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BIOLOGY--CHEMISTRY--PHYSICS, TEACHERS' GUIDE, A THREE-YEAR SEQUENCE, PARTS I AND II.

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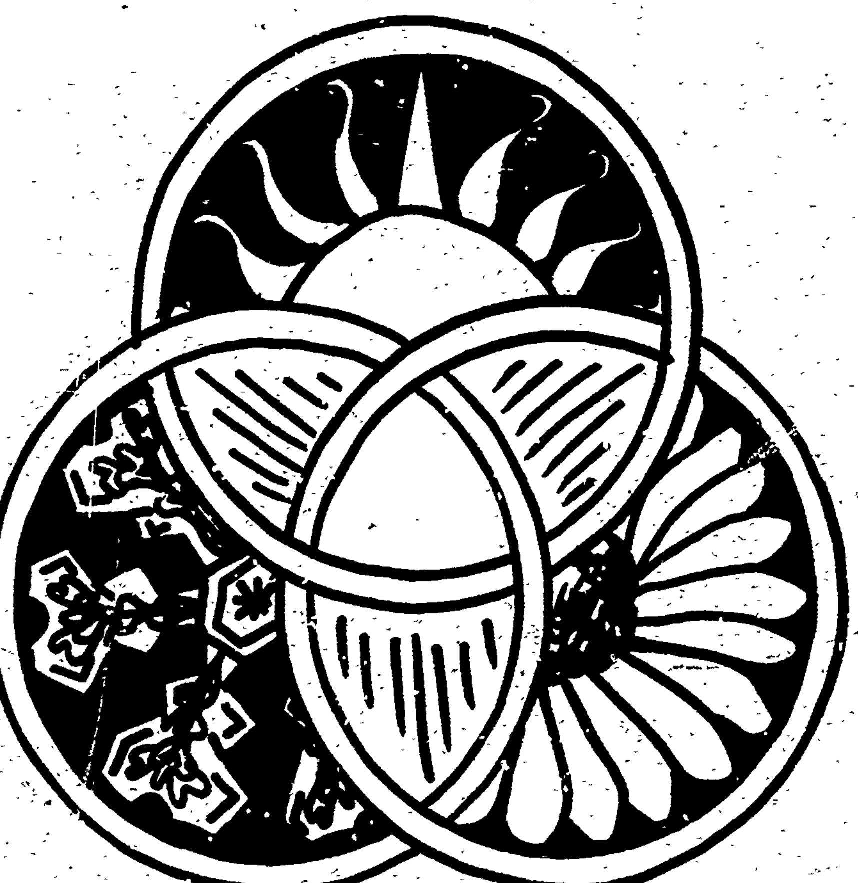
This is one of two teacher's guides for a three-year integrated biology, chemistry, and physics course being prepared by the Portland Project Committee. This committee reviewed and selected material developed by the national course improvement groups--Physical Science Study Committee, Chemical Bond Approach, Chemical Education Materials Study, Biological Sciences Curriculum Study and Introductory Physical Science--and added material written especially for the project. This guide covers Part I, "Perception and Quantification" and Part II, "Properties of Matter." These themes are developed through outlined student activity. Extensive explanation is provided for the teacher, so that he is aware of the purpose of each activity. (GR)

PARTS I & II

BIOLOGY-- CHEMISTRY-- PHYSICS

A THREE-YEAR SEQUENCE



TEACHERS' GUIDE

PILOT SCHOOL EDITION

prepared by
THE PORTLAND PROJECT COMMITTEE

under a grant from
THE NATIONAL SCIENCE FOUNDATION

TEACHER'S GUIDE FOR

BIOLOGY-CHEMISTRY-PHYSICS

A THREE-YEAR SEQUENCE

PILOT SCHOOL EDITION
1967

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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.

Introduction

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 repetition and fragmented representation of the physical sciences? they asked. Their persistence in asking these questions resulted in the formation of a Steering Committee whose function was 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.

Since inception of the Portland Project, twenty-two scientists and teachers have 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

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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 State University is the chariman of this committee.

differ, the various groups are satisfied that integration of science courses is not only feasible but highly desirable.

Empirical studies conducted by Dr. Michael Fiasca of the Education and Science Staffs of Portland State College reveal 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 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 15, 1967, showed that there are now forty-four schools in twenty states using the Portland Project integrated courses.[3]

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

> The division of science at the secondary school level, into biology, chemistry, and physics is both unreasonable and uneconomical.

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

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

> 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]

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 this year. 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 College campus during the summer of 1967 to develop materials such as teacher

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[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. Commisioner of Education, the Director of the National Science Foundation, and the Special Assistant to the President for Science and Technology, March, 1964.

and student guides. Eight local pilot schools have already 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.

Twnety-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, interests 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, CBA, CHEMS, BSCS and IP in search of material to implement the outline they constructed previously. In the absence of appropriate materials, major and minor writing projects were initiated.

It was anticipated that the conclusion of the summer should see assembly of an outline for the three-year course, production of student and teacher manuals for pilot schools and perhaps a few for distribution to interested persons, and the design and implementation of an evaluation study that sought to assess changes in student achievement in the separate academic disciplines, cross disciplinary carry-over, critical thinking abilities and science attitudes.

The Working Committee

The committee is composed of both college and high school science teachers with training and teaching experience in the separate disciplines of biology, chemistry and physics and several cross disciplines.

Carl Bachhuber--Physics
Portland State College
Portland, Oregon

Renee Bergman--Physical Science
Roosevelt High School
Portland, Oregon

Louis Bixby--Chemistry
St. Louis Country Day School
St. Louis, Missouri

Howard Browning--Chemistry & Physics
Benson Polytechnic School
Portland, Oregon

Steven Dimeo--Editor
University of Oregon
Eugene, Oregon

Karl Dittmer--Co-Director, Biochemistry
Portland State College
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Portland, Oregon

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Portland State College
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Edward Fuller--Chemistry
Beloit College
Beloit, Wisconsin

Curtis D. Guthrie--Chemistry
Wilson High School
Portland, Oregon

Glen Hampshire--Chemistry & Physics
Jefferson High School
Portland, Oregon

Lois Helton--Biology & Chemistry
Beaverton High School
Beaverton, Oregon

George Ingebo--Director of Research
Portland School District
Portland, Oregon

Henry Kilmer--Biology & Chemistry
Rex Putnam High School
Milwaukie, Oregon

Helen Koopman--Physical Science
Jefferson High School
Portland, Oregon

Alfred Levinson--Chemistry
Portland State College
Portland, Oregon

David Malcolm--Biology
Portland State College
Portland, Oregon

Edmund D. McCollough--Chemistry
Cleveland High School
Portland, Oregon

Thomas Miles--Biology
Cleveland High School
Portland, Oregon

Leon Pape--Biophysics
California State College at Los Angeles
Los Angeles, California

Arnold Pickar--Physics
Portland State College
Portland, Oregon

David Porter--Physics
Portland Community College
Portland, Oregon

Jack Sadler--Biochemistry
University of Colorado Medical Center
Denver, Colorado

Arthur Scott--Chemistry
Reed College
Portland, Oregon

Joseph Sklenicka--Physics
Franklin High School
Portland, Oregon

Donald Stotler--Supervisor of Science
Portland School District
Portland, Oregon

Harold Wik--Science Coordinator
Beaverton School District 48
Beaverton, Oregon

Pilot Schools

The following schools have offered to try the first year of the three-year integrated course during the 1967-68 academic year:

Beaverton High School
Beaverton, Oregon
Lois Helton

Benson Polytechnic School
Portland, Oregon
Howard Browning

Cleveland High School
Portland, Oregon
Edmund D. McCollough
Thomas Miles

Franklin High School
Portland, Oregon
Joseph Sklenicka

Jefferson High School
Portland, Oregon
Glen Hampshire
Helen Koopman

Rex Putnam High School
Milwaukie, Oregon
Henry Kilmer

Roosevelt High School
Portland, Oregon
Renee Bergman
Kenneth Fuller

Wilson High School
Portland, Oregon
Curtis D. Guthrie
Ernest Hohman

Acknowledgements

The Portland Project Committee wishes to acknowledge the dedicated efforts of the following people:

Mary Grant	Artist
Alice Eyman	Secretary
Pamela Thompson	Secretary
Barbara Wiegele	Secretary
Neomia Kendrix	Technician

Three-Year Course Rationale

In designing a three-year sequential science course, one of the major considerations that should be borne in mind is that the sophomore course must be looked upon as both a terminal science experinece for many students and an introductory course for those seriously interested in science. Therefore, formulation of the sophomore course must be considered together with what follows in the junior-senior courses and yet apart from it. The sophomore course must stand as a coherent entity equipping students with skills and modes of behavior which characterize the working scientist, capturing their interest and enthusiasm for later encounters with science both in formal education and outside the classroom, and impressing upon them knowledge about some of the major generalizations we call science.

Clearly, if the sophomore level course is only nominally successful in each of these three aims, it will serve well as both an introduction to more sophisticated biological, chemical and physical ideas treated in subsequent years as well as a realistic presentation of the three sciences and their epistomologies.

The committee agreed that biological content for the sophomore course should be environmental in its emphasis. This decision was made for the reasons that this kind of knowledge is fundamental to appreciation of the real problems that confront men today--e.g., control of human population; resource conservation; acute, delayed and cumulative effects of food, air and water pollution; and physiological and other biological effects of drugs and narcotics on the human organism. Molecular biology, we believe, is more appropriately placed at the senior level of the integrated sequence where students have developed some facility with ideas from chemistry and physics--e.g., quantitative knowledge about energy, mechanisms of chemical reaction, equilibrium, rate or reaction, the photon and wave nature of light, electrical phenomena and kinetic molecular theory. They should not simply parrot biochemical processes as photosynthesis and cell respiration, but should truly understand many chemical and physical ramifications of these reactions.

Excessive formalism and quantization is avoided in the sophomore course. The committee identified several reasons for this decision. Usually students at this level do not extract essential meaning from such a presentation of information. It can be defended that first encounters with new ideas should proceed from an intuitive, non-quantitative confrontation to one that is more quantitative. Many teachers have recognized and spoken out against teaching and learning methods which substitute equations, formulas and other quantitative representation for first-hand experience, word descriptions, examples and illustrations. This argument is just as valid for students who are very bright and very interested in science as it is for other students. In addition, the mathematics sophistication of sophomores often precludes immersing them too deeply into mathematical arguments as an explanation for natural phenomena.

The three-year sequence is thus calculated to semi-quantitatively introduce students to some of the significant generalizations of science and how these generalizations came to be, then to re-cycle these ideas in the junior and senior years while dressing them up with the language of mathematics. Inspection of the three-year course outline manifests re-cycling a number of topics such as properties of matter, energy, certain biological concepts and the processes and tools of science.

The typical science experiences of most secondary school boys and girls consists of one or two years devoted to general science and biology. Rarely do they study physics and chemistry. A significant advantage to the course of study embodied in this manual is that most students are given this opportunity and, what is more, on a level of rigor that they can take. Students who terminate at the conclusion of the sophomore year have had significant exposure to the structure of biology, chemistry and physics in a way that scholars view these sciences as they are presented in BSCS, IPS, CBA, CHEMS and PSSC. Bright students who may not have elected science beyond the sophomore level because of a lack of interest in biology may be challenged by the chemistry and/or physics portions of the course and elect either the second and third year of the integrated sequence or other junior-senior level science courses.

It was with the consideration of these problems and goals that the general course outline for the sophomore level was finally derived. It consists of four main parts:

(1) Perception and Measurement

(2) Properties of Matter

(3) Energy in Non-Living and Living Systems

(4) Ecological Systems

There is a rationale behind this method of organization. The study of this year of science begins with the perceiver, moves on to the perceived and ends with the interaction of both the perceiver and the perceived. The sophomore first gains a better awareness of the nature of his perception and senses--the faculties that let him realize the world about him. With an increased understanding of these perceptual abilities, he can turn to the environment, then relate himself to his environment. He will find that his perception is limited and often needs to call on technological and conceptual magnification, but that even these have their limitations.

The committee deliberately included more material than can be learned and taught in the first year of the sequence. Students coming with diverse science experiences should be given some freedom to elect where emphasis should be placed. Teachers also bring to the classroom a variety of interests and backgrounds. Together with students they should plan topic selection and emphasis after due consideration to factors mentioned above.

This sequence is certainly only a beginning to a variety of such efforts that will surely follow. Others will take up the challenge and find, as we have, that there are innumerable, reasonable approaches to the problem of science integration.

Three-Year Course Outline

TOPIC	REFERENCE
First Year	
I. Perception and Quantification	
A. Sensing and Perceiving	Pp*
B. Measurement, Distribution, Organization and Communication	PP
II. Properties of Matter	
A. The Conservation of Mass	IPS and Pp
B. Characteristic Properties	IPS and PP
C. Solubility and Solvents	IPS and PP
D. The Separation of Substances	IPS and PP
E. Compounds and Elements	IPS and PP
III. Energy and Work	
A. Temperature, Calories and Keeping Track of Them	PP
B. Heat and Chaos	PP
C. Heat and Energy Conversions	PP
D. The Work-Energy Conversion	PP
E. Trends in Nature	PP
IV. Ecology	
A. Energy Transfer within Communities	PP and BSCS
B. The Variety of Living Things	PP and BSCS
C. Descent with Modification	PP and BSCS

*PP designation signifies materials produced by the Portland Project.

TOPIC	REFERENCE
D. Reproduction	PP and BSCS
E. Development	PP and BSCS
F. The Integrated Organism and Behavior	PP and BSCS
G. Populations	PP and BSCS
H. Societies	PP and BSCS
I. Communities	PP and BSCS

Second Year

I. Functions	PSSC
II. Kinematics	PSSC
III. Dynamics	
A. Newton's Laws	PSSC
B. Motion on the Earth	PSSC
C. Universal Gravitation	PSSC
D. Momentum	PSSC
E. Work and Kinetic Energy	PSSC
F. Potential Energy	PSSC
IV. Heat and Energy Effects	
A. Heat and Mechanical Energy	PSSC
B. Heat and Chemical Reactions	PP (to be written)
C. Kinetic Molecular Theory	PP (to be written)
D. Energetics of the Earth and Sun	PP (to be written)
E. Climatology	PP (to be written)

TOPIC	REFERENCE
V. Chemical and Biochemical Reactions	
A. Chemical Reactions and the Mole	CHEM
B. Condensed Phases	CHEM
C. The Periodic Table	CHEM
D. Rates of Chemical Reactions in Biological Systems	PP (to be written)
E. Equilibrium	PP (to be written)
F. Solubility Equilibria in Biological Systems	PP (to be written)
G. Acids and Bases in Biological Systems	PP (to be written)
H. Oxidation and Reduction in Biological Systems	PP (to be written)
I. Chemical Calculations	PP (to be written)
J. Organic Chemistry	CHEM
K. Metabolism	PP (to be written)
1. Photosynthesis	
2. Cellular Respiration	
3. Related Metabolic Activities	

Third Year

TOPIC	REFERENCE
I. Structure and Function in Biological Systems	
A. Transport Systems	BSCS
B. Respiratory Systems	BSCS
C. Digestive Systems	BSCS
D. Excretory Systems	BSCS

TOPIC	REFERENCE
E. Regulatory Systems	BSCS
F. Nervous Systems	BSCS
G. Skeletal and Muscular Systems	BSCS
H. Reproductive Systems	PSP (to be written)
II. Structure and Function in Physical Systems	
A. Optical Systems	PSSC
1. Particle Model for Light	
2. Wave Model for Light	
B. Electromagnetic Systems	PSSC
1. Qualitative Facts about Electricity	
2. Coulomb's Law and Elementary Charge	
3. Energy and Motion of Charges in Electric Fields	
4. The Magnetic Field	
5. Electromagnetic Induction and Waves	
C. Atomic and Nuclear Systems	
1. Exploring the Atom	PSSC
2. Photons and Matter Waves	PSSC
3. Quantum Systems	PP
4. The Orbital Model	PP
III. Structure and Function in Chemical Systems	
A. Chemical Bonding	CHEM
B. Molecular Reproduction and Control	PP (to be written)
1. DNA	
2. RNA	
3. Enzymes	
4. The Origin of Life	

Part I:

PERCEPTION AND QUANTIFICATION

Rationale: Perception and Quantification

Our basic assumption is that tenth grade students are generally more ... centered than eleventh and twelfth grade students. Therefore, the integrated course begins with student perception--hearing, seeing, tasting, touching. The laboratory experiences for the unit on perception were carefully selected to carry student interest. Where student enthusiasm and scientific explanation were incompatible, the experiment has been deleted. For example, there is no laboratory on the sense of smell (enthusiastic student response) because the current scientific explanation of smell seems too vague.

The course opens with a simple request to "observe this turtle." If students are to observe, the must use their senses. There is a block of five experiments dealing with the senses. During this treatment the students should become convinced that they will need "sensory extenders" if they are to observe objects carefully and quantitatively.

The experiments on "sensory extenders" should convince the students that scientific instruments (meter stick, balance, microscope) are extenders and quantifiers but that the scientific instruments, just as their senses, are subject to "illusions" and limitations. An example of an instrumental "illusion" is the apparent speed of a paramecium when observed with a microscope. If human senses are subject to limitations and scientific instruments are subject to similar limitations, then it is reasonable that measurements are subject to uncertainty.

The experiment on the area of a scalene triangle introduces a detailed treatment of this kind of uncertainty.

The students have observed the generation of distributions in the first set of sensory experiments. Each time, though, the distribution was dependent upon a living system. The data from a coin flipping experiment is then graphed to show that distribution curves also occur in data collected from non-living systems. Thus they learn that distribution is a general phenomenon of nature.

If scientific data are uncertain and distributional in character, then nature probably is complex. In order to grasp the complexity of nature, man must simplify or organize. The minimum number of guesses to identify a playing card introduces the students to the use of a dichotomous key. The students apply their newly learned organizational method to a leaf collection and a junk collection after an initial organization by means of a Roman square. The goal of organization is an economy and precision in communication.

Thus students reach the end of the first unit having been intoduced to the use and units of a meter stick, balance and microscope; having studied the uncertain and distributional character of scientific data; and having studied systematic classification.

Outline: Perception and Quantification

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
I.	Sensing and Perceiving			
I.1		3 days	S.G.	The Turtle
I.2	Optical Illusions		S.G.	
I.3			S.G.	Reversible Figures
I.4			S.G.	Size Illusions
			Film	"Visual Perception" (19 minutes)
I.4a	Metrology (and Optional Questions)		S.G.	
I.5	Using Illusions		S.G.	
*I.6		1 day	S.G.	Demonstration: Light and Color
			Film	"Blind as a Bat" (7 minutes)
I.7			S.G.	Demonstration: Seeing Through Hearing
**I.8	Limitations of Our Senses	16 days	S.G.	
I.9			S.G.	Touch
I.10			S.G.	Taste
I.11			S.G.	Depth Perception
I.12	Reliability and Validity		S.G.	
I.13			S.G.	Peripheral Vision
I.14			S.G.	Response Time of the Eye

I.15			S.G.	Visual Reaction Time
I.16			S.G.	Auditory Reaction Time
I.17		3 days	BSCS (Green)	Ex. 1.4 The Use of the Microscope
I.18			S.G.	Paramecia and Their Speed
*I.19		1 day	S.G.	Demonstration: Size and Weight

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*Experiments I.6 and I.19 prepare ahead of time.

**Experiments I.8 - I.16 require extensive preparation.

II.	Measurement, Distribution, Organization and Communication			
II.1	Volume	4 days	IPS 2.1	
II.2	Measuring Volume by Displacement of Water		IPS 2.2	
II.3			S.G.	Demonstration: Volume by Water Displacement
II.4	Shortcomings of Volume As a Measure of Matter		IPS 2.3	
II.5	Mass		IPS 2.4	
II.6			IPS 2.5	The Equal-Arm Balance
*II.7			IPS 2.6	The Precision of the Balance
II.8			IPS 2.7	Beads and Grams
II.9	Measuring and Counting	8 days	S.G.	
II.10	Systems and Units of Counting		S.G.	

II.11	Distance, Mass and Time		S.G.	
II.12			S.G.	The Scalene Triangle
II.13	Uncertainty Associated with Measurement		S.G.	
II.14	Uncertainty Associated with the Instrument		S.G.	
II.15	Human Uncertainty		S.G.	
II.16	Uncertainty Due to Changes within the System		S.G.	
II.17	Range of Uncertainty		S.G.	
II.18	Place of Uncertainty		S.G.	
II.19	Rounding Off to the Correct Place		S.G.	
II.20	Propagation of Errors		S.G.	
II.21	Significant Figures		S.G.	
II.22	Adding Significant Figures		S.G.	
II.23	Subtracting Significant Figures		S.G.	
II.24	Multiplying and Dividing Significant Figures		S.G.	
II.25	Scientific Notation		S.G.	
II.26	Back to the Scalene Triangle		S.G.	
II.27		3 days	S.G.	Mass of the Turtle
*II.28			S.G.	Coin Flipping
			PSSC Film	"Random Events" (30 minutes)

*II.29		5 days	S.G.	Classification and Organization
*II.30			S.G.	Classification of Leaves
II.31			S.G.	Oral Communication Chain
II.32			S.G.	Communicating Ideas
II.33	Observing a System as a Scientist		S.G.	
II.34			S.G.	Test: The Turtle

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* The day before these experiments ask students to bring from home the following:

II,7 (IPS 2.6) 5-10 pennies

II.28 10 coins

II.30 20 leaves (as many different kinds as possible)

Chapter I: Sensing and Perceiving

I.1 - Experiment: THE TURTLE

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 turtle.

Write a description of the turtle 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 pair of students is given a turtle to observe. With three turtles on a table there could be interaction between the turtles--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. Students with any questions that arise while observing the turtle and its activities, should write them down 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.

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 they can or need to control as they observe their subject. Have them name some conditions which might 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 t[illegible]e was on the table out [illegible] its bowl.

--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 turtle's natural habitat?

—What do you think is the natural habitat of these turtles? (It has probably lived in a glass bowl all its life.)

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 make 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:

The turtle is dark green (1) with a red mark (2) on each side (3) (bilateral symmetry) of its face (4). It has a toothless (5) beak (6), two nostrils (7), two eyes (8) with short, dark, horizontal lines coming from both sides of each eye (9). Each eye has a black pupil in it (10). It has one head (11) connected by a neck (12) to a body trunk (13) encased between two bony plates (14) (upper and lower). The lower plate is yellowish (15) and the upper plate has dark green lines (16) forming a box-like pattern (17) on the dark green color. Four jointed legs (18, 19) (appendages) spread out sideways (20) from the body. The skin (21) covering them is loose (22) and scaly (23). Each leg has five jointed toes (24, 25). Each toe has a long, thin (26) claw (27). The turtle has a short (28), thin (29), pointed tail (30). Nowhere on this animal is hair or fur rooted (31).

The students may list some visible activities of the turtle including the fact that it

(1) can turn its head from side to side;

(2) can raise its head;

(3) draw it almost completely inside its shell;

(4) can open and shut its eyes and mouth;

(5) and walks on four legs

(6) may draw them inside its shell.

Some inferences would include the following:

(1) The turtle is alive.

(2) The turtle has a heart.

(3) It breathes.

(4) It can hear.

(5) It has a stomach.

(6) It cannot make any sound.

Equipment and Materials

1 turtle per two students.

I.2 OPTICAL ILLUSIONS

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

The student has observed the turtle. The 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 alike, they also perceive differently in many instances. A third 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.

