavior must be done on the basis of repetitive observation. This normal behavior we refer to is valuable to the laboratory experimenter and serves as his control as he proceeds to alter the environment in the lab and observes its effect, if any.

One further point is worth noting here. A series of experiments or tests you run in the lab may give you reproducibility within a narrow range. You are correct to consider the results reliable. But here again, as in the case of your depth perception tests in Chap. II, the results may not be valid outside the lab.

Merely imposing a laboratory environment on a living thing may be enough to modify its behavior.

E.4 - Test: THE SOW BUG

Refer to the list of observations you drew up in Experiment I.A. Could you add to this list if you were asked to observe a sow bug again?

Once again observe the sow bug, which your teacher will put before you, but this time observe it as a scientist might. Test your new techniques, maintaining an independent written record of every feature and activity of the sow bug which can be observed in one class period.

Repeat the same physical arrangement as in Experiment I.A. This final task could be done as a laboratory test on this unit of Perception and Quantification.

In addition to the possible observations listed in Experiment I.A the students should be able to find

(1) how much the sow bug weighs;

(2) its linear dimensions;

(3) its volume (by displacement of water);

(4) possibly its average density;

(5) whether it makes any sounds;

(6) how far the sow bug moves in a specific time span (some graphing) to determine its average walking speed;

(7) whether it displays any particular pattern of movement when under different colored lights. (For this purpose you have been supplied with a box that has six windows cut in its cover. Four are covered with blue, yellow, green and red transparent material. One window should be left uncovered; the other could be used for trials with different color combinations.);

(8) whether it reacts to bright light;

(9) whether it reacts to other distinct sounds.

The students may think of many others. You may find one period is not enough time to run this test.

Some Possible Criteria

(1) Number of observations made.

(2) Number of senses used (Did the student use smell, touch or temperature sensors, etc.?)

(3) Use of sense extenders (tape recorder, magnifying glass, balance, meter stick, etc.).

(4) Use of correct units of measurement.

(5) Use of significant figures.

(6) Tests performed for sow bug's responses (to bright light, colors, sounds, another sow bug, etc.).

(7) Data gathered on other sow bugs for comparison.

(8) Care exercised in handling of animal.

Exercises for Home, Desk, and Lab (HDL)

(1) A classmate is trying to sell you a ring that he claims is pure gold. Outline a procedure that you might use to determine if it is really pure gold.

(2) A student made mass and volume readings for six different sized pieces of metal and got the following data:

Metal piece	Mass (g)	Volume (cm^3)
#1	38.48	2.0
#2	86.66	4.5
#3	52.49	5.0
#4	36.78	3.5
#5	57.88	3.0
#6	26.25	2.5

a. How many significant figures should be used in plotting data?

b. Plot this data on a graph.

c. From your data, did the student have more than one metal? If so, how many?

d. What was the density of the metal or metals?

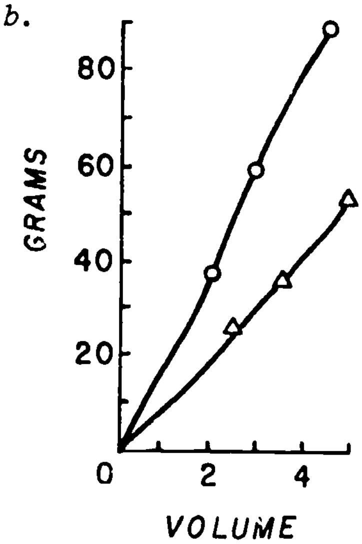
(1) a. Weigh the ring in air.

b. Put in graduated cylinder and find volume displacement of water.

c. Find density of gold in handbook and compare densities.