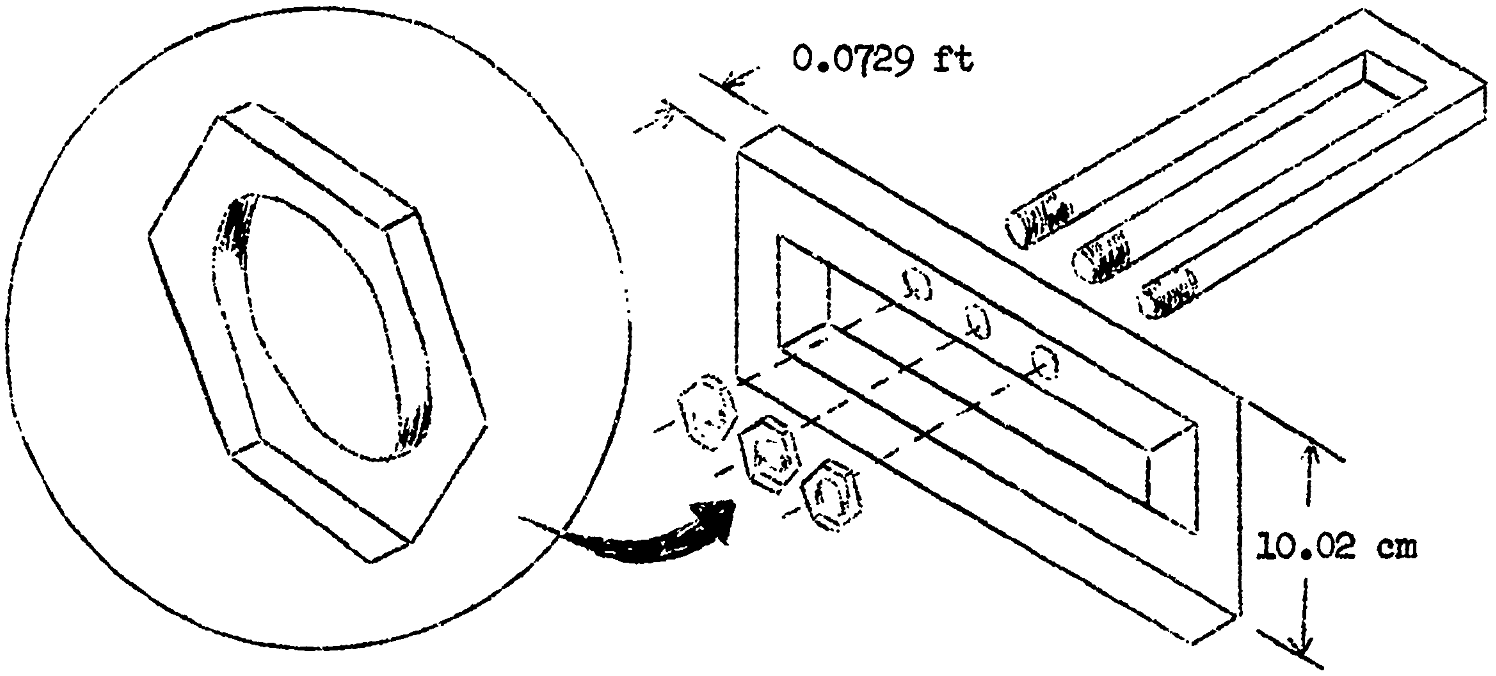


FIG. I.1 - Do you think you can build this? Look again. Observe carefully?

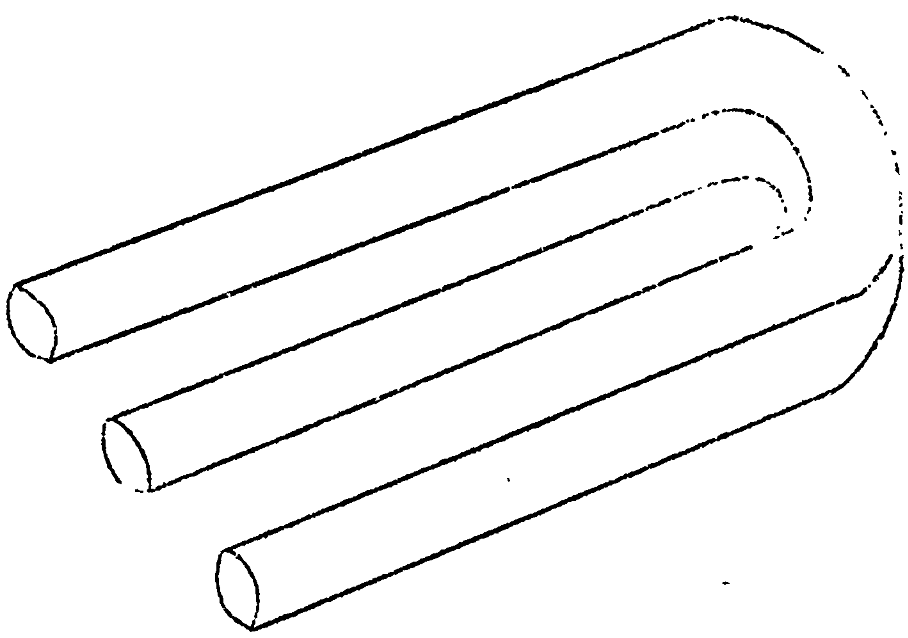


FIG. I.2 - Maybe a round three-pronged figure would be easier.

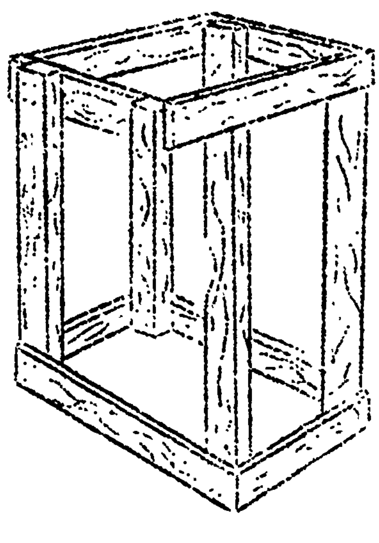


FIG. I.3 - How about a carton to ship it in?

WARNING TO TEACHERS:

Prepare for Demonstration I.6. See I.8 and start preparations for Experiments I.9 through I.16.

I.3 - Exercise: REVERSIBLE FIGURES

Look at the following pictures and write in your lab book a brief description of what you see. Stare at each figure for several seconds.

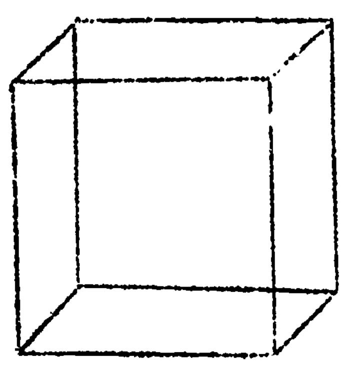


FIG. I.4

Have the students record. The purpose here is to show not only that our senses (in this case, vision) may seem to play tricks on us, but also that there are likenesses among us in our senses of perception. They need written references and should not be influenced by oral recitation at this time.

These are reversible figures which show that perception can undergo continual change. Oscillation between two alternative forms will occur if they stare at the figure for several seconds. After continued inspection, the two forms may alternate fairly regularly.

After the students have had time to write down what they saw, discuss their descriptions in class. It is to be expected that although they may not have all seen the same thing at first, this reversal will be observed consistently.

In FIG. I.4 the leading side in the Necker cube will change.

The staircase in FIG. I.5 will appear to turn upside down.

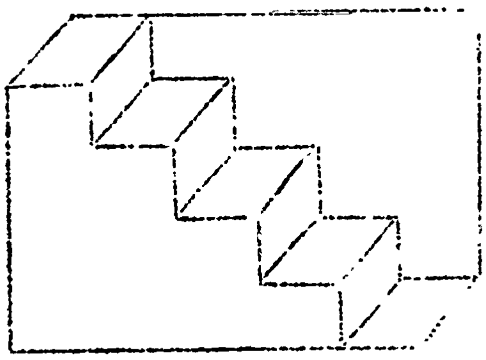


FIG. I.5

In FIG. I.6 there is a sensation of three dimensions with the smaller square sometimes away from us and sometimes toward us.

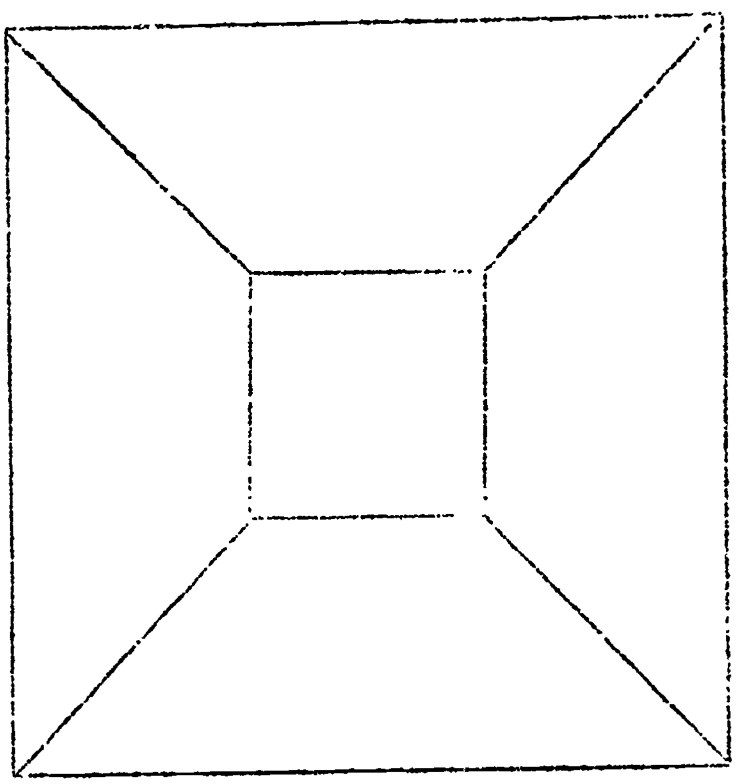


FIG. I.6

In FIG. L.7 a pedestal will appear and then two faces (or vice versa).

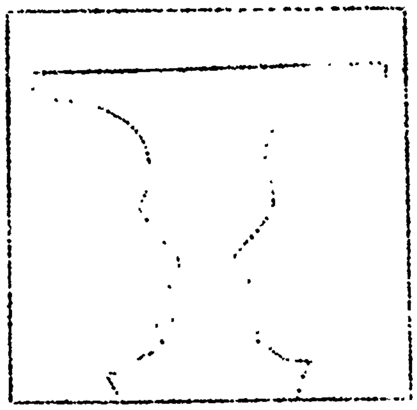


FIG. I.7

FIG. I.8

FIG. I.8 is a picture of a girl or an old lady. This one is sometimes difficult. The girl's ear becomes the old lady's eye, the chin of the girl becomes the nose of the old lady.

Did you all observe the same thing in the same way? Have you any ideas as to why you observed the phenomena that you did?

They may not have perceived the same thing initially (differences), but probably did perceive the oscillations (similarity in perception).

Let the students give any ideas they might have and suggest that those interested try to find an explanation through reading.

The only explanation that we can offer here is that perception can undergo continual changes. Oscillation between alternative forms occurs.

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.

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-images. One good example is a drawing of the American flag with black stars on yellow background and alternating blue 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 swing 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. (No. 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. (No. 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.

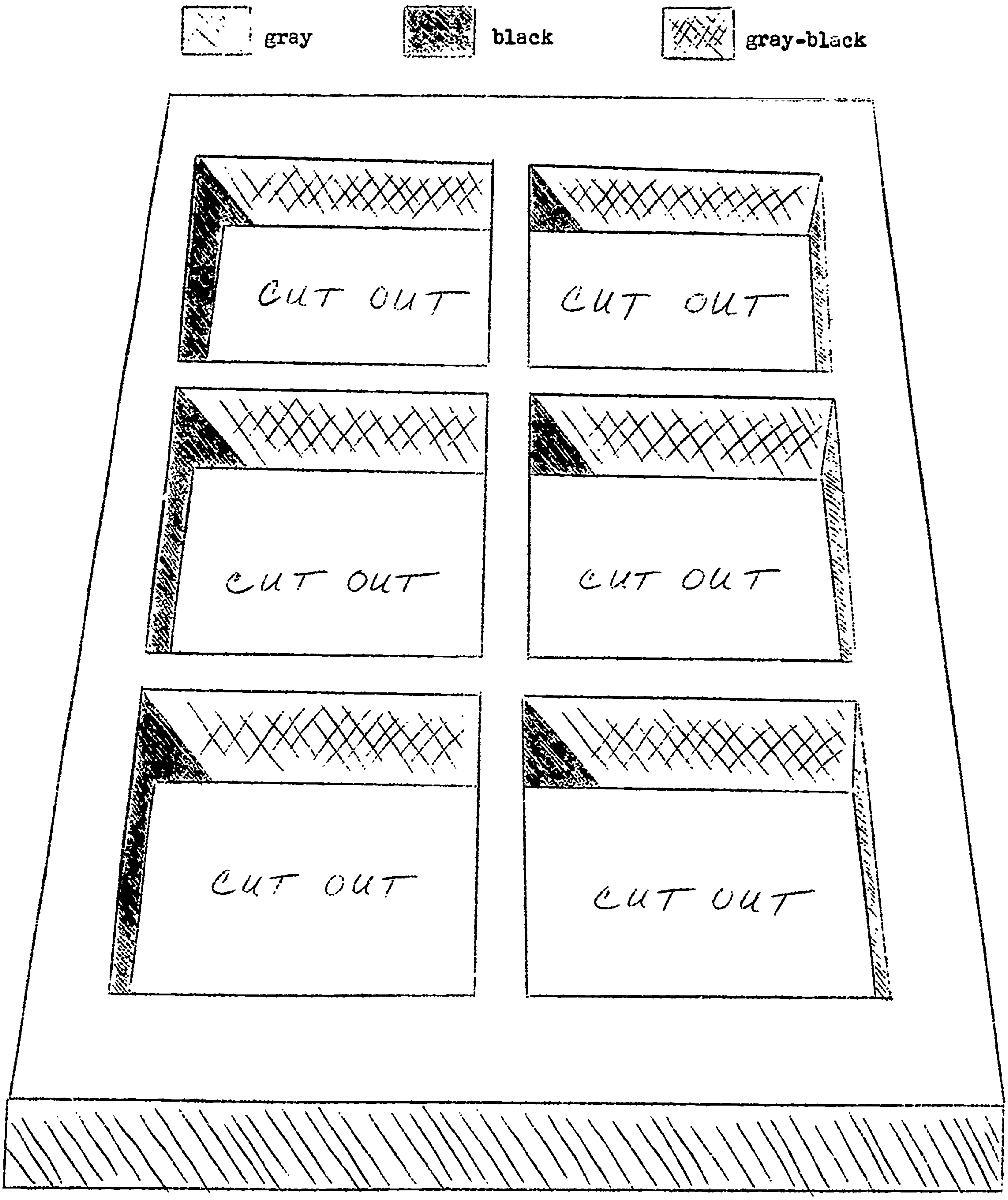
Turn the hand drill to rotate the trapezoid. Because of its shape and its coloring, the trapezoid will appear to oscillate rather than to rotate.

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.

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.


gray
black
gray-black
CUT OUT
CUT OUT
CUT OUT
CUT OUT
CUT OUT
CUT OUT

I.4 - Experiment: SIZE ILLUSION

At the conclusion of this section (I.4) show the film, "Visual Perception" (19 minutes).

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 numbers and averaging can be introduced here but they will be treated in more detail later.

Equipment and Materials

30 meter sticks or rulers with metric markings.

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)?

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.

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.

Which one do you think looks larger?

Estimate how much larger. (Do not measure.)

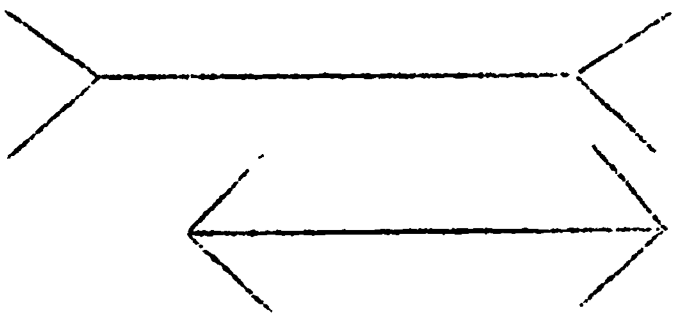


FIG. I.9 - Top one is A, bottom is B.
Which is longer?

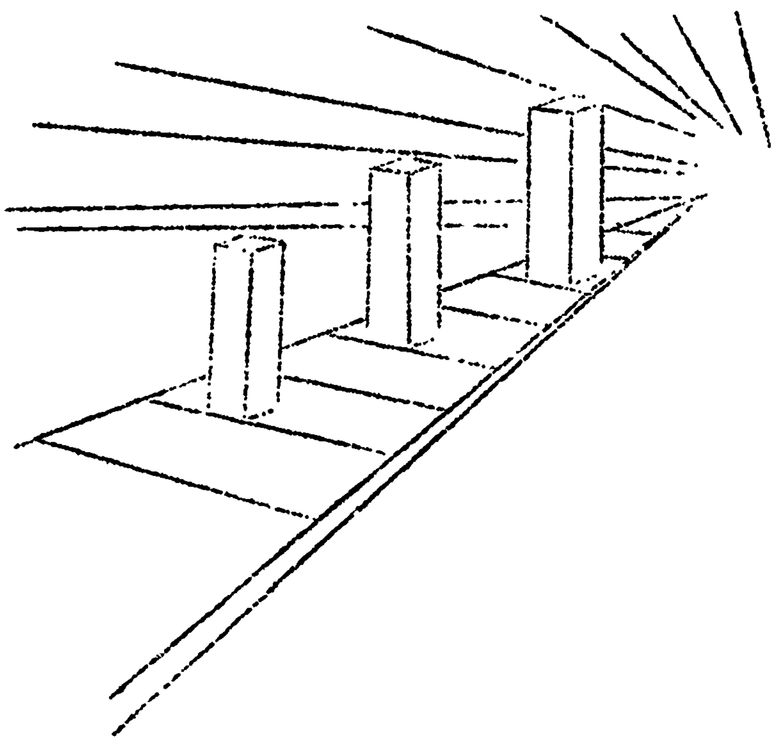


FIG. I.10 - Front post is A, back post is B. Which is taller?

They are not to make measurements of any kind at this time.

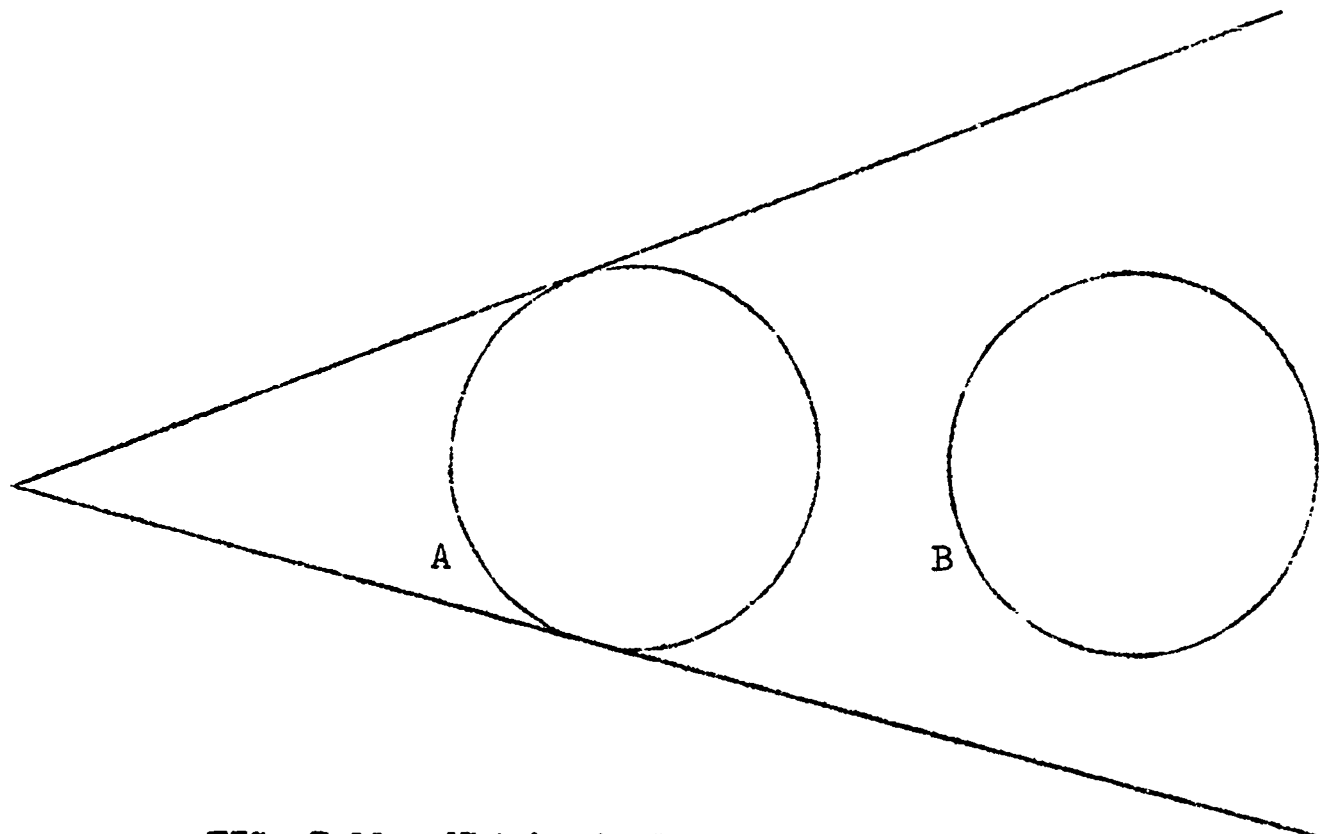


FIG. I.11 - Which circle is larger, A or B?