(2) a. Two and to the nearest 0.5 because volume was measured to the nearest 0.5 cm^3, so mass should be plotted to the nearest 1.0 gram to get two significant figures.

b.



c. Yes, two.

d. Density is mass per unit of volume, which from the graph would be the slope of the line.

$$D = \frac{gr.}{cm^3}$$

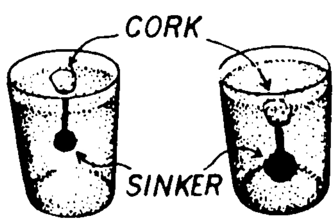
#1 $D = \frac{87 - 38}{4.5 - 2} = \frac{49}{2.5} = \frac{20 gr.}{cm^3}$

#2 $D = \frac{52 - 26}{5 - 2.5} = \frac{26}{1.5} = \frac{17 gr.}{cm^3}$

(3) Mark water level in beaker without object. Mark water level in beaker after adding object. Take object out, fill with water to the last marking, then measure out amount of water between the two lines on beaker into a graduated cylinder. This volume of water would approximate the volume of the block.

(4) Measure out an exact volume and weigh on a balance. Do this with three different volumes of water. Plot on graph, find slope, which is the density (see problem 2). Results within experimental error should be 1 gr./cm³

(5)a. Tie a heavy object to the substance. Measure water displacement of sinker. Submerge both substances under water. Measure water displacement. Difference between water displacements is volume of object.



For mass weigh on balance

b. Use different size of objects that float.

c. All should have density less than 1 gr/cm³

(3) How would you measure the volume of an object too large to fit in your graduate cylinder but large enough to fit in an uncalibrated 250 ml. beaker?

(4) How would you obtain the density of water? Try it.
What results do you get?

(5) a. How would you obtain the density of a small irregular substance, i.e., cork, that would float on water?

b. Try it with 3 or more different sized objects.

c. What results did you get?

(6) Plot the results of Problems #4 and #5 on a graph. From the graph can you tell what density materials must have before they float in water?

(6) Use results to plot mass vs. volume. Slope of line for objects that float will be less than the slope of the line for water.

(7) A cube of cork measures 1.5 cm on a side and has a mass of 1.00 gr.

a. What is its density?

b. What would be the mass of $4.0 cm^3$ of cork?

(7) a. $D = \frac{mass}{volume}$

$V_{cube} = e^3$

$D = \frac{1.0\ gr.}{(1.5 cm)^3} = \frac{1.0g}{3.4 cm^3}$

$D = 0.29 gr/cm^3$

b. $Mass = \frac{0.29 gr}{cm^3} \times 4.0 cm^3$

$= 1.2 gr.$

(8) When you look at the top of water in a graduated cylinder it is not flat but curved. How do you decide how much water is in the cylinder?

(8) Read the volume of the water by looking horizontally at the surface and reading the position of its lowest point. This should be developed in class discussion.

(9) A piece of sulfur has a volume of $80 cm^3$ and a mass of 160 gr.

a. Calculate its density?

b. Will it float in water?

c. Will it float in mercury?

(9) a. $D = mass/volume$

$D = 160 gr/80 cm^3 = 2 gr/cm^3$

b. No. Density of water is $1 gr/cm^3$

c. Yes. Density of mercury is more than six times that of sulfur.

(10) A block of magnesium whose volume is $10\ cm^3$ has a mass of 17 gr. What is the density of magnesium?

(10) $D = mass/volume$

$D = 17 gr/10 cm^3 = 1.7 gr/cm^3$

(11) A sample of alcohol amounting to 9.50 cm^3 has a mass of 0.41 gr. What is its density?

(11) D = mass/volume
D = 0.41gr/9.50cm³
0.8[illegible]gr/cm³

(12) How could you distinguish between unlabeled pint cartons of milk and of cream without breaking the seals?

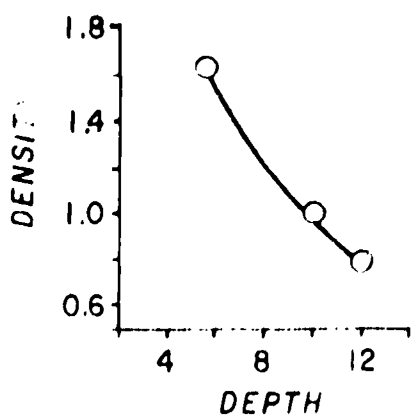
(12) Place on opposite pans of an equal-arm balance. The carton containing the milk would have the greater mass. Remember: Cream floats on milk.

(13) Weight the end of a test tube with lead shot so that the tube is one-half to two-thirds submerged in water. How could you use this device (called a hydrometer) to measure the densities of unknown liquids?

a. Plot a graph of known densities of liquids with your hydrometer. Plot density vs depth.

b. Find the density of an unknown liquid, using the data you obtained in part a.

(13) a.• Place the device n in several liquids of known density. Mark the depth on the test tube to which it sinks in each known liquid. Measure from the end of the test tube to the marks for depth test tube sinks. Graph density(known) vs. depth.



Graph would be similar to the above graph for each particular hydrometer.

b. For the unknown use the data for the given hydrometer. The density of the unknown should be a member within experimental error on the line.

(14) A student obtained the following data while heating two different amounts of the same substances over an open flame.

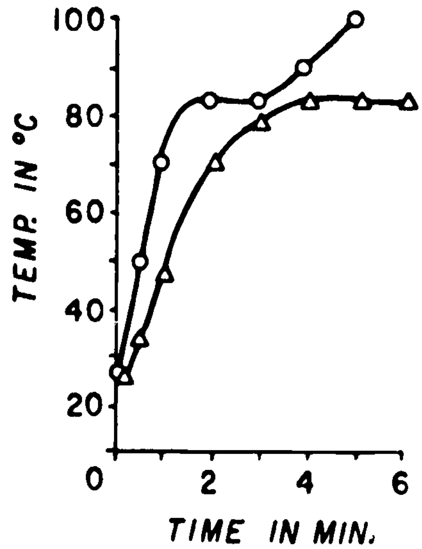
Time Min	Amount A Temp °C	Amount B Temp °C
0	25°C	25°C
1/2	50°C	32°C
1	70°C	48°C
2	82°C	70°C
3	82°C	78°C
4	90°C	82°C
5	100°C	82°C
6		82°C

a. Plot the data on a graph Temp. °C vs. Time.

b. Which amount contained the least volume of substance?

c. Plot a graph of temperature vs. time for the case in which you have equal amounts of the same substance but you are heating one with an open flame and the other with an asbestos pad over the flame.

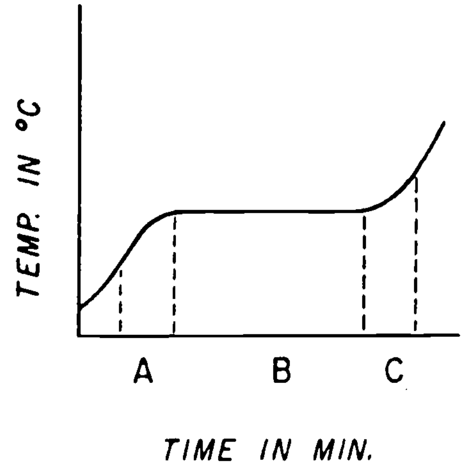
(14) a.



b. Amount A contains less volume than Amount B. Amount A. reaches the boiling point faster than Amount B.

c. Graph should have the same general shape as in part a. because the shape is dependent upon the rate of heating a substance.

(15) The following graph represents the heating curve of acetamide.



During which time interval is there:

a. only solid?

b. only liquid?

c. both solid and liquid?

(15) a. A
b. C
c. B

(16) A student was determining the solubility of different substances in water at room temperature. He obtained the following data.

a. Washing soda
200 gr. in 1000cm^3 of water

b. Baking soda
24gr in 350cm^3 of water

Express the solubility of each substance in gr/cm^3.

(16) a. $\frac{200gr}{1000cm^3}$

$2.0 \times 10^{-1} gr/cm^3$

b. $\frac{24gr}{350cm^3}$

[illegible] $\times 10^{-2} gr/cm^3$

(17) The solubility of chalk is 10^{-5}gr/cm^3 of water. How much water is necessary to dissolve 5gr. of chalk?

(17) 5 gr chalk x $\frac{1 cm^3 water}{10^{-5} gr chalk}$
[illegible] x 10[illegible] cm^3 water

(18) A student collected the following data when dissolving an unknown substance in water.