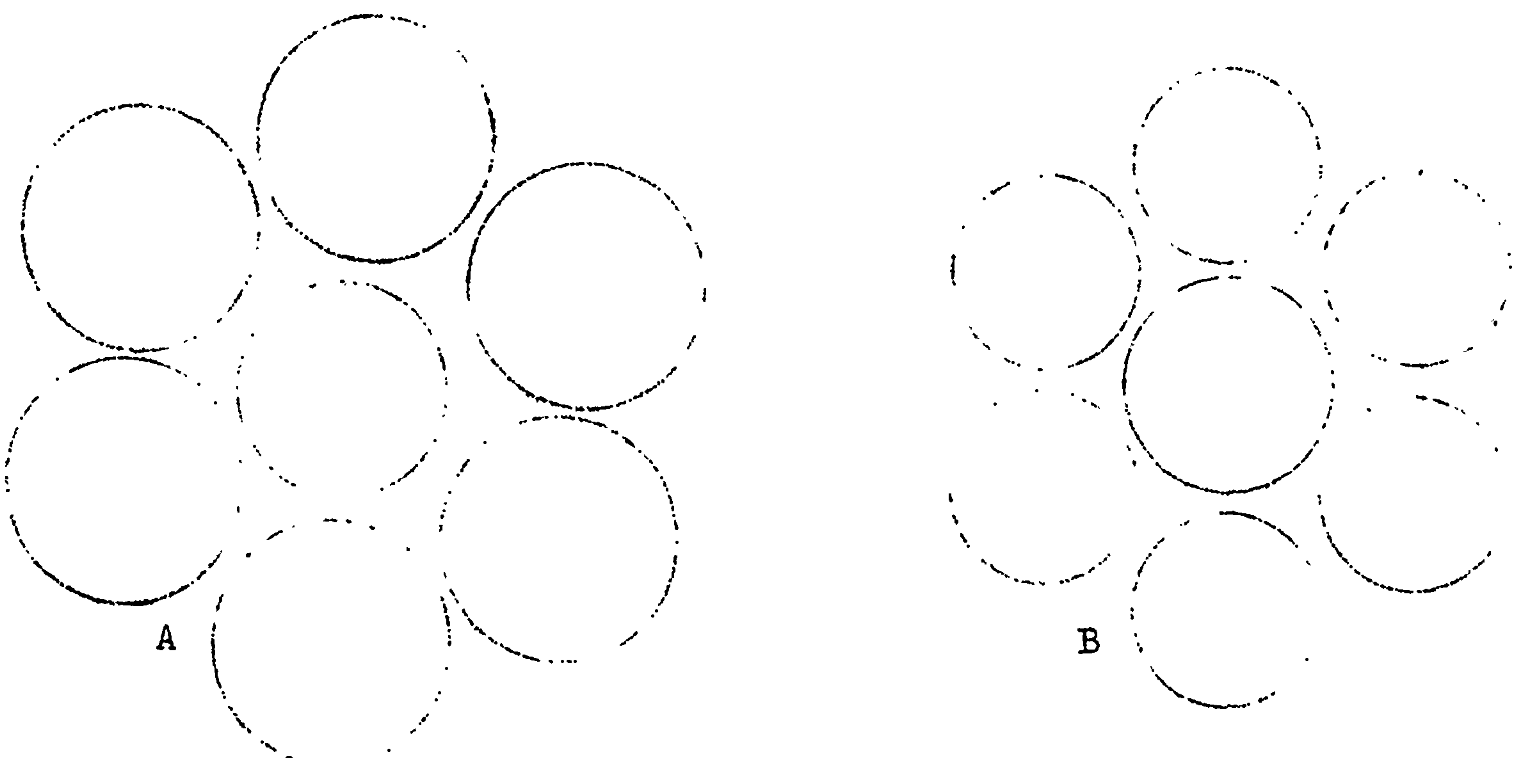


FIG. I.12 - Look at the center circle. Is the center circle in A the same size as the center circle in B?

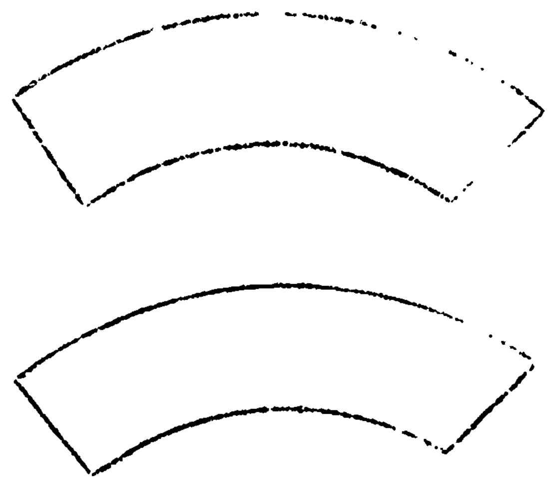
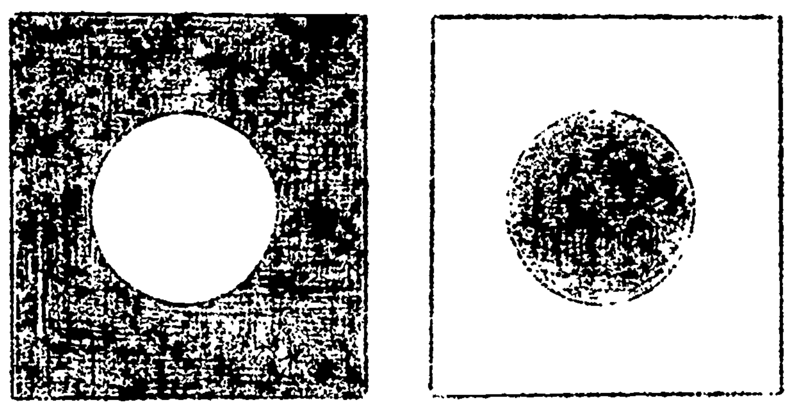


FIG. I.13 - Which is larger?



A B

FIG. I.14 - 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.

It is hoped that at this point students will see the need for a measuring instrument and ask for a ruler. They would still be recognizing the need for measurement even if they use a pencil or a similar object as a measuring instrument to make comparisons.

Now ask for the actual figures (the number of centimeters for line A in FIG. I.9) 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 $\frac{1}{4}$ 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 FIG. I.9. (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 FIG. I.9, 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 numbers and averaging.

Optional: If you wish, or if the question arises as to why the answers given here vary slightly, refer to and discuss the optional student questions # 1-5. I.4a - METROLOGY is also optional.

Reasons might include the following: the surroundings FIG. I.9-12; the position FIG. I.13; color and light and dark FIG. I.14. The eye is not able to isolate the object or line from its surrounding. The idea of isolation for the purpose of analysis is very important in science.

Exercises for Home, Desk and Lab (HDL)

The following questions (#1-5) are optional.

(1) Notice that the measurements listed on the board differ somewhat. What are the possible reasons for these differences?

(1) Some possible reasons for differences might be these: the rulers differ slightly (instrumental error); students read the rulers differently (human error); some students estimated to the second place—for example, 3.5 cm or 3.55 cm.

(2) Let's say, for example, that two measurements are given for the line, one 3.5 cm; the other 3.55 cm (assume that the ruler is accurate). Since the ruler or meter stick is marked in tenths of a cm is the second number acceptable?

(2) Yes, you may estimate one place (significant numbers). We are asking them to assume that the ruler is accurate. This will be discussed later in Chapter II.

(3) Would a measurement of 3.558 be better in this case?

(3) No, the ruler is not marked in such a way that you can estimate .008. Never estimate more than one place.

(4) If you wanted a measurement to the third or fourth place, what might you do?

(4) Get an instrument that is marked or calibrated to a greater degree than the ruler (vernier calipers or micrometer).

(5) If you wish to report the results of the measurements on the board, which number would you choose?

(5) An average of all of them after throwing out obvious extremes. (Any value that is four times or more the average deviation should be considered an extreme.)

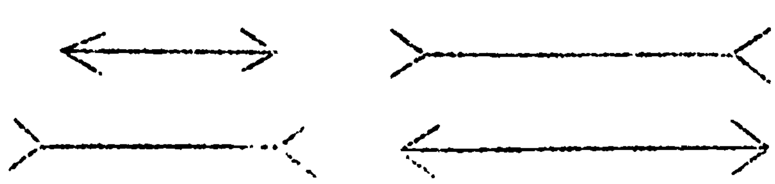
I.4a - METROLOGY

This is optional reading.

Metrology refers to the science of measurement. Scientists are necessarily concerned with the need to make more and more accurate measurements and with the problems involved in doing so. For example, if the bearing hole of a guidance gyroscope is off a millionth of an inch (and if no "in-flight" corrections could be made), it is estimated that this could cause a satellite to miss the moon by 1,000 miles.

Man measures extremely small distances. He can, however, never be absolutely accurate. Measurement is not exact.

Use these lines as an example:



If you were asked to count them without concern for length, your answer would be four. Counting is exact and discrete. Now if you are asked to measure them, you might use one line and compare the others to it. You might answer that one line is twice as long; the other is two-and-a-half times as long and the other is three-and-a-half times as long as the shortest one. Measurement always involves comparisons and that is what was done here where the shortest line became the standard. But if you are trying to tell someone else how long the lines are and they cannot see the shortest one, this procedure would not be very useful.

Maybe you could pick a standard such as a paper clip which is fairly uniform in length and is an object that is familiar to all. In using this, you might get such answers as $1\frac{1}{2}$, 1, 3/4 and $\frac{1}{2}$ paper clips. Except for 1, the answers given are not whole numbers nor are they multiples of one paper clip. You must estimate the fraction. To make this easier, you might mark the paper clip off in equal parts. But how many divisions do you make? The distance between the ends of the paper clip are continuous so the divisions can be made again and again. You might divide it into tenths, but then each of these divisions could be divided in two so that the markings would now be .05 of the paper clip. Obviously there is a practical limit to the number of divisions that can be made. This is true regardless of the instrument. Measurement is therefore inexact and uncertain.

The number of divisions on a measuring instrument such as a ruler will be sufficient depending on how the ruler is used. Remember the limitations of the instrument. It is unreasonable to try to measure a tenth of a second with a wrist watch; it is also unreasonable to try to measure a thousandth of a cm with a ruler.

If the work you are doing requires a more exact measurement, you must have a better instrument. But even with the best instrument, an absolutely exact measurement cannot be found. The divisions could be divided further.

Another problem exists. The device used to measure often affects the object being measured. For example, if light is being used, the object being measured will expand. An error is introduced.

Scientists using even the most accurate measuring tool still take many measurements and average them and they still consider and report in terms of the probable error.

I.5 - Experiment: USING ILLUSIONS

In FIG.I.10 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?

FIG. I.15

In the picture above the lighter object looks larger. The next time you go into 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. They also might consider how lines affect your appearance. Which of the identical girls below looks thinner?

The one wearing the dress with vertical lines looks thinner.

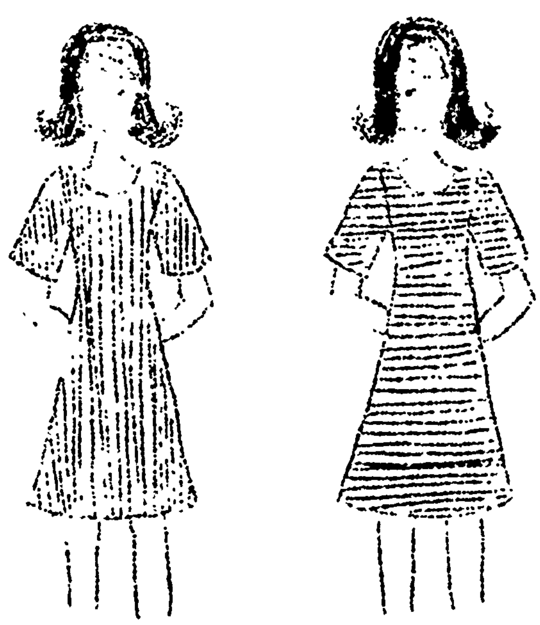
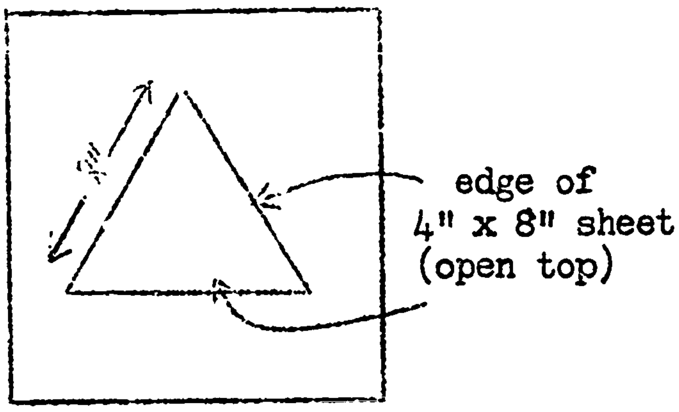


FIG. I.16

Can you think of other examples of using optical illusions?

I.6 - Demonstration: LIGHT AND COLOR

Most of you have seen a prism before and know what it does to white light. Now you should look again more carefully and with some thought. What do you conclude about the nature of "white" light? Can you recall from your own experience the names of some kinds of light which are invisible to the eye? Do you have any means of perceiving these? Do any other living organisms have means of perceiving these?



View from directly overhead

Infrared (IR) and ultraviolet (UV) are invisible. They can only be perceived with instruments. Snakes perceive IR and insects perceive violet to UV.

If it is true that white light is the result of mixing colored light, then you should be able to reverse the effect of the prism by mixing various colors of light to produce white light. Although this could be done using the light output of the prism, it would be complicated and it is easier to do it by means of color filters which remove from white light all but one color. Try it with the colored lights provided by shining them into the beaker filled with the milky liquid. The color obtained is to be observed

The easiest means for the resolution of white light is a water prism. This can be constructed in a matter of minutes from four sheets of glass and "silastic" silicone rubber cement. The glass and cement can be obtained in most hardware stores. The sizes for the sheets of glass are

3 sheets 4" x 8" for sides
1 sheet 12" x 12" for base

The side sheets are cemented together and to the base to form an equilateral triangle, 8 inches on a side and 4 inches high. The cement is allowed to cure overnight. The prism can be filled either with water or with through the window cut in the black cover placed on top of the beaker. What happens when you mix red and blue or red, blue and green? Do we need all of the colors shown by the prism in order to get white? Do you think that the color filters used give a "pure" color? How could you test this? What is the purpose of the milky liquid?

ethyl cinnamate if better dispersion of the spectrum is desired.

Any incandescent bulb desk lamp can be used as a light source, although some sources such as a slide projector which has a housing, is to be preferred. A cardboard box with a hole in one side could serve as a housing to cut down stray light if a desk lamp is used.

If you choose to use instead a glass prism which is available, then it may be necesaary to collimate (make the beam smaller by passing it through a slit) the light beam because of the small size of the prism. This can be done by interposing between the light source and prism a cardboard sheet with a 1-2 mm width slit cut in its center. It probably will also be necessary for you to spend an hour or so experimenting with the set-up to insure a successful demonstration.

The colored flashlights are made using the red, blue, green and--if you wish, yellow cellophanes. A single thickness should do in every case except yellow where two sheets are sufficient.

The milky solution is made by mixing $\frac{1}{4}$ teaspoon of "Pream" or any other coffee creamer in approximately 500 ml of water contained in a 600 or 800 ml beaker. A 8-10" disc of black construction paper with a centered

$1\frac{1}{2}$" diameter window is placed over the beaker to cut out the colored illumination from each individual light. The color mixing is further improved if the window is covered with a piece of wax paper or frosted glass.

The students should try each light singly to prove to themselves that the white milky solution does not change the color seen but serves simply as a light-scattering medium to provide intimate mixing of the various colors.

With the cellophanes provided, the mixing of green and red will give a very light yellow, and blue and green, a very light blue (cyan) because the range of color transmitted by these cellophanes is too wide to provide the optimum color mixing. Because of this, the teacher may want the students to "test" the spectrum of each filter by means of the prism.

In the discussion that follows these demonstrations, the teacher should strive to get across the idea that the eye automatically adds various colors to obtain something completely different, and that the separate color sensations are combined into one color. The teacher could at this point make a distinction between sight and sound—that is, that the latter sense is very good at perceiving a mixture of high and low frequency sounds as a mixture, whereas the eye cannot do the same for light. When the frequency of vibration of light of two different frequencies falls on the eye, only one color is seen. However, when sound of two frequencies falls on the ear, we hear both frequencies (both pitches) simultaneously. The discussion could be enlivened by asking the student if it would be possible to compose color music by projecting light of different colors on the same spot on a screen.

The idea of invisible light might be brought up by the students themselves since many will have heard of ultraviolet or infrared light. The tack then might be to ask the respondent if he has any personal experience with these. The hot object which can be sensed at a distance would become the illustration of infrared; a sunburn would be the effect of ultraviolet. In the latter connection you might ask the student if he could get sunburned through an ordinary window and if not, why.

I.7 - Demonstration: SEEING THROUGH HEARING

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

The film, "Blind as a Bat" (7 minutes), available at Portland Administration Building, can be shown immediately preceeding 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 all[illegible]

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 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.

I.8 - LIMITATIONS OF OUR SENSES

In Experiment I.4 - 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 differently 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.

Lab instructions for Experiments I.9 - I.16.

In these seven 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 seven 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 seven 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 Taste, Touch, Visual and Auditory Reaction Time experiments require the least amount of equipment, 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 seven experiments to be done:

Touch

Taste

Depth Perception

Peripheral Vision

Response Time of the Eye

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).

so use two lab "setups" for these as needed.

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

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

$\bar{X}$ 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.

(2) In class 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 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.

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 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)

.9 - Experiment: TOUCH

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?

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."

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.

Equipment and Materials

Student compass or divider (or other sharp object)
Meter stick

I.10 - Experiment: TASTE

(A) You will be given a sugar solution. Determine at what dilution you can no longer taste the sugar by making a series of dilutions of the original solution. To do this, add an equal amount of water to the original sugar solution. Be sure to mix the solutions well then taste about one spoonful. Rinse your mouth after each testing. Pour about one-half of the diluted solution into a clean test tube and add an equal amount of water. Again mix well and taste. Continue this process of dilution, mixing and tasting, being sure to record your operations until you can no longer taste the sugar. The point at which you last taste sweetness is your taste threshold for sugar.

(1) 1 part sugar solution to 2 parts water.
(2) Weigh one gram and add it to 1000 ml of water; the point is to use some dilution method.

Equipment and Materials

Test tube rack or large beaker to hold test tubes
Small paper cups to aid the student in tasting the sugar solutions
10 test tubes for dilution (150 mm x 13 mm, but any tube with a capacity of about 20 ml will serve)
100 ml of 1 M sucrose solution made by dissolving 34 g of table sugar in 100 ml of water
100 ml of 0.1 M saccharin solution made by dissolving 55 tablets (½ grain) of commercial saccharin in 100 ml of water (any drug store sells saccharin tablets).

Does your taste threshold differ from that of your lab partner's?

(B) You will be given a saccharin (low-calorie sugar substitute) solution. Determine how much sweeter the saccharin is than the sugar.

(1) Explain how you could prepare a solution that is one-third the concentration of your original solution.

(2) If the best balance available will weigh no less than 1 gram explain how you could prepare a solution containing only 0.001 gram per milliliter.

Since each group of students doing the taste experiment will be given 10 ml of sugar solution, 100 ml of stock solution will be enough for ten sets of students.

The students should take the whole 10 ml sugar sample which you give them and add an equal volume of water to it. By adding a column of water equal in height to the sugar solution, they will avoid the need for the use of any graduated equipment. The important point is dilution by a known amount ($\frac{1}{2}$ in this specific case), not how to use volumetric equipment.

Part (B) of this experiment is intended to teach students the use of serial dilution. If students understand that a dilution to their taste threshold for saccharin will give them a means of comparing the sweetness of sucrose and saccharin, then they understand the principle of serial dilution. There is no need to tell the students that the sucrose solution is 1 M and the saccharin solution is 0.1 M, though there is also no reason not to tell them. The student's assignment is only to tell how much sweeter the saccharin solution is than the sucrose solution and there is no implication that the two solutions are at the same concentation.

One of the HDL problems (1) asks about a 2:1 dilution. The reason that a 1:1 dilution is used in this experiment rather than any other ratio is because of operational ease. The 2:1 dilution HDL problem should show the students that they could prepare any given dilution if they have some means of determining volume ratios.

I.11 - Experiment: DEPTH PERCEPTION

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 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 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

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.

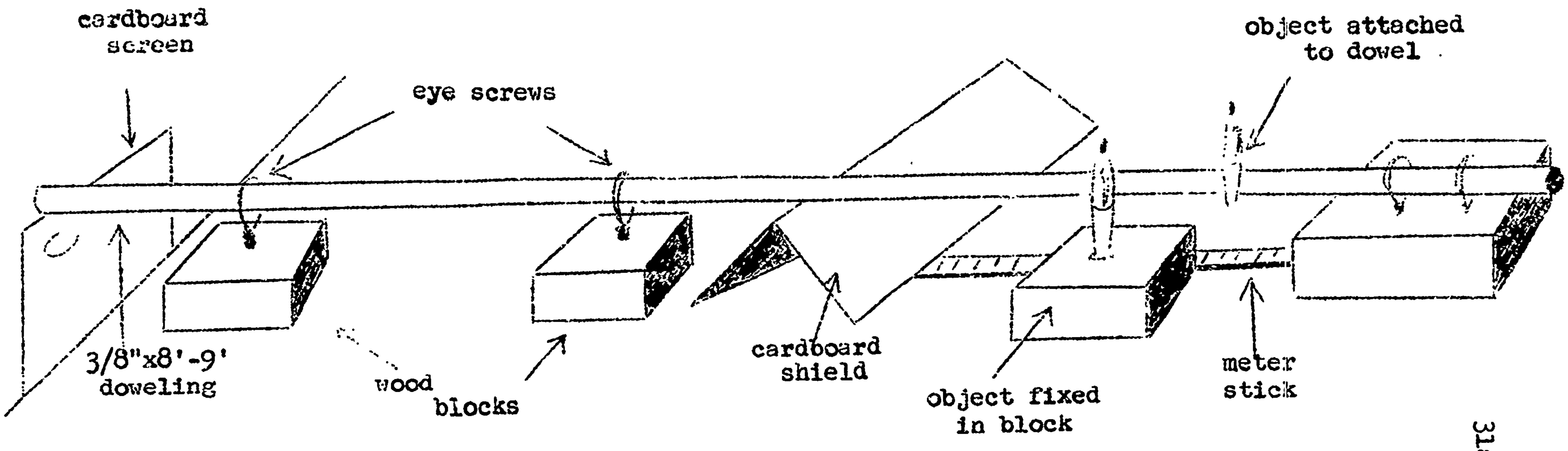
The experiments show similarities (binocular distance perception will be better) and differences (individual scores will differ) in visual perception.

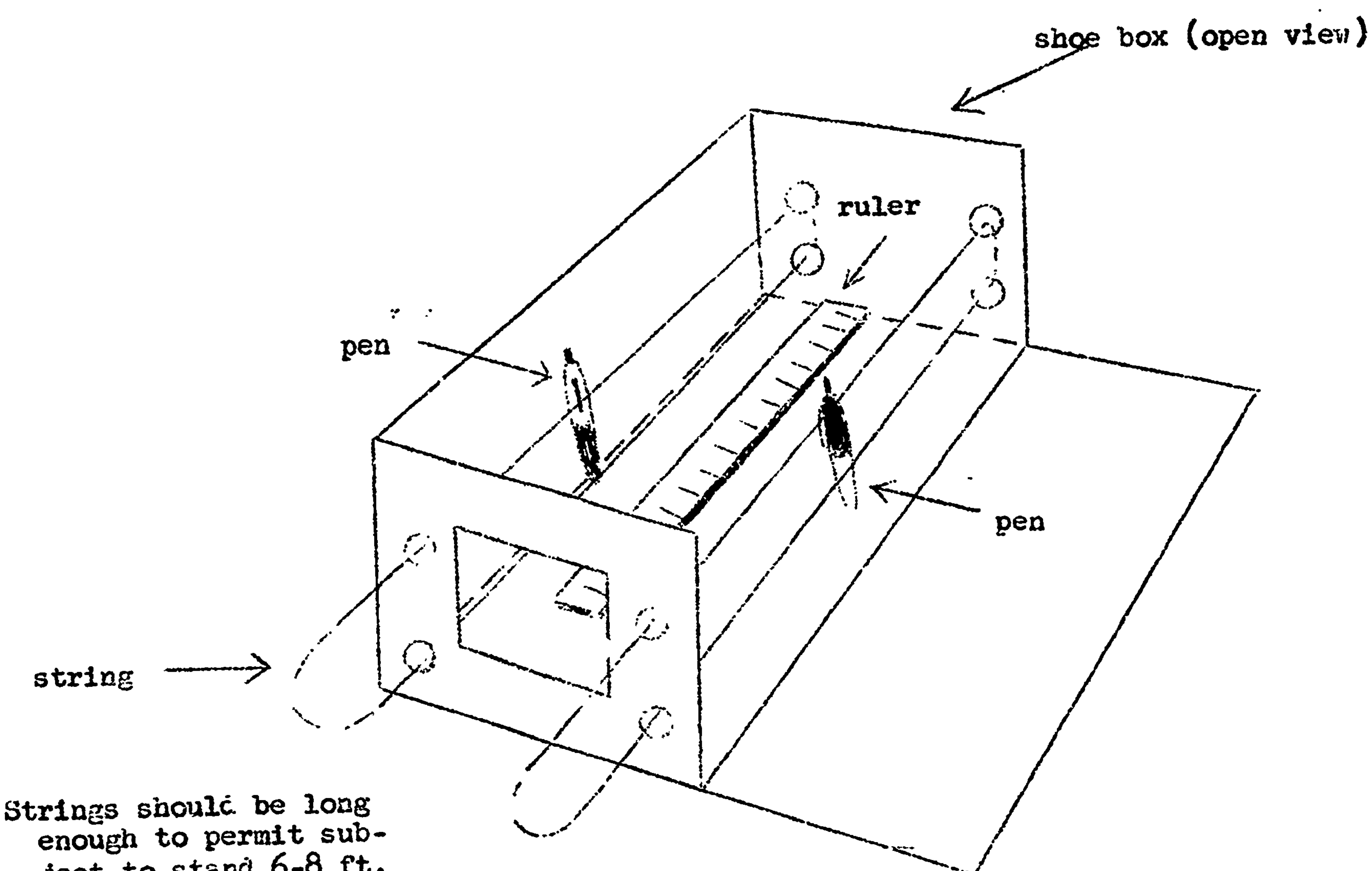
There will be a need to find an average or mean error score.