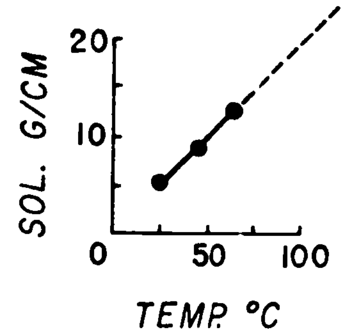
Temperature °C	Solubility mass/100cm^3
25°C	5gr.
50°C	10gr.
75°C	15gr.

a. Plot the data obtained on a graph, solubility gr/cm^3 vs. temperature °C.

b. What would you expect its solubility to be at 40°C?

c. What would you expect its solubility to be at 90° C?

(18) a.



b. This is a problem in interpolation; at 40°C the mass per 100cm^3 would be 8gr.

c. This is a problem in extrapolation; at 90°C the mass per 100cm^3 would be 18gr.

(19) It is found that 1.4×10^{-2}gr. of a substance will dissolve in 15cm^3 of methanol at 20°C. How much of this substance will dissolve in 30cm^3 of methanol at the same temperature?

(19) At a given temperature the quantity of the substance will dissolve is directly proportional to the amount of solvent used.

$$30cm^3 \times \frac{1.4 \times 10^{-2}gr.}{15\ cm^3}$$

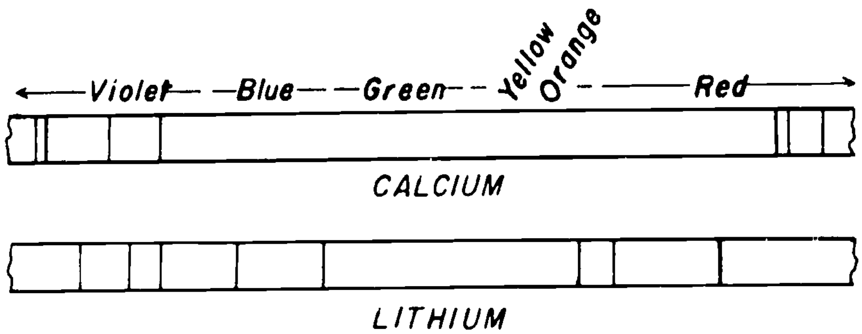
$$= 2.8 \times 10^{-2}gr.$$

(20) How do you explain the fact that if you spill a few drops of soup or milk on a pale-blue gas flame when cooking, the flame changes to a mixture of colors with yellow most common?

(20) Sodium compounds are almost universally present in foods; the yellow color of the sodium flame is being observed.

(21) *a. Calcium*
b. Lithium

(21) Use the spectral lines you drew in Exp. D.6.a. "Analysis of Colors," and identify the following elements.



(22) *a. Compare amounts that will dissolve in $100cm^3$.*

Substance A

$100cm^3 \times \frac{3.4 \times 10^{-3}gr.}{94cm^3}$

$= \frac{3.6 \times 10^{-3}gr.}{100cm^3}$

Substance B

$100cm^3 \times \frac{17 \times 10^{-3}gr.}{500cm^3}$

$= \frac{3.4 \times 10^{-3}gr.}{100cm^3}$

Hence, substance B appears to be slightly less soluble than substance A.

b. $4.5 \times 10^6 cm \times$

$\frac{3.6 \times 10^{-3}gr.}{100cm^3} = 160gr.$

(23) *Lithium bromide. Follow the directions given in student guide.*

(22) Two substances are only slightly soluble in methanol. Only 3.4×10^{-3}gr. of substance A will dissolve in $94cm^3$ of methanol, and only 17×10^{-3}gr of substance B will dissolve in $500cm^3$, of methanol.

a. Which substance is more soluble in methanol?

b. How much of substance A could you dissolve in $4.5 \times 10^6 cm^3$ of methanol?

(23) Use the punch cards and the following data to identify a specific compound.

Density	Solubility	M.P.	Color
3.46gr/ml	150+/ml	547°C	None

In the flame test a purple color is given. What compound is it?

(24) A student has a white unknown substance. He found that the density was 2gr/cm^3.

a. Give the procedure you would use in identifying the compound.

b. Do the procedure and identify the compound.