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

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

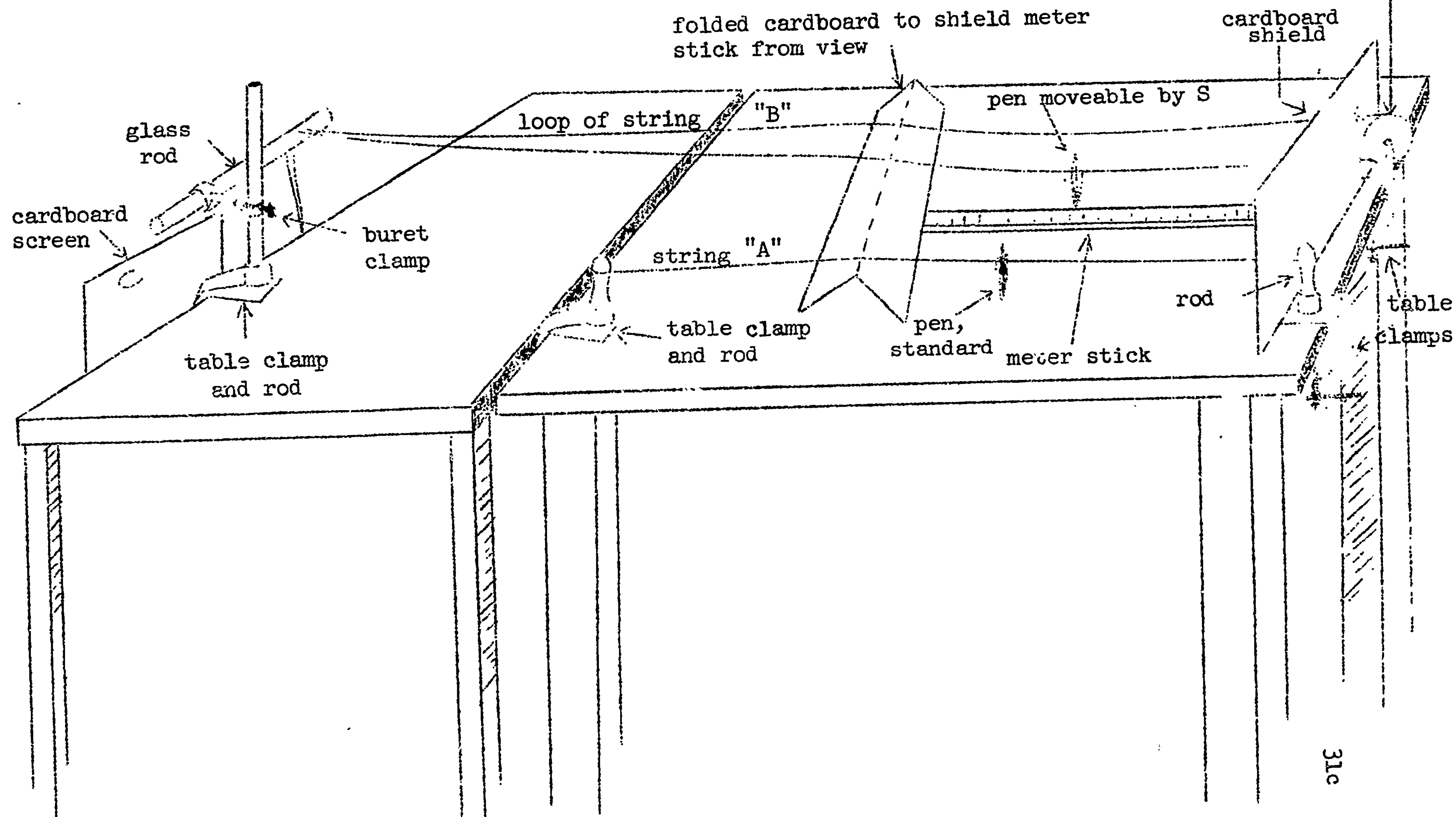
The following are alternate suggestions for the Depth Perception set-up. They are more compact and more easily moved. They were not tested but should work well. Some adjustments may be necessary.





Strings should be long enough to permit subject to stand 6-8 ft. from the box.

Length of string "A" about 180 cm. Distance from pulley to cardboard screen about 270 cm. Distance between string "A" and "B" 8-10 cm. Strings are above table top about 14 cm, just so pens do not touch table top.



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 give you the proper condition to use. Take the string and adjust the moveable 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 moveable 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. This error score is the number of centimeters (to the nearest 0.1 cm) that the moveable pen is from the standard pen. If the moveable pen

String A is fastened securely to supports. A pen is hung on it by the clip and can be slipped along the string by the experimenter in order to move it to a new position.

String B is strung through the pulley and tied together to form a loop. Another pen is hung on one part of this loop at the same height as the first pen. The subject can then move the pen back and forth by pulling on the upper or lower part of the loop.

The strings are run through holes in a neutral colored cardboard shield.

Two cardboard screens should be made--one with a small hole in it so that the subject uses just one eye and no head movement, the other with a large hole in it so that the subject can use both eyes but no head movement. Tape these screens as needed to the edge of the table. They should be low enough so that the subject does not see the meter stick over the folded cardboard shield.

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 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 score, he will compensate for it. He may also find other clues to use.

Equipment and Materials

4 table clamps with 3 rods to fit (Substitutions can be made here depending on available equipment. Ring stands can be clamped to the table with C clamps.)
Heavy string (one about 200 cm long, another about 600 cm long))
2 pens, same color and size with clips.
Cardboard for shielding and screens, neutral color.
Buret clamp
Glass rod
Pulley, rod type (Collar mounting pulley could be clamped to a rod or a plain pulley tied to the support. If the pulley is not available, the string could be pulled over a ring or rod.)
Meter stick

and direction of error as given to you by E.

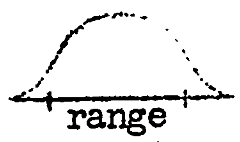
Exercises for Home, Desk and Lab (HDL)

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

(1) 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.

(2) 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.

(2) 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.

(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.

I.12 - 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.

I.13 - 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.

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 to do the necessary mathematics involved.

So that they will have some standard to compare to, $\bar{X}$ 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.

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 cardboard and the colored dots on the moveable 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 for that eye if available). Stare straight ahead at the white X mark.

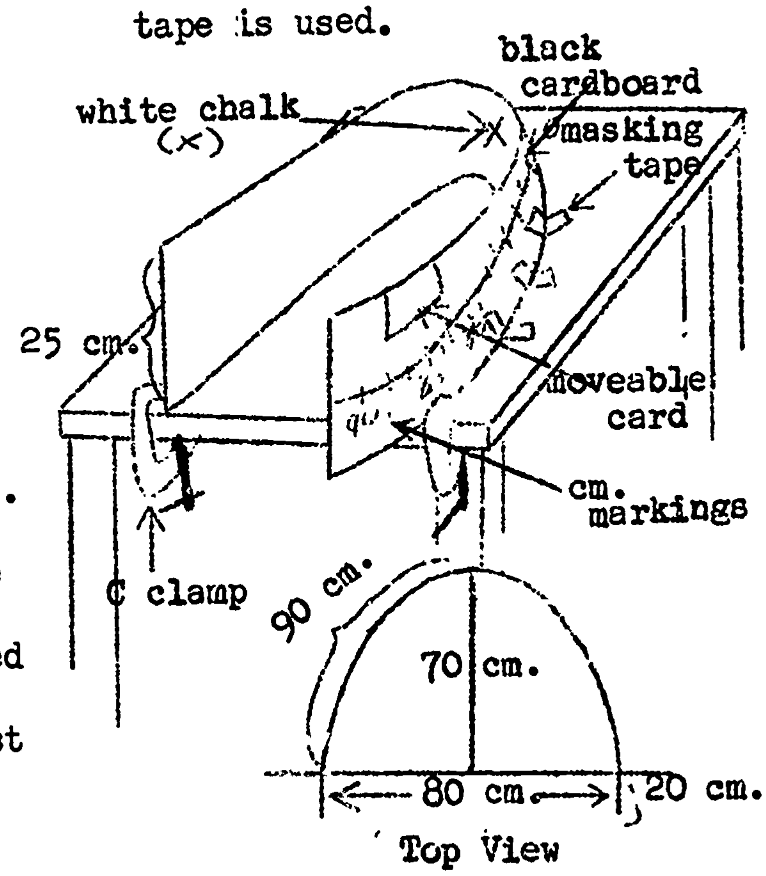
There will be a great tendency to move your eyes. If you give in to this temptation, you should inform E so that trial can be disregarded. Your results will not be reliable unless this is done.

As E, you place one of the moveable 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)

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.



and move toward the center (0) until S identifies the color 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 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?

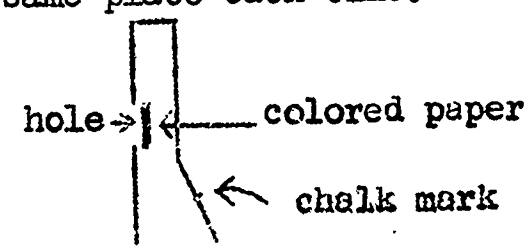
Also be sure that you give no clues to S as to what the color might be. For example, do not take a longer period of time, make a different sound or move in a different way when changing colors. Move each color at about the same speed.

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

about 7 cm.

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.



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

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.

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 but 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 interfer 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.

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 $1\frac{1}{2}$ sq. cm) of red, blue-green, and yellow construction paper.
2 blindfolds, one for the right eye, one for the left (optional)

Exercises for Home, Desk and Lab (HDL)

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

(1) $\bar{X} = \frac{\sum X}{N}$

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

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

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

(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.

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

Questions for Further Study and Experimentation

(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 your data if you knew what color was to be presented? Check your hypothesis by experimentation.

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

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

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

(3) Yes.

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

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

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

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

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.

I.14 — Experiment: RESPONSE TIME OF THE EYE

Like many "event-recording" instruments, the eye has a response time. That is, it takes a certain period of time for the eye to process and transmit an image and to prepare itself to receive a new one.

A 33 1/3 rpm phonograph turntable—preferably one not recessed in a case—will do here. It should be placed in a well-illuminated location. Most students will see green with the fourth wheel which has sectors 1.2 cm wide at the outside.

If a second, different image succeeds the first in a time less than what the eye requires, then the two images become scrambled and we "see" a mixture of both.

Using a phonograph turntable and a series of color wheels, you will now try to determine what the response time of the eye is. Since the speed of rotation of the turntable is fixed, you will vary the speed of image succession by changing the width of the colored sectors on the wheel.

Because the eye tends to follow a moving object, it will be necessary for you to fix your vision on some stationary point just above and beyond the edge of the rotating color wheel. You may want to look through a tube made of a sheet of paper to help in this process.

The sequentially numbered blue-yellow color wheels are constructed such that each wheel has twice as many sectors half as wide as those of the preceding wheel. Thus the number of images presented to the eye per second will be

Subjective honesty will be required of each student in this experiment since there is no easy way of testing what they see.

The sharpest color change is noted when the wheel is constructed such that the rotation brings into the visual field the colors in the sequence white, yellow and blue or, with the optional wheel constructed by the students, white, green and red.

The response times obtained by an experimental group ranged from .028 to .036 seconds with blue-yellow wheels, and averaged about .02 seconds with red-green wheels. This illustrates that there are many response times for the eye that are dependent upon how and what you measure, but that all such times are quite similar. This range of values will agree well with the number of frames per second (24 to 30) in motion pictures and will also fit in with the reaction times (around 0.15 seconds) obtained by the students in the visual reaction time experiment.

It is anticipated that the students may have trouble in calculating the response time from the observed data. This will be due to their lack of experience in unit analysis. It is their first contact with this topic and the teacher should spend some doubled when the second wheel is spun at the same speed as the first wheel.

In addition, materials are provided so that you can, if you have time, build wheels with other sector widths and other colors.

Now spin the wheels in their numbered sequence and observe each one as described. With which wheel do you first see a color change? What color do you see? Do you see this color change sooner if you fix your vision on a point farther above the wheel?

With the meter stick provided, measure and record (in centimeters):

(1) the diameter of the wheel and

(2) the width of each colored sector at the outside edge of the wheel.

Using a stopwatch or the sweep hand of a wall clock, determine the speed of your turntable in revolutions per minute (rpm).

Using the three numbers you have obtained and knowing the equation which relates the circumference of a circle to

time discussing it. It may be necessary for the teacher to lead them through the calculation in class session in a manner such as this:

(a) The wheel is 25 cm in diameter; therefore, it is $25\pi = 79$ cm in circumference.

(b) The wheel is spinning at 33 1/3 rpm or at $33.3/60 = 0.55$ revolutions per second.

(c) Therefore, at the periphery, the wheel passes a fixed point at the rate of 79 cm/revolution $\times$ 0.55 revolutions/second = 43 cm/second.

(d) With 0.8 sectors/cm for the fourth wheel, this means that the number of sectors passing the fixed point/second is $0.8 \times 43 = 34.4$ sectors/second.

(e) Therefore, the response time must be somewhat longer than $1/34.4 = 0.029$ seconds/sector.

The white covering disc with the quarter-disc window was found to help in the fixation of the eye during tests on this experiment. This arrangement may induce a small conceptual "roadblock" in the students since in the calculation of sectors/second as above, it is assumed that the entire wheel is composed of the colored sectors. There are its diameter, you should now try to calculate how long it takes one sector to pass a fixed point at the edge of the wheel. Is the time interval you calculate what you would have guessed for the response time? Do you know how many frames (pictures) per second are shown in a motion picture? How does this number relate to the response time of the eye? Looking back at the sequence of wheels which you tested, can you estimate how accurate your calculated response time is? To put it another way, do you think the response time could actually be almost twice as long? Half as long? You may want to build your own wheel to obtain a more accurate answer.

A black-white wheel attached to a hand drill is provided. As you spin it faster and faster, do you "see" color anywhere on the wheel? What happens if you spin it in the opposite direction? Now look carefully at the pattern of black and white on the wheel. Can you see any relationship between where you saw color and the pattern of the wheel?

other routes of calculation which avoid this problem; the teacher may simply ask the doubters to try the same experiment without the covering disc. They should obtain roughly the same answer.

A motion picture shows 24 to 30 frames/second.

The sequence of wheels provided should allow the student to decide that the response time is less than .06 seconds (the third wheel) but longer than .03 seconds (the fourth wheel). If he wishes to build wheels of intermediate sector width, he may be able to reduce the range. These wheels are constructed by attaching the loose sectors provided to the white base disc by means of paper clips. The sector width showing is varied by overlapping the sectors to the desired extent.

The order of appearance (white wedge to black finger or black finger to white wedge) will determine the appearance of color.

I.15 - Experiment: VISUAL AND AUDITORY 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. Also compare your visual reaction time found in this experiment to the response time you find for the eyes in the experiment with the color wheel.

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,

In this experiment students are to compare their reaction times to a visual stimulus to their reaction times to an auditory stimulus. They should also compare their visual reaction time they find in this experiment to the response time of the eyes found in the color wheel experiment.

Students should see the need to find an average or mean $\bar{X} = \frac{\sum X}{N}$

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.

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.

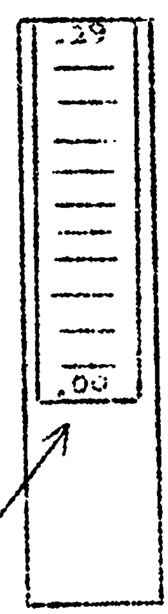
E should say "Ready" about 1 to 4 seconds before suddenly jerking back his thumb to allow the stick to fall freely.

Make two Pieron sticks by taping a strip of calibrated paper to each meter stick. 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/sec^2); T is time in seconds.

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.



calibrated strip of paper

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.

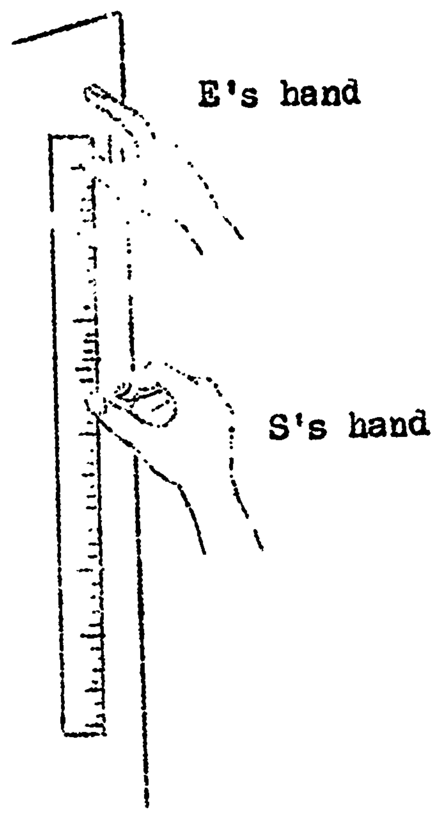
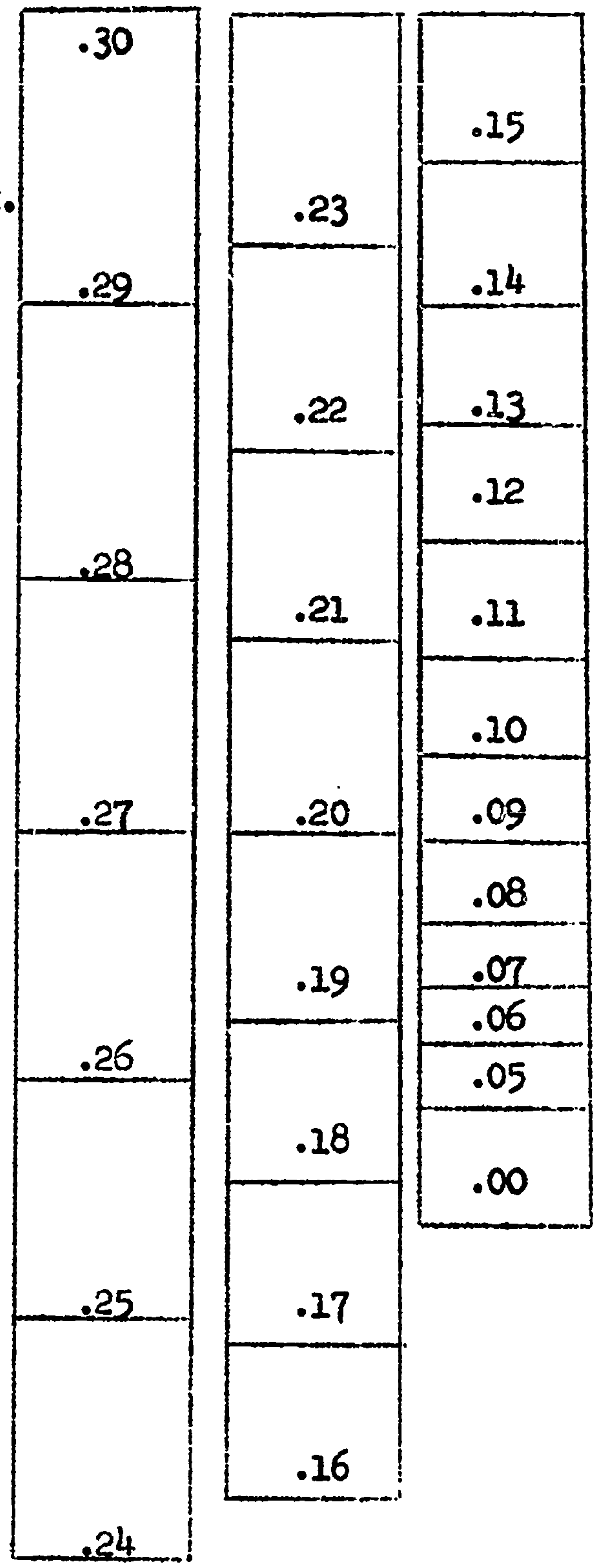


FIG. I.17

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.



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.

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

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.

Equipment and Materials
(for two lab groups of three)

2 meter sticks
2 eye shades (Halloween masks with the eye holes covered with black paper)*
2 toy mechanical crickets* (one about 3 inches long by 1 3/4 inches wide is a good size)
60 sheets of graph paper
* These can be purchased at variety or novelty stores.

K.16 -- 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

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.

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 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.

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.

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

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.

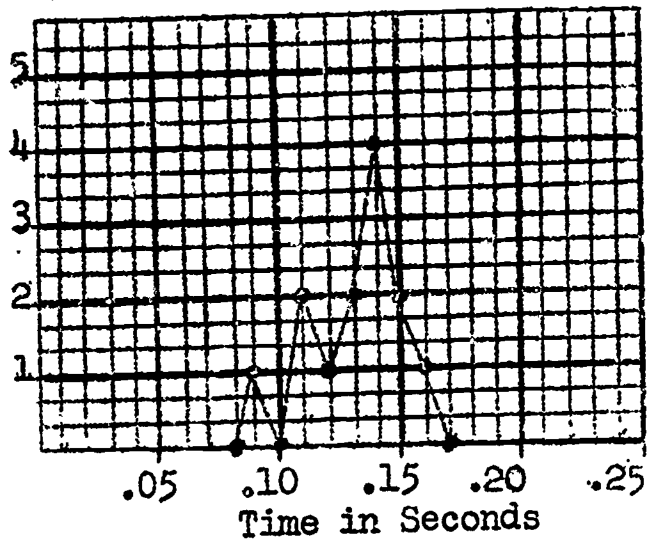
When they have finished, you will have a histogram. It should show the distribution quite clearly.

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

Graph your results. 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 separate graphs, one for the visual reaction times. In order to compare them, however, label each graph the same way. You may put both graphs on the same graph paper. Use a different color for each for easier reading.

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.

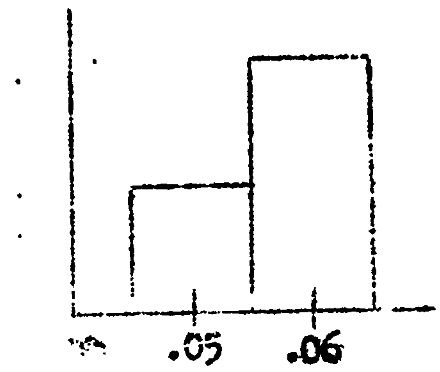


Students' graphs should come out something like the example above.

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 for 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 rounaed. In a histogram the center of the bar is placed at the proper time like this:



Exercises for Home, Desk and Lab (HDL)

(1) Compare your graph for the auditory reaction time to the one for the visual reaction time. Are the shapes of the curves similar? Do they peak near the center? Are they somewhat symmetrical? How does the range (the amount of spread of values) of one differ from the other? In which case would you think you would get a shorter reaction time?

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

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

(3) What was your shortest reaction time for each stimulus? What was your longest time for each stimulus? What was your average reaction time for each stimulus? Which ones should you report as your reaction times? Why?

(3) Students may want to report the average.

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

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) 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. Are the differences between the two scores about the same in magnitude and direction (auditory or visual)?

(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.

(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? What evidence do you have to support your belief? 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) How do you account for differences in your visual reaction time in this experiment as compared to the response time of the eyes that you found in the experiment with the color wheel?

(6) This experiment also involved muscular reaction time and a delay due to the transmission of the impulse to the muscle. The reaction time here will therefore be longer.

(7) What 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?

(7) Some things that may cause the scores to fluctuate might be (a) factors that affect your reaction time such as learning and fatigue (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.

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

(8) 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 experiment to see if age seems to affect reaction times. Those who are interested

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.

From materials you have already studied, you have seen that your senses are subject to a sensitivity threshold, a time threshold and to illusions. You and have time may experiment further.

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.

After completing the set of seven experiments on the senses, use of the microscope will be introduced . Conceptually, work with the microscope fits the set of seven sensory 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 and widely used sensory extender.

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.

I.17 - BSCS Green Experiment 1.4:
USE OF THE MICROSCOPE

I.18 - 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 the sub-stage diaphragm 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

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.

It is possible to grow your own culture of paramecia (see Chapter XX 1.12), but it is probably much easier to purchase them from Carolina Biological Supply, called Powell Laboratories, in Gladstone, Oregon. Powell Laboratories 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.

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.

I.19 - 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 (IPS Chapter II).

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).

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

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? In the first group did the volunteers consistently judge one of the cans heavier than the other? If so, how might you account for this? In the second and third groups, did the volunteers consistently judge one can heavier than the other? Try to explain any similarities and differences in the judgments of the three groups as to which can was heavier. Is there any consistency

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

(a) In the first group 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 which will still experience the illusion.

in the judgments as to "times heavier" or in the actual estimates of weight? Did one group definitely make better judgments than the other groups? If so, try to explain why.

(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) What degree of confidence do you have in the conclusions you made? What factors can you think of that might have caused you to draw a faulty conclusion?

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

(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 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 (refer to IPS, Chapter II).

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.

Questions for Further Study and Experimentation

(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 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?

(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.

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

(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.

Chapter II: Measurement, Distribution, Organization and Communication

IPS ('67 ed) - Chapter II: QUANTITY OF MATTER: MASS

Because our sense of heft or weight is so easily deceived, we are forced to an instrumental aid for extension of our sense of heft.

II.1 - VOLUME (IPS II.1)

Refer to the 1967 edition of IPS, Chapter II, sections 1-7 (1966 edition--sections 1-6). Refer to the IPS Teacher's Guide for questions related these sections.

II.2 - MEASURING VOLUME BY DISPLACEMENT OF WATER (IPS II.2)

Only read this section. Your teacher will demonstrate.

II.3 - Demonstration: VOLUME BY WATER DISPLACEMENT

Have students read section II.2. Demonstrate the technique of finding volume by water displacement. Have a student find the volume of water in a graduated cylinder. Immerse an object such as a rock in the water and again have a student find the volume of the water. Subtract the first reading on the graduated cylinder from the second reading to find the volume of the object. (Groups of students could do this.)

II.4 - SHORTCOMINGS OF VOLUME AS A MEASURE OF MATTER (IPS II.3)

II.5 - MASS (IPS II.4)

II.6 - Experiment: THE EQUAL-ARM BALANCE (IPS II.5)

II.7 - Experiment: THE PRECISION OF THE BALANCE (IPS II.6)

II.8 - Experiment: BEADS AND GRAMS (IPS II.7)

WARNING TO TEACHER:
Ask students to bring five to ten pennies for II.7 (IPS II.6).

Equipment and Materials (II.1-II.8)

1 graduated cylinder ($250\ cm^3$)
An irregular object such as a small rock
15 equal-arm balances
15 sets of bead masses
Various objects such as test tubes, paper clips, filter paper, etc.
10 pennies (have students bring them from home)
4 sets of gram masses (1, 2, 5, 10 gram)
60 sheets of graph paper

Exercises for Home, Desk and Lab (HDL)

(1) In Experiment I.19 you made estimates of mass. How is your judgment of volume? How much greater is the volume of the larger can? Estimate the actual volume.

(1) They can make estimates and find the volume:

$$V = \pi r^2 h t$$

(2) What are the differences in the density of the two cans?

(2) $D = \frac{m}{V}$ After they have done Chapter II and have some experience with finding mass and volume, you may want

to refer back to Experiment I.19. The size-weight illusion seems to result from our experiences with density. They may be able to find density now and may therefore be able to understand this illusion better.

II.9 - MEASUREMENT AND UNCERTAINTY

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 to the right has more area? Even more specifically, what is the ratio of area A to area B?

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?

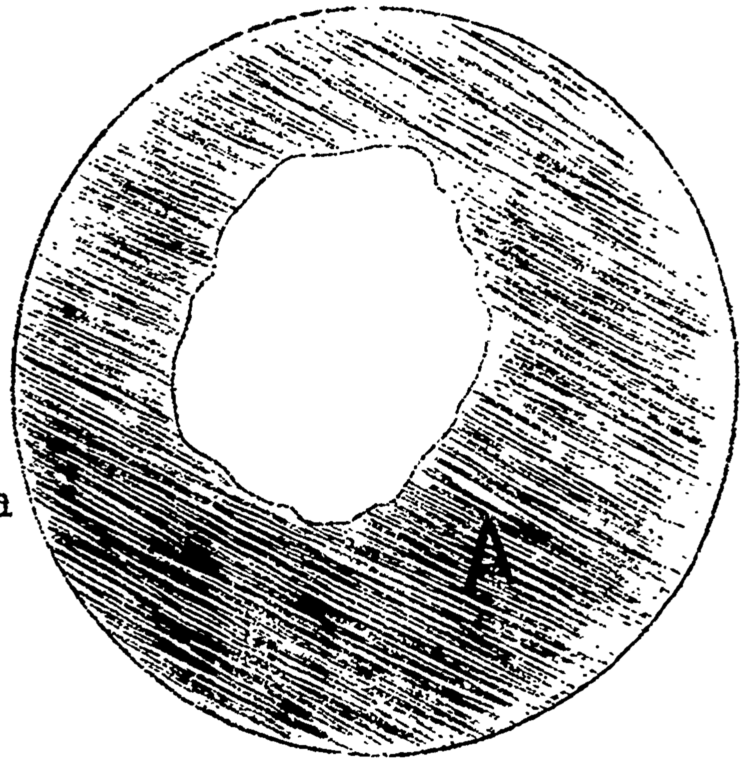


FIG. II.1 - A

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

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: all measurement is counting. In measuring anything, we choose a basic unit and ask how many of the basic units will fit into the object being measured.

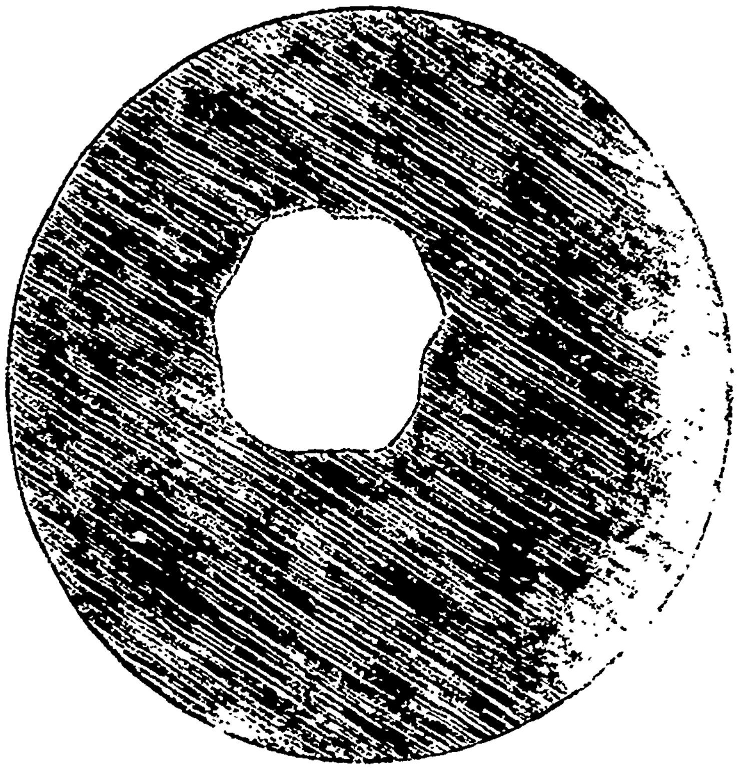


FIG. II.1 - B

II.10 - SYSTEMS AND UNITS OF COUNTING

Suppose we had used a different sheet 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 as large, the count for both A and B would have been one-half the original count. The ratio of the areas would be the same no matter what size squares were used. We would 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.

HDL #2 goes with this section.

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

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

II.11 - 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

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

(1) measurements of distance [D],

(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 distance multiplied by distance, therefore expressed as D^2. In fact, area is always some factor multiplied by distance times distance. The area of a triangle is equal to the factor "$\frac{1}{2}$" multiplied by the distance (the base) multiplied by the distance (the height). What is the factor in the equation 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 D^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

The dimensions of volume are D^3.

all of these are really one dimension--i.e., distance.

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, D^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.

II.12 - Experiment: THE SCALENE TRIANGLE

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

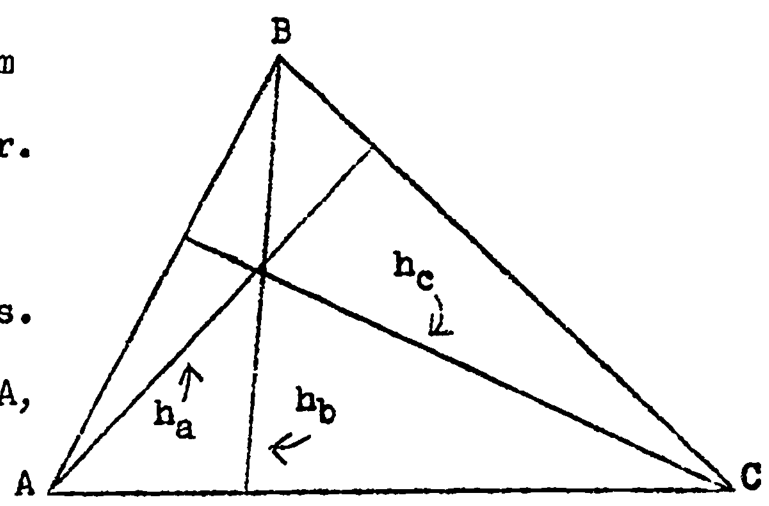


FIG. II.2

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.

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.

II.13 - 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.

II.14 - 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."

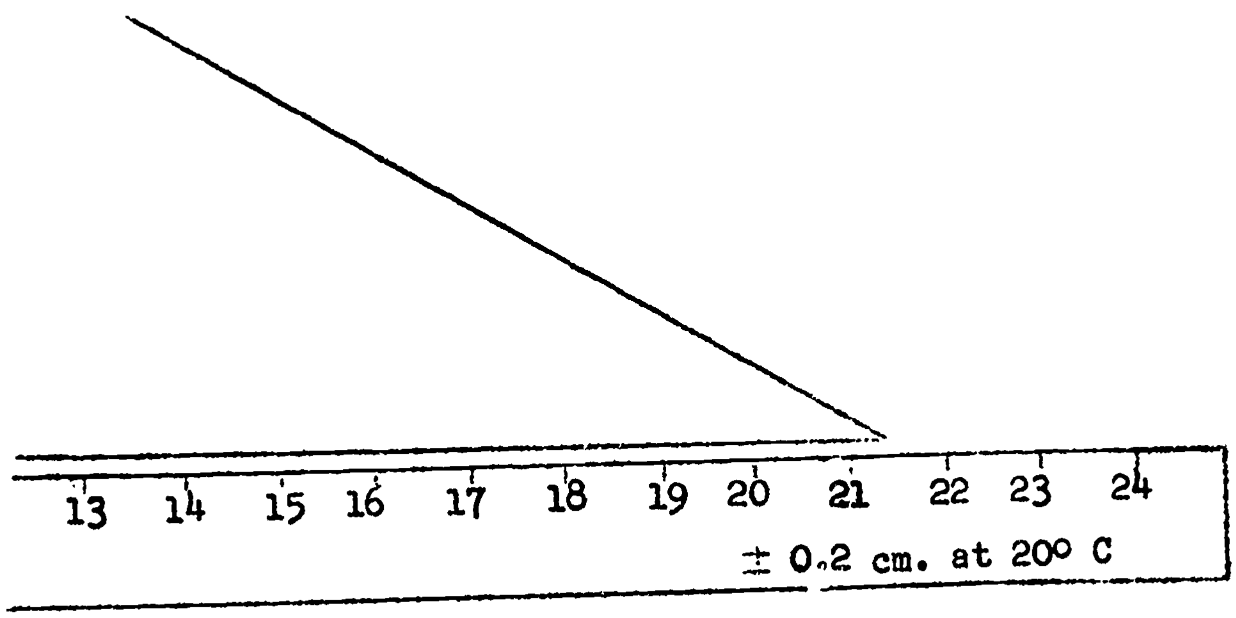


FIG. II.3

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. It 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

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

II.15 - 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. II.3) 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 21.5 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 $\pm$0.1 cm." This type of uncertainty associated with measurement is called human error.

II.16 - UNCERTAINTY DUE TO CHANGES WITHIN THE SYSTEM

Can you think of any way the triangle might be changed because of the measurement? Perhaps the scietist 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 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 suf-

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 polyficiently to cause sizeable errors in measurement.

graph on the subject may excite him as much as any incriminating question.

II.17 - RANGE OF UNCERTAINTY

HDL #8 and 9 go with this section.

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 0.0 cm for the error due to change within the system. The scientist's reading was 21.5 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 21.5±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 21.2 cm and 21.8 cm.

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

II.18 - PLACE OF THE UNCERTAINTY

HDL #10 and 11 go with this section.

As you probably recall, we have names for the positions [illegible] occupy in numbers. For example,

hundreds	tens	ones	.	tenths	hundredths
___	___	___	.	___	___

The place of the uncertainty is the same place occupied by the range of the uncertainty. In our previous example, 21.5 ± 0.3, the range of the uncertainty is in the tenths place. Therefore, the place of the uncertainty is also in 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.

II.19 - ROUNDING OFF TO THE CORRECT PLACE

HDL #12 goes with this section.

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 ± 1.689, the uncertainty (1.689) 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 ± 1.689 becomes 103 ± 2 when rounded off properly. Before you read any further, round off the following measurements to the proper place.

(1) 421 ± 210 miles

(2) 6591.2 ± 12 meters

(3) 1.269 ± 0.068 centimeters

(4) 500 ± 109 seconds

(5) 50,000 ± 100 kilograms

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

(1) 400 ± 200
(2) 6590 ± 10
(3) 1.27 ± 0.07
(4) 500 ± 100
(5) 50,000 ± 100

II.20 - 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."

II.21 - SIGNIFICANT FIGURES

Significant figures are the digits that are certain plus one more. The measurement 21.5 ± 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 21.5. 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.

HDL #13 goes along with this section.

(1) 251 ± 1 kilograms

(2) $6{,}532 \pm 0.04$ grams

(3) 500 ± 10 seconds

(4) 500 ± 1 centimeter

(5) 4.0002 ± 0.00149 square meters

II.22 - 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.

$$\begin{array}{r} 112.2\boxed{3} \\ 100.\boxed{0} \\ 519.169\boxed{8} \\ 2.00\boxed{1} \\ \hline 723.\boxed{3998} \end{array}$$

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

(1) 251
(2) 6532.39
(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

HDL #14 goes along with this section.

figures.

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

(1) 1601

(2) 49.8003 ± 0.03
1.000 ± 0.001

(2) 50.80

II.23 - 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,

HDL #15 goes along with this section.

$$\begin{array}{r} 32.\boxed{5} \\ -\ 8.59\boxed{8} \\ \hline 23.\boxed{598} \end{array}$$

The proper answer, rounded off, is 23.6. Try the following problems and check with your teacher before you continue.

(1) 973.009
-70.004

(1) 903.005

(2) 523.0013 ± 0.0235
-34.00298 ± 0.00069

(2) 487.00

II.24 - MULTIPLYING AND DIVIDING SIGNIFICANT FIGURES

When you multiply or divide, your answer should have no more significant figures than the smallest number of

HDL #16 and 17 go along with this section.

significant figures originally available.

For example,

$$
\begin{array}{rl}
156 & \text{(three sig. figs.)} \\
\underline{365} & \text{(three sig. figs.)} \\
780 & \\
936 & \\
\underline{468} & \\
\cancel{56940} & \\
56{,}900 & \text{(therefore, three sig. figs.)}
\end{array}
\qquad
\begin{array}{rl}
89453 & \text{(five sig. figs.)} \\
\underline{111} & \text{(three sig. figs.)} \\
89543 & \\
89543 & \\
\underline{89543} & \\
\cancel{10030283} & \\
10{,}000{,}000 & \text{(therefore, three sig. figs.)}
\end{array}
$$

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

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

Multiply:

(1) $\begin{array}{r} 269.4 \pm 0.1 \\ \underline{16.2 \pm 0.1} \end{array}$ (2) $\begin{array}{r} 1000.0 \pm 0.1 \\ \underline{1.0 \pm 0.1} \end{array}$

(1) 4360
(2) 1000

Divide:

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

(1) 8.2481
(2) 4800

II.25 - 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 460,000, we cannot tell whether the uncertainty lies in the ones, tens, hundreds or thousands place.

To eliminate the confusion, scientists 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 460,000, 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 (460×10^5).

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 ± 1.35 cm

(2) 10,000 ± 12 miles

(3) 0.0258 ± 0.013

(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

II.26 - 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, W.J. Youden, Experimentation and Measurement (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 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.

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 *is* uncertain.

Exercises for Home, Desk and Lab (HDL)

(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.

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

(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?

(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.

(3) If you multiply distance times distance times distance, what are the dimensions of your answer? (Use D for

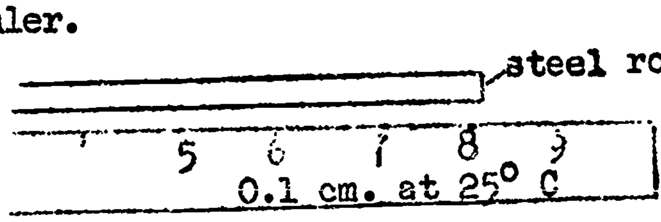
(3) D^3, which is the dimension of volume, is the correct answer.

distance, M for mass and T for time.)

(4) What are the dimensions associated with the speed of your family car? (Use D for distance, M for mass and T for time.)

(5) If you multiply mass times distance per time squared, then multiply by distance, what are the dimensions of your answer? (Notice the similarity to the expression for E_k.)

(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.



(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

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

(5) $M\left(\frac{D^2}{T^2}\right)$ is the correct answer. ($M\left(\frac{D}{T}\right)^2$ is mass times velocity squared which are the dimensions of E_k.1.)

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

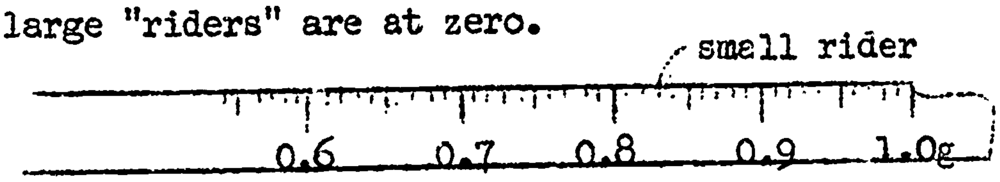
(a) Total uncertainty would be ± 0.3 cm.

(b) 8.2 ± 0.3 cm

(c) The range would be 0.6 cm.

triple-beam centigram balance. The large "riders" are at zero.

(7)-



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

(a) ± 0.005 g

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

(b) ± 0.01 g

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

(c) ± 0.015 g

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

(8) The range is 0.4 grams.

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

(9) The range is 0.16 seconds.

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

(10) The tenths place.

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

(11) The hundredths place.

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

(a) 1.065 ± 0.0295

(b) 0.0059 ± 0.005

(c) 1649 ± 100

(12)-

(a) 1.07 ± 0.03

(b) 0.006 ± 0.005

(c) 1600 ± 100

(13) Express the following using significant figures:

(a) 649.2 ± 0.5

(b) 0.00059 ± 0.00015

(c) 5649 ± 29.5

(13)-

(a) 649.2

(b) 0.0006

(c) 5650

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

$$\text{(a)}\quad \begin{array}{r} 649.2 \pm 0.5 \\ 29.26 \pm 0.01 \\ 1.269 \pm 0.001 \\ \hline \end{array} \qquad \text{(b)}\quad \begin{array}{r} 527.8 \pm 0.1 \\ 61.39 \pm 0.01 \\ \hline \end{array}$$

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-do the problems, expressing their answers using scientific notation.

(14)-
(a) 6.797×10^2
(b) 5.892×10^2

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

$$\text{(a)}\quad \begin{array}{r} 32.50 \pm 0.01 \\ -\ 8.902 \pm 0.001 \\ \hline \end{array} \qquad \text{(b)}\quad \begin{array}{r} 657.89 \pm 0.06 \\ 549.01 \pm 0.01 \\ \hline \end{array}$$

(15)-
(a) 2.360×10^1
(b) 1.0888×10^2

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

(16)-

(a) $\frac{156 \pm 2}{365 \pm 6}$ (b) $\frac{1.009 \pm 0.001}{2 \pm 1}$

(a) 5.69×10^4
(b) $2\ \ 2 \times 10^0$

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

(a) $\frac{654.298 \quad 0.001}{2.0 \quad 0.1} =$

(b) $\frac{54.07 \quad 0.05}{1.68 \quad 0.01} =$

(17)-

(a) 3.3×10^2

(b) 3.22×10^1

II.27 - Experiment: MASS OF A TURTLE

You observed a turtle earlier in the course. Weight your turtle to the nearest gram and write its mass on the board. Prepare a class histogram or bar graph showing the number of turtles at a given mass on the y axis and the mass of the turtles on the x axis.

This experiment gives students weighing (massing) experience and data is collected that should show another distribution curve. If no two turtles 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 turtle masses will give a better distribution curve. You will have to decide for the students after they have written the turtle masses on the board. Use at least fifteen turtles.

You have already determined your reaction times in Experiment I.15 and I.16. Refer to the graph of your results. Does the turtle-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.

Yes, the two graphs should be similar.

WARNING TO TEACHER: Ask students to bring ten coins for II.28.

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

II.28 - Experiment: COIN FLIPPING

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

This experiment may be done in groups or may be done individually if you have enough coins and boxes. 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.

Yes, the graphs should be similar.

Yes.