(25) You are a lab technician for a chemical company. You receive an order for three different chemicals with the following specifications:

Chemical A: Density 2-3gr/ml

Color - white

M.P. - approx. 450°C

Solubility - 90-100gr/cm^3

Chemical B: Density 4-5gr/ml

Color - pink

M.P. - greater than 1000°C

Solubility - 1-2gr/cm^3

(24) Give the student about 10gr of potassium dihydrogen phosphate.

a. Use punch card to separate cards by color and density.

b.1 Students determine solubility according to methods previously learned. Solubility is 40gr/100ml.

b.2 Use flame test to get characteristic purple of potassium.

b.3 Potassium dihydrogen phosphate.

(25) Chemical A: Ammonium bromide

Chemical B: Cobalt fluoride

Chemical C: Lead chromate

Chemical C: Density - 6-7gr/ml

Color - yellow

M.P. - 800-900°C

Insoluble

Using the punch cards, name a compound that would meet the specifications in each case.

Appendix A: Suggestions for Laboratory Procedures

A laboratory is a place where scientists look at phenomena under controlled conditions. It is a place for serious work. Always prepare for an experiment by reading the directions in the manual before you come to the lab. Make a special effort to know all precautions.

Do only the experiments approved by your teacher. If you wish to do an extension (this is encouraged), check with your teacher. This general rule is for your safety and that of your fellow students. Laboratory safety is as much an attitude as a set of rules. The lab will become a safe place for investigation if the student continually uses common sense about his safety and the safety of others. If any accident does occur, report to your teacher. What seems a minor injury may have severe consequences.

You will be asked to write laboratory reports. Opinions concerning the content of these reports vary greatly. It follows that teacher judgment will determine the type of laboratory reports you are asked to write. The following ways to improve laboratory reports are to be taken as suggestions only.

(1) Mistakes should not be erased. If there is room for the correction, the mistake should be crossed out without obliterating it and the correction made. If ther is insufficient room, an extra piece of paper should be added.

(2) Spelling and punctuation are important. Sentence fragments should be avoided.

(3) The report should be carefully planned. It is best to know what type of observations should be sensed and, if possible, what regularities can be found. Planning will lead to the placement of items in a logical sequence in the report.

(4) The name of the experiment should be included.

(5) The date on which the experiment was done should be included.

(6) The names of all participants should be included and the name of the person who actually prepared the report should be designated.

(7) Some reports should include a simple statement or schematic diagram of the apparatus used in the investigation.

(8) Some reports will require a brief explanation of purpose and procedure If these are given in the laboratory manual, they should not be included in the report. Copying items is "busy work."

(9) Nearly all experiments require taking measurements and subsequent collection of data. This must be carefully tabulated. If it is possible for you to make data tables before coming to the laboratory, you will have more time for observation, which is a major part of any laboratory experience.

(10) If computations are required to interpret results, they should be included in the report. However, if several computations of a similar nature are needed, they should be illustrated with a typical example. Mathematical equations, not arithmetical operations, should be shown.

(11) If the investigation could be altered to get better results, a statement to this effect should be included.

(12) If the investigation suggests extensions, these should be described.

(13) Reading professional reports from magazines such as The Journal of Chemical Education and Scientific American should result in better reports.

(14) Many times the most significant information about the experiment is to be found by graphing results. Whenever appropriate, graphs should be included in the report; they give a picture from which regularities can be sought. You will find the following suggestions very helpful.

(a) Always use a full sheet of graph paper.

(b) Position the ordinate and abscissa far enough from the edge of the paper to allow proper labeling.

(c) Assuming a relationship exists, the abscissa should represent the independent variable; the ordinate, the dependent variable. As an example: The distance of the gas pedal from the floorboard in an automobile would be the independent variable, plotted on the x axis; while the speed of the car would be the dependent variable, plotted on the y axis.

(d) Each axis must show units--e.g., cm, ml, sec.

(e) Labeling of each axis should run parallel to the axis.

(f) The scale of each axis should be chosen such that the functional plot covers most of the graph paper.

(g) The name of the graph, the name of the experiment, and the date of the experiment should be suitably placed on the graph.

(h) When plotting data, draw a circle around each point to indicate the uncertainty associated with the measurements.

(i) Draw the smoothest possible curve suggested by your data.

Appendix B: Supplementary Perception Experiments

I. Negative Afterimage of Motion:

Place the spiral disk on a record turntable and rotate it at 78 rpm. The observer fixates his gaze at the center of the card for about 30 seconds at which time:

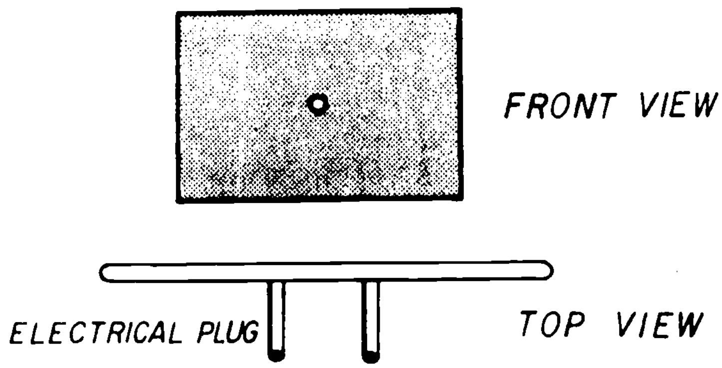
1. The turntable is stopped while the subject continues to look at the disk, or
2. The subject looks at a page of graph paper, or
3. The subject looks at his partner's face.

An interesting test to indicate whether the effect takes place at the retina of the eye or in the central nervous system can be conducted by having the subject look at the rotating disk with one eye and test for an afterimage with the other eye.

(The effect is central.)

II. Autokinetic Effect:

A luminescent night light is masked so that a 3 mm. aperture remains open.



This small spot of light is observed from several feet away in a completely dark room. After a period of time the spot will appear to move.

The effect is due to the movement of the eye, which, in this situation of no visual context around the spot, is interpreted on the basis of past learning as movement of the object in the periphery.

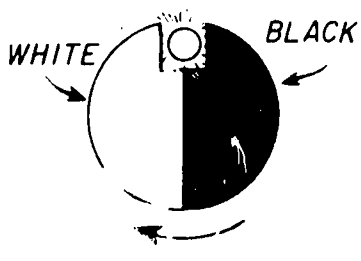
A motor may be placed beside the night light so that its hum can be suggestive of an electrically powered device.

In formal experiments it has been shown that prestige figures have more effect than peers in influencing the members of a group to report movement of a given amount. Due to this group interaction effect, it is best to allow the viewers to communicate with each other as they are watching.

III. Bidwell Effect:

A good demonstration of negative color afterimages can be provided with the following apparatus:

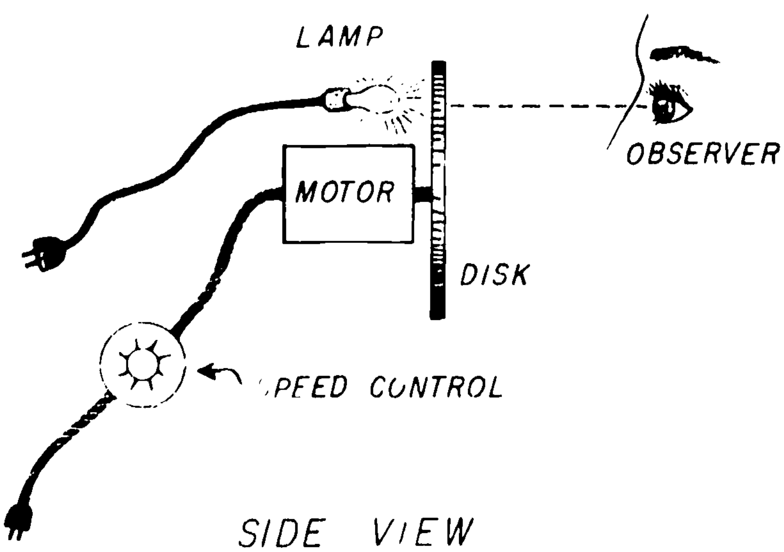
slot   Christmas tree lamp (blue, yellow, red, green)



5-6" cardboard disk with slot

rotation of about 3 rev./sec.   Speed should be variable.

The disk can be turned by a sewing machine motor controlled by a rheostat. An old mixmaster ($1.25) has been successfully used to rotate the disk.



SIDE VIEW