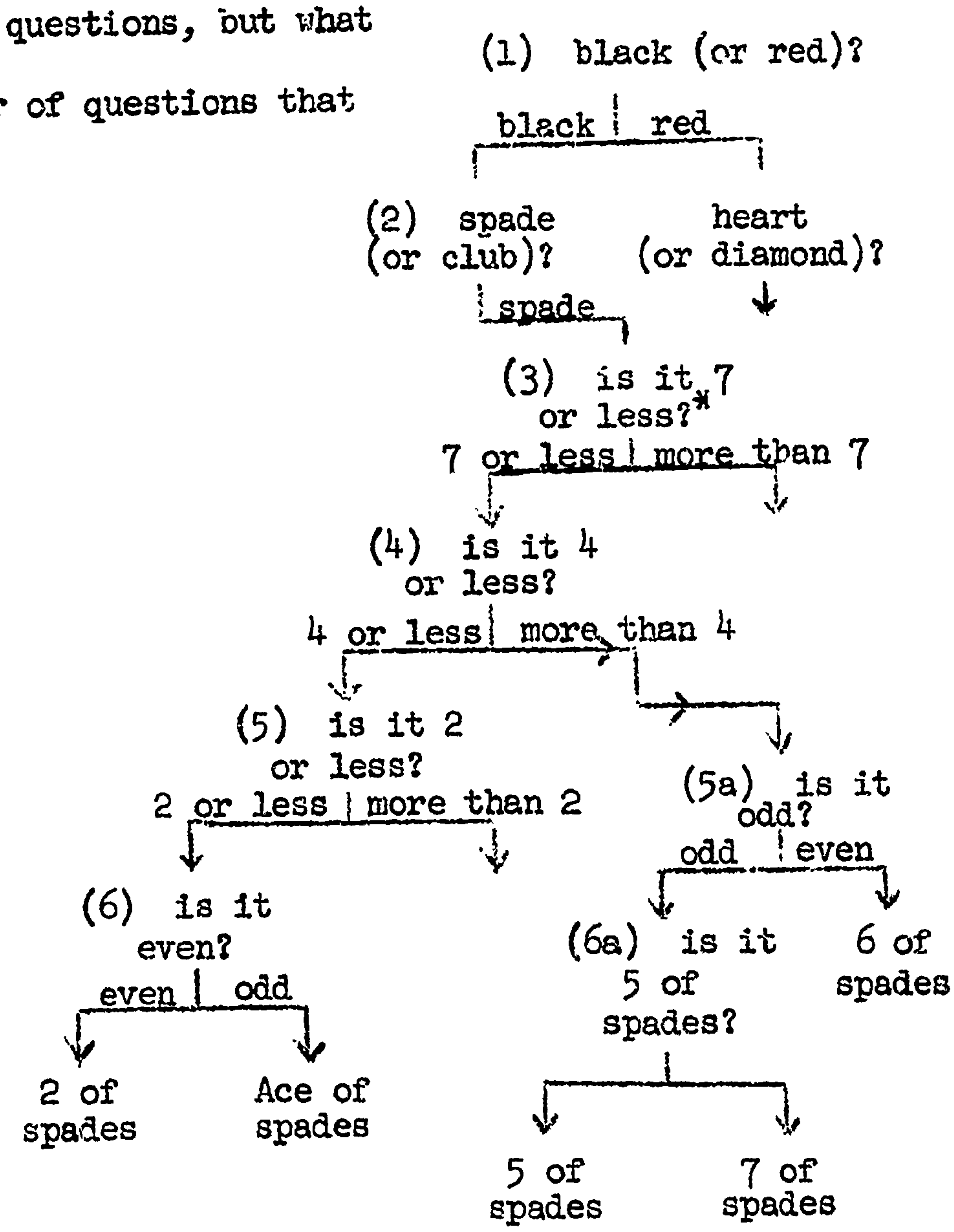
II.29 - Demonstration: CLASSIFICATION AND ORGANIZATION

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.

... 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 eventually 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?

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 and 13, respectively.

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 and responsibility in organizations or genealogical tables.

WARNING TO TEACHER: Ask the students to bring in about twenty leaves (as many varieties as possible) for II.30.

II.30 - Experiment: CLASSIFICATION OF LEAVES

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 20 to 30 minutes to determine as many characteristics as you can, and then to try to arrange or

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.

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.

Leaf Number	CHARACTERISTIC SHAPE → Tear-drop	Heart	Blade	Round	Paral-lel un-branched	VEINING → 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								

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

The main purposes of this exercise are to acquaint the student with the Romau Square method of handling observations or data; to contrast for him the relative difficulties in classification encountered in a simple man-made system like the deck of cards with those found in biological systems; 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 that is the case, the teacher should store 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.

Once you are satisfied with your Roman Square, you may want to re-organize 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.

II.31 - 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 com-

the leaf collections overnight in damp newspaper or damp paper towels.

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

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 municate 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.

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.

II.32 - 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.

Equipment and Materials

Overhead projector
Prepared color transparency

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.

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

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.

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.

<u>Equipment and Materials</u>

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 non-recognizable 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.

II.33 - 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 <u>one</u> 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 <u>control</u> 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 (Exp. I.11), 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.

II.34 - Test: THE TURTLE

Refer to the list of observations you drew up in Experiment I.1. Could you add to this list if you were asked to observe a turtle again?

Once again observe the turtle which your teacher will put before you, but this time observe it as a scientist might do it. Test your new techniques, maintaining an independent written record of every feature and activity of the turtle which can be observed in one class period.

Repeat the same physical arrangement as in Experiment I.1. 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.1, the students should be able to find

(1) how much the turtle 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 turtle 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; and

(10) what it does in water (CAUTION: the turtle is an air breathing animal and the students should be warned at the outset that no test done with it should harm it).

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 turtle's responses (to bright light, colors, sounds, another turtle, etc.)

(7) Data gathered on other turtles for comparison

(8) Care exercised in handling of animal

Part II:

PROPERTIES OF MATTER

Rationale: Properties of Matter

This part of the course is designed to follow the '67 edition (blue cover) of the IPS course, Chapters II.8 through VI.12 inclusive. Since there may be those students who have already had the IPS course, we have provided an alternate path that still uses the IPS text material but substitutes new experiments for most of the IPS experiments. There are at least three versions of IPS material in existence at this writing. Since you may be using any one of them, we have correlated these versions in terms of numbering systems and some information that appears in the '67 edition. We suggest that you acquire a copy of the '67 edition for your own use.

The numbering of this course has been designed such that the section numbers in brackets refer to the material for the particular section which, when it occurs in both editions, is numbered according to the '67 edition.

Such items as were determined to be of value to the student who is not using the '67 edition have been written into the student guide where they apply.

Notation such as III.1a indicates a supplemental experiment. The lower case "a" indicates that it is the first such supplement; therefore, III.2b would indicate the second supplement to III.2.

Should you have high ability students capable of going beyond the IPS material, the supplementary material could be used to challenge them.

Using the process of experimentation, observation and comparison, the student will be guided toward the notion that there are certain characteristic properties of matter that allow one to differentiate and to classify material substances. As a result of this orientation, the student will then see that these characteristic properties can be useful in the separation and analysis of materials. The insight that the student gains here will be useful at a later point in the course when the concept of "fundamental particles," or building blocks of matter, is discussed.

The study of characteristic properties of matter is approached with the emphasis being placed on the substance and not upon a given sample; the student must look for properties that are independent of the size or the shape of the sample.

Outline: Properties of Matter

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
('66 ed)				
II.7		3 periods	IPS	The Mass of Dissolved Salt
II.8			IPS	The Mass of Ice and Water
II.9			IPS	The Mass of Mixed Solutions
II.10			IPS	The Mass of Copper and Sulfur
II.11			IPS	The Mass of Gas
II.12	The Conservation of Mass		IPS	
II.13	Laws of Nature		IPS	
*	*	*	*	*
('67 ed)				
II.8		3 periods	IPS	The Mass of Dissolved Salt
II.9			IPS	The Mass of Ice and Water
II.10			IPS	The Mass of Mixed Solutions
II.11			IPS	The Mass of Copper and Sulfur
II.12			IPS	The Mass of Gas
II.13	The Conservation of Mass			
II.14	Laws of Nature			

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
III	Characteristic Properties	20 periods	IPS	
III.1	Density		IPS	
III.2			IPS	The Density of Solids
III.3			IPS	The Density of Liquids
III.4			IPS	The Density of a Gas
III.4a			SG	Weights and Densities of Equal Volumes of Gases
III.5	The Range of Density		IPS	
III.6			IPS	Thermal Expansion of Solids
III.7			IPS	Demonstration: Thermal Expansion of Liquids
III.8			IPS	Demonstration: Thermal Expansion of Gases
III.9			IPS	Demonstration: Elasticity of Solids
III.10			IPS	Demonstration: Elasticity of Gases
III.11			IPS	Freezing and Melting
III.11a			SG	Behavior of Solids on Warming
III.11b			SG	Freezing and Melting Curves
III.12			IPS	Micro-Melting Point

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
III.13			IPS	Boiling Point
('66 ed)				
IV	Solubility and Solvents	14 periods	IPS	
IV.1			IPS	Solubility
IV.1a			SG	Temperature Versus Solubility
IV.1b			SG	The Effect of Temperature on Solubility
IV.1c			SG	The Effect of Temperature on Solubility
IV.2	Wood Alcohol and Grain Alcohol		IPS	
IV.3			IPS	Methanol as a Solvent
IV.4			IPS	Preparation of Oil of Vitriol
IV.5			IPS	Two Gases
IV.5a			SG	Two Gases
IV.6	Hydrogen		IPS	
IV.7	Carbon Dioxide		IPS	
IV.3			IPS	Testing Some Unknown Gases

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
IV.8a			SG	The Gaseous Products of a Burning Candle
IV.9	The Solubility of Gases		IPS	
IV.10			IPS	The Solubility of Ammonia Gas
IV.12	A More Careful Look at the Distillation of Wood		IPS	
*	*	*	*	*
('67 ed)				
IV	Solubility and Solvents	14 periods	IPS	
IV.1			IPS	Solubility
IV.2			IPS	The Effect of Temperature on Solubility
IV.1a & IV.2a			SG	Temperature Versus Solubility
IV.2b			SG	The Effect of Temperature on Solubility
IV.2c			SG	The Effect of Temperature on Solubility
IV.3	Wood Alcohol and Grain Alcohol		IPS	

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
IV.4			IPS	Methanol as a Solvent
IV.5			IPS	Preparation of Oil of Vitriol
IV.6			IPS	Two Gases
IV.6a			SG	Two Gases
IV.7	Hydrogen		IPS	
IV.8	Carbon Dioxide		IPS	
IV.8a			SG	The Gaseous Products of a Burning Candle
IV.9	The Solubility of Gases		IPS	
IV.10			IPS	The Solubility of Ammonia Gas
IV.11	Other Solvents		IPS	
IV.12	A More Careful Look at the Distillation of Wood		IPS	
*	*	*	*	*
('66 ed)				
V	The Separation of Substances	23 periods	IPS	
V.1			IPS	Fractional Distillation
V.1a			SG	Fractional Distillation

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
V.2	Petroleum		IPS	
V.3	The Direct Separation of a Mixture of Solids		IPS	
V.4a			SG	Separation of a Mixture of Solids
V.5			IPS	Fractional Crystallization
V.5a			SG	Fractional Crystallization
V.6			IPS	The Substances in a Sample of Black Ink
V.7			IPS	Paper Chromatography
V.7a			SG	Paper Chromatography
V.8	Mixtures of Gases		IPS	
V.9			IPS	Separating a Gas from Air
V.9a			SG	Separating a Gas from Air
V.10			IPS	Another Component of Air
V.11	Nitrogen and Oxygen		IPS	
V.12	Low Temperatures		IPS	
V.13	The Fractional Distillation of Air		IPS	
V.14	Mixtures and Pure Substances		IPS	

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
('67 ed)				
V	The Separation of Substances	23 periods	IPS	
V.1			IPS	Fractional Distillation
V.1a			SG	Fractional Distillation
V.2	Petroleum		IPS	
V.3	The Direct Separation of Solids from Liquids		IPS	
V.4			IPS	Separation of a Mixture of Solids
V.4a			SG	Separation of a Mixture of Solids
V.5			IPS	Fractional Crystallization
V.5a			SG	Fractional Crystallization
V.6			IPS	The Substances in a Sample of Black Ink
V.7			IPS	Paper Chromatography
V.7a			SG	Paper Chromatography
V.8	Mixtures of Gases: Nitrogen and Oxygen		IPS	
V.9	Low Temperatures		IPS	
V.10	Mixtures and Pure Substances		IPS	

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
VI	Compounds and Elements	18 periods	IPS	
VI.1			IPS	Decomposition of Sodium Chlorate
VI.1a			SG	Decomposition of Potassium Chlorate
VI.2			IPS	Decomposition of Water
VI.2a			SG	Decomposition of Dilute Salt Solutions
VI.3	The Synthesis of Water		IPS	
VI.4			IPS	Synthesis of Zinc Chloride
VI.4a			SG	Synthesis of a Chloride
VI.5	The Law of Constant Proportions		IPS	
VI.6			IPS	A Reaction with Copper
VI.6a			SG	A Reaction with Magnesium
VI.7			IPS	Reduction of Copper Oxide
VI.7a			SG	Oxidation-Reduction
VI.8	Elements		IPS	
VI.9	Two Special Cases: Lime and Oxymuriatic Acid		IPS	

SECTION	TOPIC	TIME	TEXT	EXPERIMENT
VI.10			IPS	Flame Tests of Some Elements
VI.11			IPS	Spectra of Some Elements
VI.12	Spectral Analysis		IPS	

Chapter II ('66 ed): Mass

II.7 - Experiment: THE MASS OF DISSOLVED SALT

II.8 - Experiment: THE MASS OF ICE AND WATER

II.9 - Experiment: THE MASS OF MIXED SOLUTIONS

II.10 - Experiment: THE MASS OF COPPER AND SULFUR

II.11 - Experiment: THE MASS OF GAS

II.12 - THE CONSERVATION OF MASS

II.13 - LAWS OF NATURE

*   *   *

Chapter II ('67 ed): Mass

II.8 - Experiment: THE MASS OF DISSOLVED SALT

II.9 - Experiment: THE MASS OF ICE AND WATER

II.10 - Experiment: THE MASS OF MIXED SOLUTIONS

II.11 - Experiment: THE MASS OF COPPER AND SULFUR

II.12 - Experiment: THE MASS OF GAS

II.13 - THE CONSERVATION OF MASS

II.14 - LAWS OF NATURE

Chapter III (IPS): Characteristic Properties

III.1 - Density

III.2 - Experiment: THE DENSITY OF SOLIDS

III.3 - Experiment: THE DENSITY OF LIQUIDS

III.4 - Experiment: THE DENSITY OF A GAS

III.4a - Experiment: WEIGHTS AND DENSITIES OF EQUAL VOLUMES OF GASES

We have seen in IPS 3.4 that the gas we used did in fact have mass; therefore, we were able to establish its density.

In this experiment you will have the opportunity to attempt to weigh equal volumes of different gases -- i.e., oxygen, carbon dioxide, natural gas and perhaps other gases if available. From the accumulated information, you will then be able to compare the relative densities of these gases.

Obtain a one-hole stopper and cut a deep groove around it as shown in the accompanying diagram.

Remove the rubber cap from a medicine dropper and carefully insert the tapered end through the large end of the rubber stopper until it is completely through the stopper. Place the end of a plastic bag over the large end of the single-hole rubber stopper and secure it in place with a rubber band. Press out all of the air in the plastic bag and replace the rubber cap on the tapered end of the medicine dropper. Weigh this assembly and record.

Remove the rubber cap and connect the assembly to an oxygen gas source as supplied by your teacher. Hold the bag assembly by the rubber stopper and fully inflate the bag. Let the excess gas escape so that the gas pressure inside the bag equals the atmospheric pressure, then replace the rubber cap on the medicine dropper. Weigh the bag of gas and record.

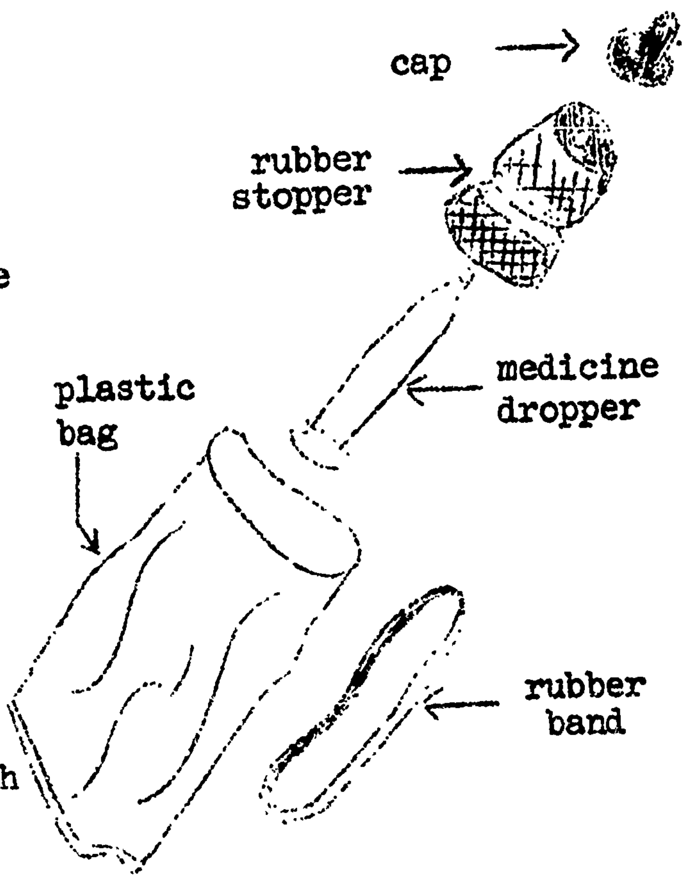


FIG. III.1

This is an extension of of Exp. III.4 and is designed for the purpose of making a comparative study of several gases involving the characteristic property of density. This experiment will also demonstrate to the student that there is a need for controlling any existing variables, such as temperature and pressure, for accurate measurement.

Repeat the above procedure using carbon dioxide, natural gas or any other gas that may be available to you, and record the weights for each.

To determine the volume of the plastic bag, completely fill a large bottle with water and arrange as shown in the accompanying diagram.

Remove the cap from the medicine dropper as before and attach in its place a piece of rubber tubing. Put the other end of the hose into the neck of the bottle and gently squeeze the bag until all of the air or gas used is removed. After removing the tube from the inverted bottle, place a solid stopper in the jug, remove the jug and place it upright on the table. Determine the volume of water remaining in the jug. The difference between this volume and the total volume of the jug will represent the volume of the plastic bag.

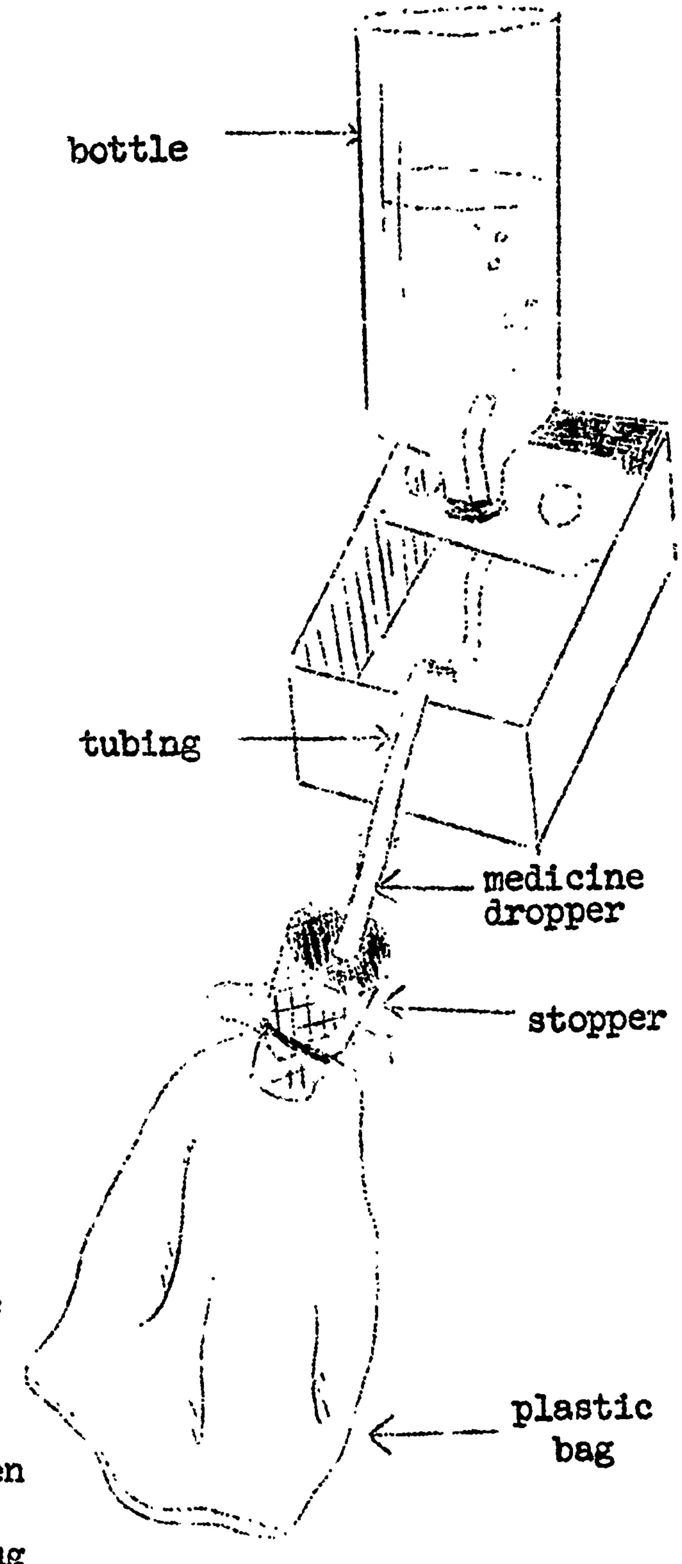


FIG. III.2

Having determined both the weights and the volumes of the respective gases, you

If compressed bottled gas is not available in the laboratory, it may be necessary to generate the gas in the lab.

(a) Oxygen

Set up a generator by inserting a dropping funnel into a two-hole rubber stopper equipped with a delivery tube. Place the stopper assembly into a 250 ml flask containing 5 grams MnO_2 powder. Using distilled water, dilute 50 ml of 30% H_2O_2 to 100 ml. Add the diluted H_2O_2 via the dropping funnel as needed to release a steady flow of oxygen. Pass the generated gas through a drying tube containing either $CaCl_2$ or $CaSO_4$. This amount of peroxide will give about 5 liters of oxygen. (CAUTION: This should be done by the teacher. H_2O_2 burns the flesh. Use safety glasses and rubber gloves. In case of accident, wash thoroughly with water.)

An alternate method for generating oxygen would be to use Na_2O_2 in a flask into which water is introduced.

(b) Carbon Dioxide

Dry ice is a good source for this gas. Eight ounces of this material will provide enough gas for thirty students. Place chunks of this in warm water and use a long delivery tube leading from the generator so that the gas will warm up to room temperature.

If dry ice is not available, set up a CO_2 generator using $CaCO_3$ and HCl. In a 250 ml flask fitted with a long stem funnel and delivery tube, place 25 gm $CaCO_3$ and 100 ml of 6 M HCl. This will produce about 6 liters of gas at room temperature and pressure

(c) Ammonia gas

For a class of 30 students warm a dry mixture of 50 gm of NH_4Cl and 50 gm $Ca(OH)_2$.

(d) Natural gas

This may be obtained by filling the plastic bag directly from the gas lines. Note, however, this would not be satisfactory if one wishes to determine the molecular weight or density of Methane gas (natural gas is a mixture).

Determination of Volume of Plastic Bag.

Have the students determine the bag volume after the gases have been collected and weighed. Empty the bag and fill with air. Repeat a time or two in order to insure that the air is essentially the only gas in the bag. Then obtain the volume by water displacement.

This will avoid getting the bag wet before all the gas weights are determined.

now can calculate the respective densities of these gases. Record this information and arrange these gases in the order of their increasing densities.

This experiment was performed at room temperature and atmospheric pressure. What would be your prediction of the outcome of this experiment if it had been carried out on top of Mt. Hood instead of here in the school laboratory? For example, would your data have been affected in any way and would the resulting densities of your gas samples be changed in any way? Explain the reasoning for forming your prediction.

Note that on this level the student will be dealing only with the apparent weights of the gases used and it will not be desirable to involve him with the bouyant affect of air at this point in the course.

On the basis of the data that he receives, he should then determine that the order of increasing densities would place them in the following fashion -- NH_4 -- CH_4 (Nat.gas) O_2 -- CO_2.

The clue to the student's answer as to the outcome of the experiment if performed on Mt. Hood lies in the fact that the pressure inside the bag is equalized with the atmospheric pressure before each weighing. Since the atmospheric pressure at that elevation would be less than the laboratory pressure, it then follows that the weight of the gas would be somewhat less The relative positions of the gases, however, would not be changed.

Equipment and Materials (for thirty students)

15	1 qt size plastic bags
15	single hole rubber stoppers
15	rubber bands
15	medicine droppers
	Balance (centigram)
15	large jars or $2\frac{1}{2}$ liter acid bottles
15	rubber delivery tubes
15	thermometers ($-10^{\circ}C$ to $110^{\circ}C$)

III.5 - THE RANGE OF DENSITY

15 large graduates
sources of O_2, CO_2, NH_3, nat. gas

III.6 - Experiment: THERMAL EXPANSION OF SOLIDS

The teacher may wish to demonstrate sections III.7 through III.10 as they are discussed. See these sections in the IPS textbook:

III.7 - THERMAL EXPANSION OF LIQUIDS

III.7 Demonstration
III.8 Demonstration
III.9 Demonstration
III.10 Demonstration

III.8 - THERMAL EXPANSION OF GASES

III.9 - ELASTICITY OF SOLIDS

III 10 - ELASTICITY OF GASES

III.11 - Experiment: FREEZING AND MELTING

III.11a - Experiment: BEHAVIOR OF SOLIDS ON WARMING

This experiment involves the 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.

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.

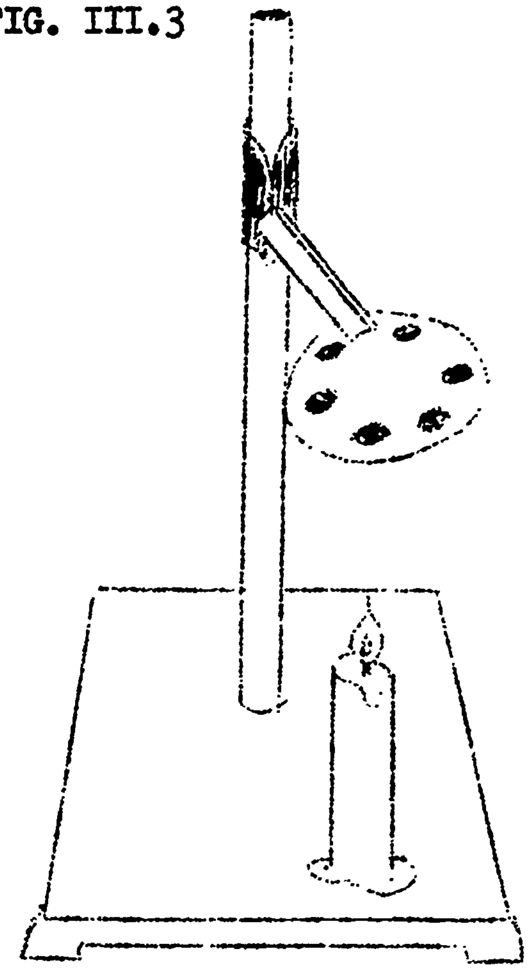
Place a lid from a tin can on an iron ring stand as shown in the figure at the right. The lid should have some depression made in it to hold the substances to be tested. Adjust the height of the ring so that it is about 8 cm above the tip of your candle. Place on the lid, equally spaced near the edge, 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. 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.

FIG. III.3



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.

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 substances starts to melt. Allow the beaker and its contents to cool and discard the solid material. (Do not put it in the sink.)

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 mat-

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.

erial 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.

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 (for thirty students

15 candles
15 bunsen burners
15 ring stands, ring, wire guaze
15 250 ml beaker
15 tin can lids
Small pieces of sulfur, lead, tin, copper and steel wool

III 11b - Experiment: FREEZING AND MELTING CURVES

In experiment III.11 we attempted to show whether the freezing point was really a characteristic property of matter. We then assumed that if this was true, it would also be true that the melting point of a substance is also a characteristic property of matter. In

This is an extension of Exp. III.11 using both the cooling and warming curves of several substances. It also provides the student with an opportunity to make an analysis of the characteristics of several substances and to determine their basic differences and similarities.

this experiment we attempt to show that both these statements are true by studying the cooling curve of a liquid substance through its freezing point and then to study the warming curve of the same substance as it passes from its solid state through the freezing point into the liquid state.

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^{o} C. Remove the test tube from the hot water bath and place in a beaker of cold water at about 30^{o} 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.

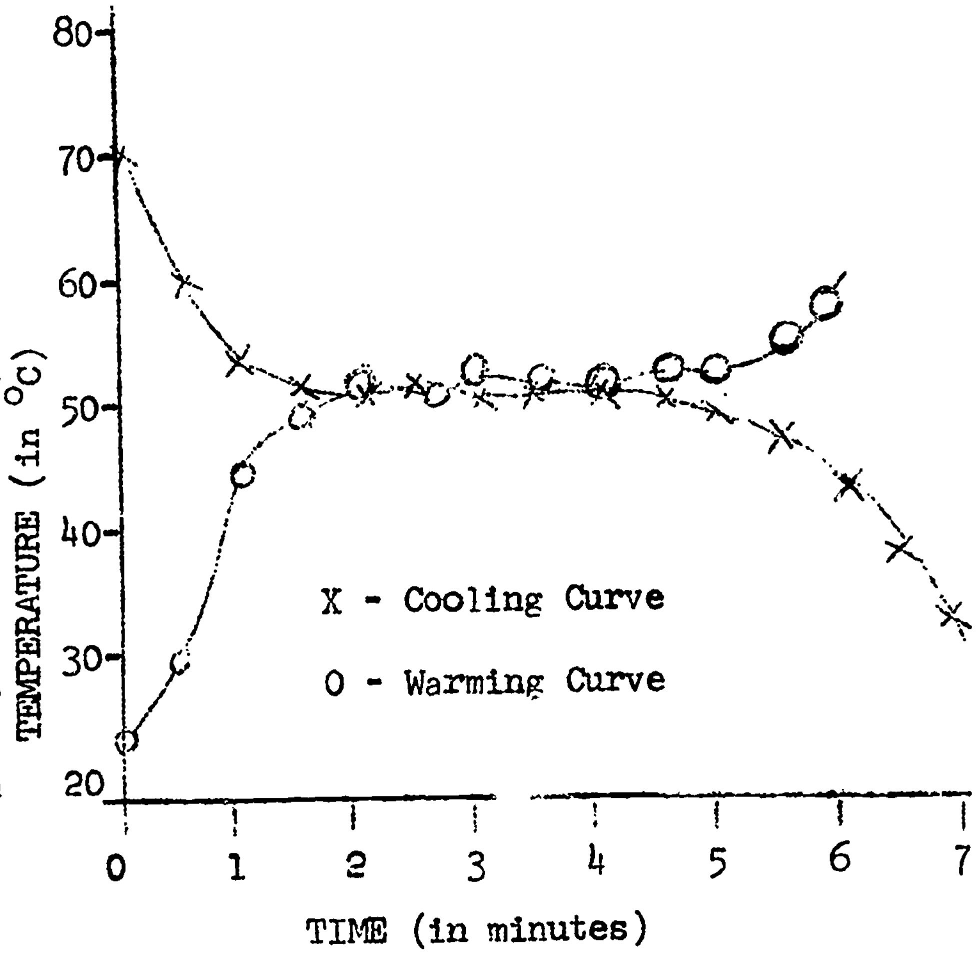
Using an entire sheet of graph paper, record your data in graphical form, plotting the temperature as a function of time. (Enter the time on the horizontal axis and the temperature on the vertical axis.)

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.

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 25° C.

In the second part of the experiment the temperature of 70° C is considerably more critical in order to get a satisfactory result.

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

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

15 test tubes
15 centigrade thermometers
15 ring stands
15 rings
15 wire gauze
15 bunsen burners
15 timing devices
15 large beakers
150 g each of paradichlorobenzene, naphthalene and candle wax

III.12 - Experiment: MICRO MELTING POINT

III.13 - Experiment: BOILING POINT

Chapter IV (IPS): Solubility and Solvents

The section number(s) in brackets refer to the material for this section which, when it occurs in both editions, is numbered according to the '67 ed. numbering system.

IV. 1 - Experiment: SOLUBILITY

This series (IV. 1 a, b, and c) is meant as a replacement and an extension of IV. 1. In IV. 1 the student made a solubility curve that goes up. In this series he will make a curve that goes up, one that goes down, and one that goes up then goes down.

IV. 1a (IV. 1a and IV. 2a) - Experiment: TEMPERATURE VERSUS SOLUBILITY

* * *

Chapter IV (IPS): Solubility and Solvents

IV. 1 - Experiment: SOLUBILITY

IV. 2 - Experiment: THE EFFECT OF TEMPERATURE ON SOLUBILITY

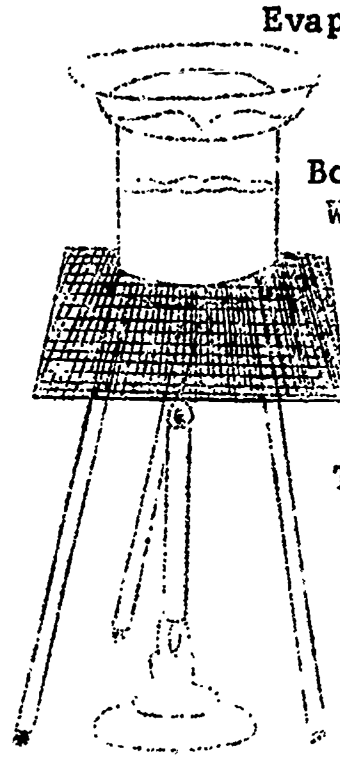
This series (IV. 1a, IV 2a, b and c) is meant as a replacement and an extension of IV. 1 and IV. 2. In this series the student will make a solubility curve that goes up, one that goes down, and one that goes up then goes down.

IV. 1a and IV. 2a - Experiment: TEMPERATURE VERSUS SOLUBILITY

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

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.

FIG. IV.1



Make several saturated solutions of potassium dichromate at temperatures ranging from 5° C to 90° C. Pour 100 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.

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 not to make an excess of the saturated solutions.

Caution students to weigh the evaporating dish itself first.

Now pour 100 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

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 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.

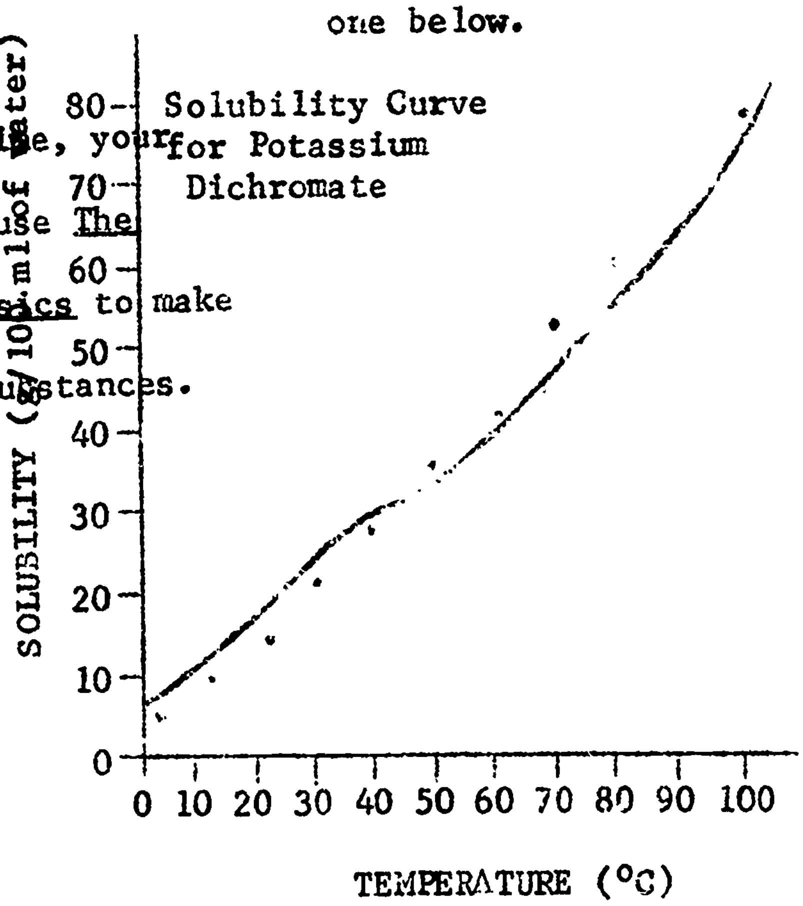
Can you predict from your graph the solubility of potassium dichromate at a temperature you did not use? How many grams of potassium dichromate will dissolve in 1 ml of water at 60° C? Can you assume the same sort of graph is typical of the solubilities of all substances?

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.

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. Experiment IV. 2b and IV. 2c 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.



Equipment and Materials

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

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

('66 ed.)
IV. 1b (IV. 2b) - Experiment: THE EFFECT OF TEMPERATURE ON SOLUBILITY

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('67 ed.)
IV. 2b Experiment: THE EFFECT OF TEMPERATURE ON SOLUBILITY

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

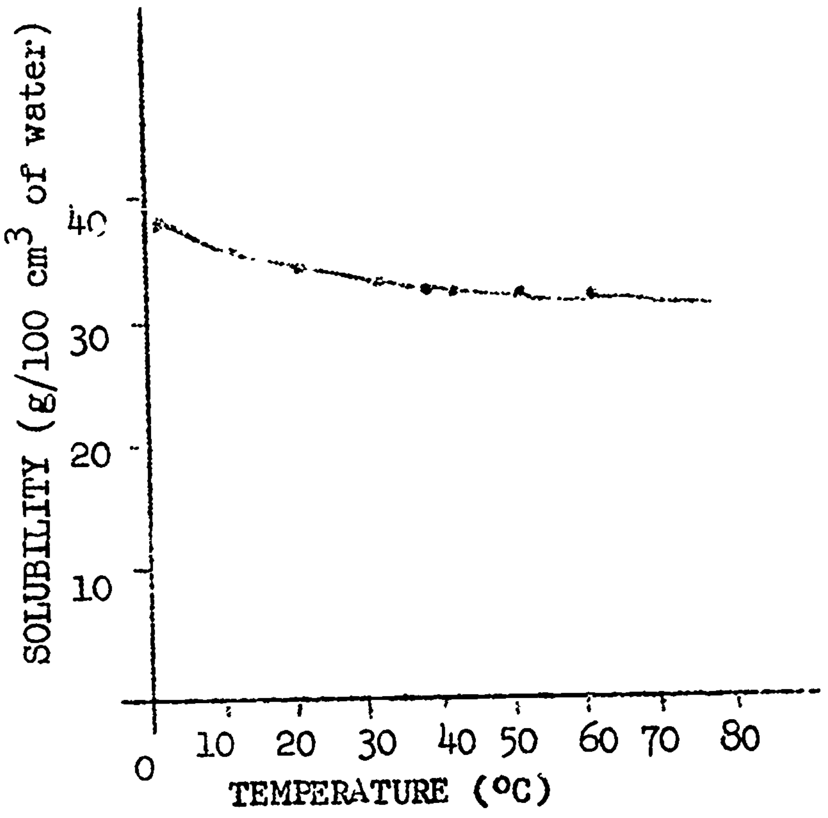
The solubility of $Ca(C_2H_3O_2)_2$ decreases with increasing temperature. It is an exception to the solubility patterns the student has observed in the IPS method.

Prepare 100 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.

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.



<u>Equipment and Materials</u>

Non-expendable:
Same as IV. 1a and IV. 2a

Expendable:
1 lb Ca $(C_2H_3O_2)_2 \cdot H_2O$ (assuming about 5 data points/class); technical grade is okay.

('66 ed.)
IV. 1c (IV. 2c) - Experiment: THE EFFECT OF TEMPERATURE ON SOLUBILITY

* * *

('67 ed.)
IV. 2c - 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

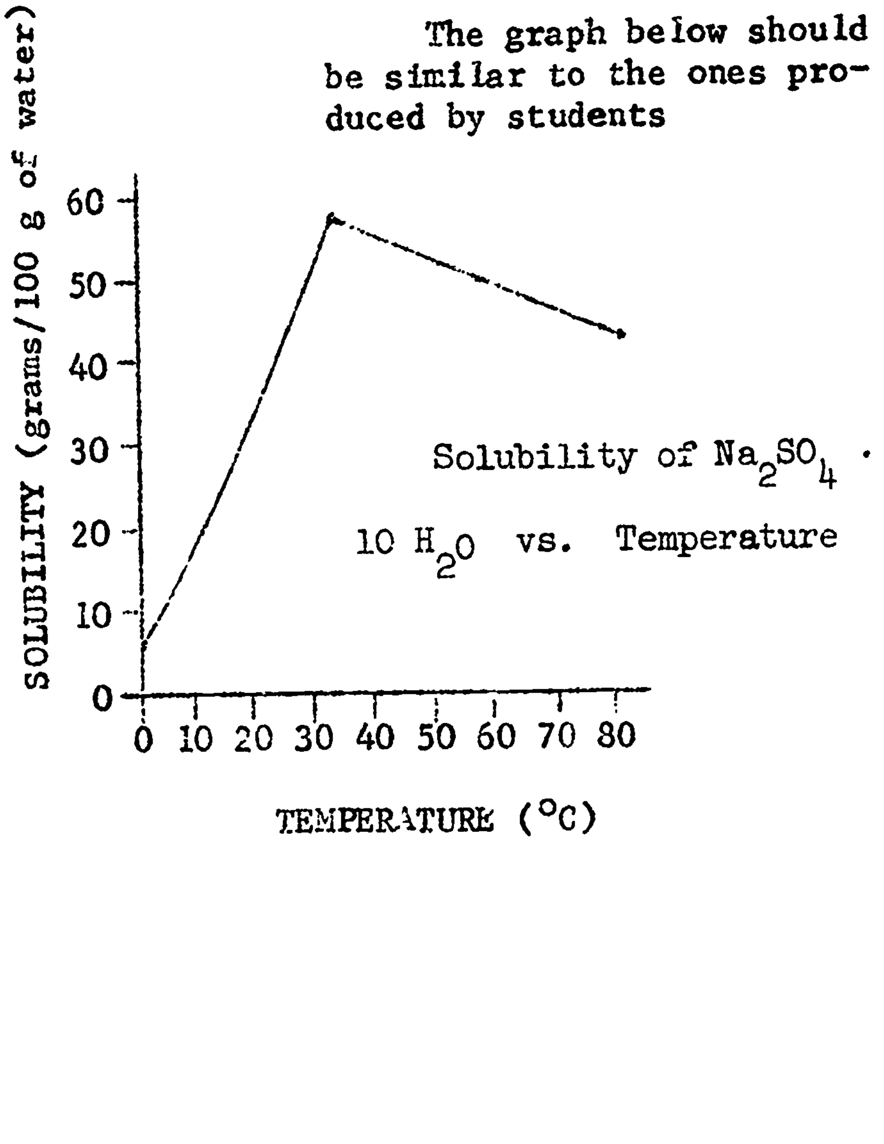
We suggest the use of $Na_2SO_4 \cdot 10\ H_2O$. $Na_2SO_4 \cdot 7H_2O$ may be used but the results will not be as dramatic. The solubility curve for $Na_2SO_4 \cdot 10\ H_2O$ presents a singular feature. Up to 32.4 degrees it rises rapidly in a normal way, but decreased with increasing temperature. 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.

above that point it falls. An examination of the solids above and below this point shows they are not the same. Below 32.4° C the solid is $Na_2SO_4 \cdot 10\ H_2O$, 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 $Na_2SO_4 \cdot 10\ H_2O$ and the second part of the curve demonstrates the solubility of Na_2SO_4.

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



Equipment and Materials

Non-expendable:
Same as IV. 1a and IV. 2a.

Expendable:
1 lb. $Na_2SO4 \cdot 10\ H_2O$ (assuming about 5 data points/ class); technical grade is okay or $Na_2SO_4 \cdot 7\ H_2O$.

('66 ed.)
IV. 2 - WOOD ALCOHOL AND GRAIN ALCOHOL

IV. 3 - Experiment: METHANOL AS A SOLVENT

IV. 4 - Experiment: PREPARATION OF OIL OF VITRIOL

IV. 5 - Experiment: TWO GASES

IV. 5a (IV.6a) - Experiment: TWO GASES

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('67 ed.)
IV. 3 - WOOD ALCOHOL AND GRAIN ALCOHOL

IV. 4 - Experiment: METHANOL AS A SOLVENT

IV. 5 - Experiment: PREPARATION OF OIL OF VITRIOL

IV. 6 - Experiment: TWO GASES

IV. 6a - Experiment: TWO GASES

Different gases are produced when magnesium and magnesium carbonate are added to sulfuric acid. Are the same gases produced when magnesium and magnesium carbonate are added to hyrdrochloric acid? Use

Use 1 M HCl. This is the same as 1 N HCl (86 ml of concentrated reagent/liter) the same apparatus you used in Experiment III. 4 of your IPS book. Use about half a test tube of the hydrochloric acid and five 6.5 cm lengths of magnesium ribbon to produce several test tubes of gas. You should discard the gas collected in the first test tube. Why? Test the gas to determine whether it is hydrogen. Test the gas to determine whether it is carbon dioxide. Is the gas more dense or less dense than air?

Repeat the experiment using magnesium carbonate instead of magnesium.

Clear limewater should be prepared several days in advance. Two g/1000 ml is sufficient. Keep the bottle stoppered because there is CO_2 in the air.

Remind students that to make the density test meaningful, open test tubes of gas should be held right side up or upside down for about 60 seconds before testing.

The large test tubes are for the $MgCO_3$, and HCl. Do not use powdered $MgCO_3$ because of the reaction rate.

<u>Answers to Questions</u>

The gas in the first test tube should be discarded because it is probably contaminated with air originally in the test tube. A test for hydrogen is positive with the HCl and Mg strip reaction. A test for carbon dioxide is negative with the HCl and Mg strip reaction. A test for hydrogen is negative with the HCl and $MgCO_3$ reaction. A test for carbon dioxide is positive with the HCl and $MgCO_3$ reaction. It appears that carbon dioxide is more dense than air and hydrogen.

is less dense than air when the test tubes are inverted and their contents tested.

Equipment and Materials

Non-expendable:
- 1 peg board
- 2 small clamps
- 6 small test tubes
- 1 large test tube
- 1 test tube rack
- 1 plastic bucket or large pan
- 1 No. 2 one-hole stopper
- 1 No. 4 one-hole stopper
- 4 No. 2 no-hole stoppers
- 2 right-angle glass bend
- rubber tubing

Expendable:
- 1 molar HCl (60 cc/ student)
- Limewater (10 cc/ student)
- magnesium ribbon, five 6.5 cm strips/ student
- magnesium carbonate (2 g/ student)
- matches (or striker)
- wood splints
- water
- paper towel

('66 ed.)
IV. 6 - HYDROGEN

IV. 7 - CARBON DIOXIDE

IV. 8 - Experiment: TESTING SOME UNKNOWN GASES

IV. 8a - Experiement: THE GASEOUS PRODUCTS OF A BURNING CANDLE

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('67 ed.)
IV. 7 - HYDROGEN

IV. 8 - CARBON DIOXIDE

IV. 8a - Experiment: THE GASEOUS PRODUCTS, OF A BURNING CANDLE

Can we use our present knowledge to help us determine some of the gases produced by a burning candle?

Invert a large (1000 ml) beaker or jar over a burning candle and leave it there until the candle is extinguished. Test the thin liquid film with a strip of cobalt chloride test paper. Moisten a second strip of cobalt chloride test paper with a drop of tap water. What conclusions can be drawn from this test? Does the evidence eliminate the possibility that something other than water caused the observed change in the test paper? Why? If the liquid film is water, where does it come from? Would you expect water to be produced if an electric heater were used in place of the candle under the beaker? Why? (You may want to try this at home.)

Determine the length of time a candle

Cobalt chloride test paper turns pink in both trials.

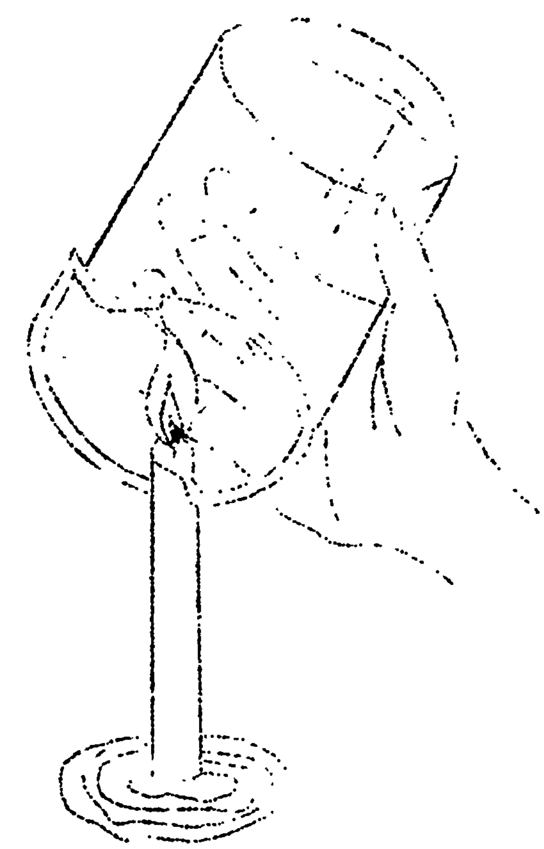

FIG. IV.2

The cobalt chloride paper must be dry. It is wise to store it in a desiccator.

continued to burn when a quart jar is inverted over it. Next, relight the candle and use a pint jar in place of the quart jar. How do the times compare? Obviously the candle goes out in both cases. What causes it to go out? Here are two possible answers:

(a) The burning produces a gas which "quenches" the flame.

(2) The burning consumes a gas which is present in air. When this part of air is gone, the candle goes out.

Perhaps we can do some further experiments to help us decide if (a) or (b) or both is correct. Use a blowpipe to add air to a candle flame. Blow air from your mouth through the blowpipe into the flame until you produce a jet of flame. What does this tell you about the relative amount of carbon dioxide in your breath? Does this part of the experment tend to prove or disprove either of the given possible answers (a) or (b)? Why?

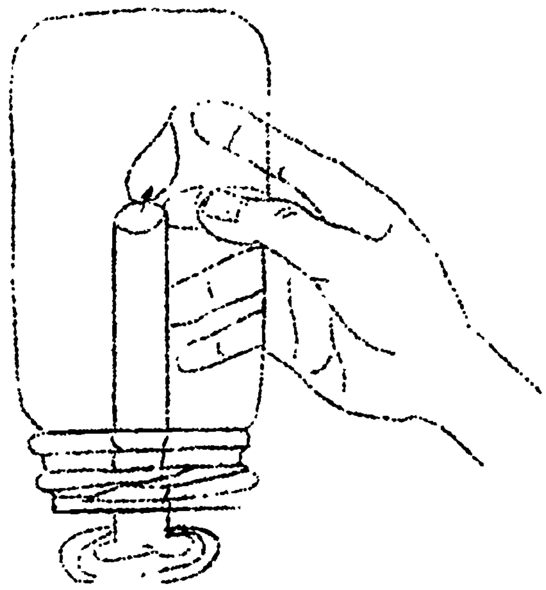

FIG. IV.3

The candle burns about 35 seconds in the quart jar and about 17 seconds in the pint jar.

The candle flame appears to melt the wax more rapidly.

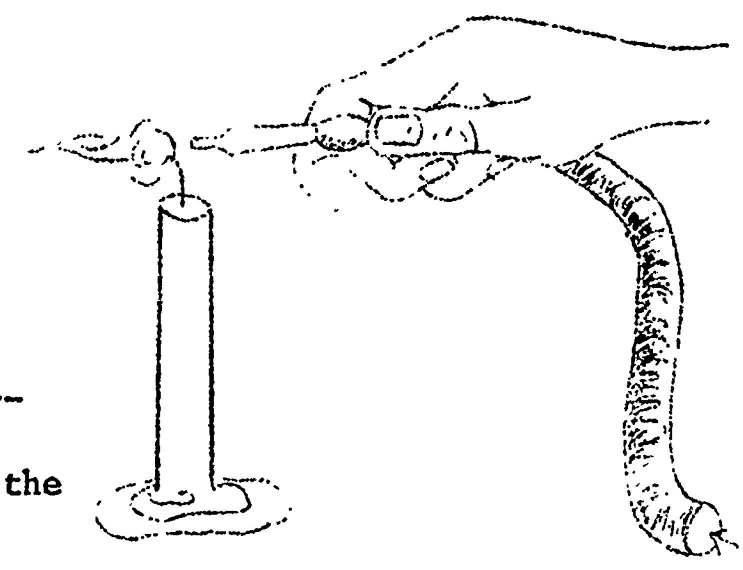

FIG. IV.4

Invert a 250 ml Erlenmeyer flask over a burning candle. When the flame goes out, quickly place the flask right side up on the table. Use a second 250 ml Erlenmeyer flask as a control. Add about 25 ml of limewater solution to each flask. Swirl the solution in each flask until a change takes place in one of the flasks. Does this part of the experiment tend to prove or disprove either of the given answers (a) or (b)? Why? Name some possible products when the candle burns as indicated by this experiment. If you are interested in further study of the properties of a burning candle, refer to Appendix 6, Experiment 4a of the CHEM Study Laboratory Manual. Your teacher probably has a copy of the manual at his disposal.

The limewater becomes cloudy in the flask that was over the candle. It does not become cloudy in the control flask.

The student should be able to use his present knowledge to help determine the presence of CO_2. When the cobalt chloride test is done the most obvious tentative conclusion that can be drawn is that the film in the beaker is water. This evidence does not definitely indicate the film is water. Some liquid other than water might also turn the cobalt chloride test paper pink. If the liquid film is water, it must be a combustion product of the candle. One would not expect the liquid film to come from an electric heater because there is no chemical reaction involved. (Students may confuse the condensation of water on a cold beverage glass with the formation of water on the inside of the beaker.)

It takes approximately twice as long for the candle to go out in the larger container. Any answer that is logical is a possible reason for the candle flame's going out.

If the breath of a person increases the rate of combustion, and CO_2 causes a flame to be extinguished (see IPS, sec. IV. 8), then the relative amount of carbon dioxide in a person's breath must be small. This part of the experiment tends to prove answer (b). Although the evidence is not conclusive, it would appear something in the air causes the combustion rate to increase; hence, (b).

This part of the experiment tends to prove answer (a) because it is obvious a product of the burning candle is CO_2 and CO_2 makes flames go out. Water and carbon dioxide are indicated by this experiment. We might also mention heat and soot as possible products.

Equipment and Materials

Non-expendable:
- 1 wide-mouth quart jar or 1000 ml beaker
- 1 wide-mouth pint jar or 500 ml beaker.
- 3 250 ml Erlenmeyer flasks
- 1 blowpipe

Expendable:
- 1 candle, about 6 cm long
- 2 pieces of cobalt chloride test paper
  150 ml saturated limewater, $Ca(OH)_2$ (use about 10 g/liter)

Chapter V (IPS): Separation of Substances

V.1 - Experiment: FRACT··NAL DISTILLATION

V.1a- Experiment: FRACTIONAL DISTILLATION

In V.1 we found some liquids were mixtures even though they appeared to be just one substance. We also used a few of the methods used by the scientist to separate the components of the mixture. But we should not assume these will work in all cases. Sometimes we have to work out new techniques with the approval of your teacher when those we have used in the past do not fit our present needs.

Your teacher will supply you with a mixture that you are to separate. First try fractional distillation. If necessary, try other methods with the approval of your teacher.

This is an extension of V.1. It is intended for the student that has good lab technique and is capable of accurate observation. The extension requires the student to understand what is happening well enough to be able to revise the procedure to include melting point.

In V.1 the student used isopropyl alcohol and water. These materials have a wide enough separation in their properties so that even with inadequately skilled technique, the student could come up with acceptable and meaningful results. Now let us try to challenge the more able student by giving him a sample with more than two materials in the sample and/or materials that are different in only one of the properties tested for--e.g., a sample containing t-butyl alcohol and isopropyl alcohol. The materials given in the following chart, along with water, should allow the teacher to choose samples that will challenge each student at their own level of ability and understanding.

The same apparatus set up as shown in Fig. V.1 may be used or the alcohol burner test tube distillation chamber may be replaced by using a bunsen burner and a flask. If a bunsen burner is used, care should be taken by the student to move the bunsen burner back and forth under the flask slowly so as not to heat the sample so fast that a meaninful graph cannot be made. NOTE: If t-butanol and isopropanol are included in a mixture, the student must extend the concept of separation by boiling temperatures to the separation by freezing temperatures.

[illegible] is a list of c[illegible] that can be substit[illegible] or those in the IPS t[illegible] A simple variation would be to use different numbers of materials for different student samples.

UNDER NO CONDITIONS SHOULD MATERIALS SUCH AS CARBON TETRACHLORIDE OR ACETONE BE USED.

	SPECIFIC GRAVITY	BOILING POINT °C	MELTING POINT °C	COMMENTS
Ethyl alcohol	0.79	78.4	-14.5	Denaturants may or may not cause variations.
Methyl alcohol	0.79	64.7	-97.8	Usually ditto fluid is technical grade methanol.

	SPECIFIC GRAVITY	BOILING POINT °C	MELTING POINT °C	COMMENTS
t-Butyl alcohol	0.78	82.6	25.6	
Isopropyl alcohol	0.79	82.4	-98.5	Common rubbing alcohol may already be a mixture of alcohols.

V.2 - PETROLEUM

V.3 - THE DIRECT SEPARATION OF SOLIDS FROM LIQUIDS

V.4 - THE SEPARATION OF A MIXTURE OF SOLIDS

V.4a - Experiment: SEPARATION OF A MIXTURE OF SOLIDS

In V.1a we separated various liquids from each other but could we separate solids from each other by the same method? We know some stains we get on our clothes can be washed out with water while others require cleaning solvent. If we examine our sample carefully, we find it very hard to see any visible difference between the crystals. Does the odor give you an indication as to what at least one of the substances might be?

Mix your sample with some water and filter. Wash the residue twice and set aside with the filter paper to dry on a paper towel. Evaporate the filtrate to dryness and compare the filtrate crystals to the residue crystals. Are they the same? Could they possibly be the same?

This experiment is an attempt to improve the student's technique and powers of observation in preparation for V.5 or V.5a.

(Solids can be separated by sublimation. If the student suggests this, let him try it!)

P-dichlorobenzene is insoluble in water, so grinding it up and mixing with ground-up table salt should make a good sample for the student. Napthalene is slightly soluble in water so will not work as well.

The odor of the p-dichlorobenzene will probably be taken as mothballs by the student and, because table salt has no odor, will be the only odor detected.

If the filtrate is boiled to near dryness and then allowed to dry completely overnight the crystals should be large enough for all students to see the difference and perhaps for a few of them to be able to see the characteristic angle of the sodium chloride which is 90° and cubic in nature.

With the difference in solubility and difference in crystal structure, the student should be able to challenge the possibility of these salts being the same.

Equipment and Materials

- Water
- P-dichlorobenzene
- Table salt (sodium chloride)
- Filter paper
- Funnel
- Funnel holder or stand
- Beaker to catch filtrate
- Beaker to mix sample with water and to wash the residue
- Burner
- Stand to hold beaker while water is boiled from filtrate
- Paper towels
- Magnifying glass or microscope (optional)

V.5 - Experiment: FRACTIONAL CRYSTALLIZATION

V.5a - Experiment: FRACTIONAL CRYSTALLIZATION

Examine the sample supplied by your teacher. How many different types of solids can you observe?

V.5a - Experiment: FRACTIONAL CRYSTALLIZATION

Examine the sample supplied by your teacher. How many different types of solids can you observe?

Place your sample in a beaker and add a small amount of water. Heat the mixture until boiling begins. As boiling continues, add water a little at a time until all the sample is dissolved. Use as little water as possible. Add a few boiling chips. Note the volume of the solution and continue boiling gently until approximately half the water is boiled away. Were there any changes you noticed during the boiling process?

Filter the solution into a clean test tube using the hot filtration method and allow the filtrate to sit overnight. The precipitate, along with the filter paper, should be placed on a paper towel and allowed to dry.

After both solids have been allowed to sit overnight, observe them carefully. Do they look alike? If not, how do they

Follow the instructions in the IPS Teacher's Guide for making the sample.

In one of the additional experiments in Chapter IV, the student made a solubility curve for potassium dichromate. Having to refer back to his own data strengthens the value of keeping a good laboratory book as well as stressing the need for improving laboratory technique.

Potassium dichromate is orange and sodium chloride is white, so different types of solids should be apparent to the student.

As derived from the information in the charts and tables below, the maximum volume the student should be allowed for dissolving the sample is about 25 ml and the minimum, about 20 ml.

As boiling continues, a precipitate of sodium chloride should begin to form as the volume is reduced below 19 ml during the boiling process.

The crystal structure of these two salts are different, sodium chloride having the characteristic 90° angle with cubic tendencies as mentioned in V.4a. This may lead to some students guessing one of the materials is NaCl.

differ? Pour the liquid off the filtrate solid and dry this solid on a paper towel. Place small, equal quantities of these solids in separate test tubes and add about 2 or 3 cc of water (equal volumes) to each test tube. Observe the solubilities of each and then boil. Continue to boil until the point of saturation is reached. How do the solubilities of these two materials compare at various temperatures? What tentative conclusions can you make about these materials?

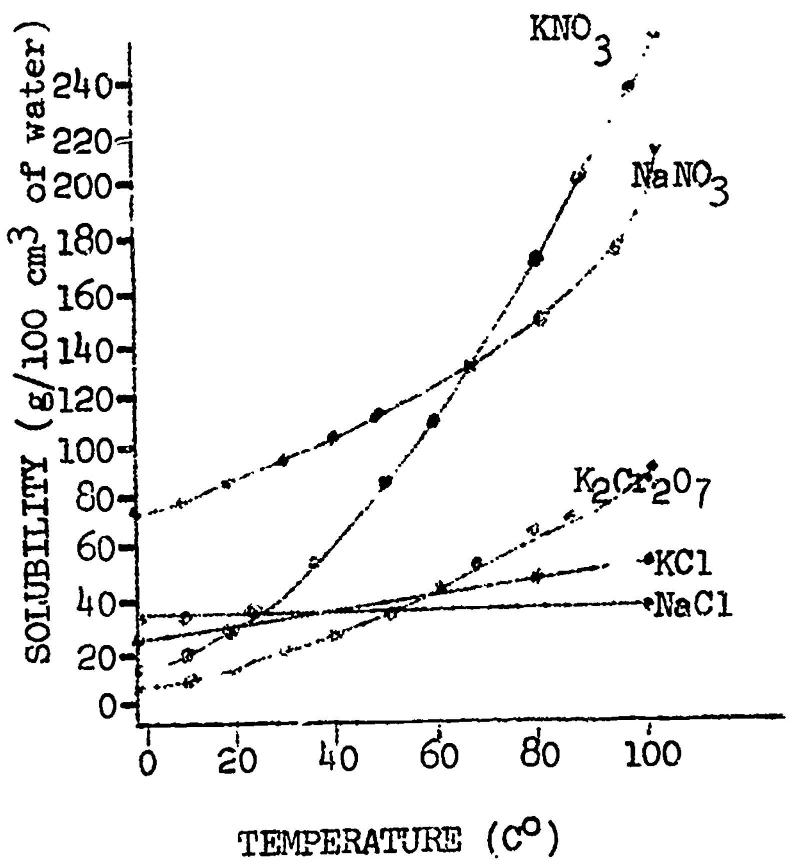

FIG. V.5a - Solubility curves of different substances dissolved in water

The tables below show solubilities of various salts at different temperatures. The student should be able to see the differences in color or crystal form.

Equipment and Materials

With the exception of potassium nitrate being replaced with potassium dichromate, this list should be the same as for V.5.

Table V.5a - 1

Volumes to which solutions containing 7.5 g of the following salts must be reduced at various temperatures before precipitation will occur.

	25° C	100° C
KCl	21 ml	13 ml
KNO_3	18 ml	3 ml
$K_2Cr_2O_7$	50 ml	11 ml
NaCl	20 ml	19 ml
$NaNO_3$	9 ml	4 ml

Table V.5a - 2

Points of saturation for various salts at various volumes and temperatures.

	g per 25 ml 100° C	g per 12 ml 100° C	g per 12 ml 25° C
KCl	14	7	4
KNO_3	60	30	5
$K_2Cr_2O_7$	20	10	2
NaCl	10	5	4.5

Table V.5a - 3

Grams of precipitate formed for various salts from 7.5 g of salt in original sample.

	g per 12 ml 100° C	g per 12 ml 25° C	loss due to Δ t
KCl	0.5	3.5	3.0
KNO_3	0	2.5	2.5
$K_2Cr_2O_7$	0	5.5	5.5
NaCl	2.5	3.0	0.5
$NaNO_3$	0	0	0

V.6 - Experiment: THE SUBSTANCES IN A SAMPLE OF BLACK INK

The material as listed in the IPS teacher's guide is very good for the purposes intended. Small flasks are suggested instead of test tubes during the distillation.

V.7 - Experiment: PAPER CHROMATOGRAPHY

V.7a - Experiment: PAPER CHROMATOGRAPHY

Many substances we use in the home and laboratory are mixtures. Some of these can be separated by paper chromatography using water as the vehicle, but some materials must have different vehicles such as alcohol or other. Why is this?

Using a graduated cylinder in the laboratory and perhaps a fruit jar or milk bottle at home, construct a paper chromatographic separation apparatus.

The material being separated must be soluble in the vehicle or it will not move up the paper.

Occasionally the paper is not long enough to allow complete separation of all the materials. Where they overlap, a mixing of colors will result, and in two color systems the original color appears at the point of overlap. If the paper you choose allows the fluid to rise too rapidly, it does not provide a good separation. The slower the fluid rises, the better the separation, but time is a factor to be considered.

When color separation is incomplete, try rotating and repeat the same process.

Is it necessary to use materials that are water soluble if the vehicle used is water, or will any material work? Why? Occasionally a separation occurs with the original color between two other colors. How can this happen?

An HDL problem at the end of this chapter suggests items in your home that can be used. Try some of these and perhaps other materials such as food coloring, and bring the dried papers (chromatograms) to class to share with your classmates.

Green food coloring that Safeway sells usually shows good separation into blue and yellow colors. Because of the many variables involved, any material used should be checked out before the experiment.

After going through this experiment in the laboratory, the student should have little or no problem at home. The student should be encouraged to use his own ideas and a variety of materials in his home experimentation. HDL problem number 23 (17) gives some suggestions.

To insure proper preparation of the filter paper strips, they should be prepared by the teacher prior to the experiment.

Equipment and Materials

Same as used in V.7 except replace the ink with green food coloring from Safeway or some other tested material.

V.8 - MIXTURES OF GASES

V.9 - Experiment: SEPARATING A GAS FROM AIR

The intent here is to cover the same concepts as in V.9 and to introduce the idea of fixed composition. Although air is a mixture, it gives consistent results. This experiment, along with the color change in the potassium permanganate in V.10, is a good introduction to chapter VI.

V.9 - Experiment: SEPARATING A GAS FROM AIR

As we watch the smoke from a fire rise into the atmosphere or smell the exhaust from a bus or car, we begin to wonder about the composition of air.

Affix a strip of masking tape to the outside of each of four test tubes. Place the mouth of tube #1 down in a large beaker filled 3/4 full of water so that the mouth is beneath the surface of the water.

Insert a stopper in each of the remaining three tubes and mark the farthest extent of the stopper in the tube as mark "A". Remove the stopper in tubes 2, 3 and 4 and add 25 ml of sodium hydroxide solution to each. Replace the stopper to point A, invert the tube and mark the level of the liquid as mark "B". Turn the mouth of test tube #2 up and remove the stopper. Very quickly add 0.5 g of pyrogallic acid. Replace the stopper to point A and shake vigorously for 2-3 minutes. Do you notice any evidence of change in the tube? Place the mouth of the test tube under the surface of the water in the beaker. Repeat this process for tubes 3 and 4. Remove the stoppers from tubes 2, 3 and 4 very carefully. Wait a few minutes,

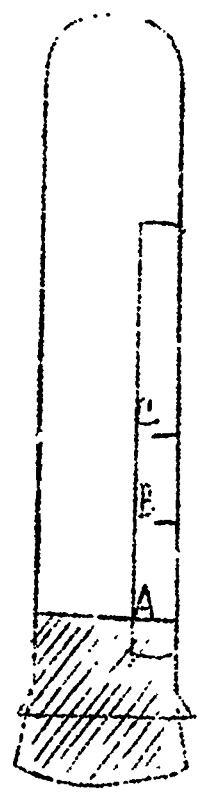

FIG. V.1

When the test tube is shaken, the solution turns a dark color as it removes the oxygen from the air.

As the stopper is removed from the tube under water, the vacuum formed by the removal of the oxygen from the air will become apparent.

then move test tubes 2 and 3 up and down until the liquid levels inside and outside the tubes are the same. Mark the level of the liquid as mark "C". Replace the stopper in tube #2. Save tube #2 for experiment V.10.

Put your thumb over the open end of tube #1, which did not contain any sodium hydroxide or pyrogallic acid, and remove it from the water. With your thumb still over the end, turn it right side up, light a wood splint, remove your thumb, and insert the barely glowing splint into the tube. What happens? Try this test with a tube filled with air from the room. What do you conclude about the gas in the tube that was suspended over water but did not contain any chemicals? Try this same test with tube #3. Save tube #3 for further measurements.

A glowing splint continues to glow in the tube that does not have the oxygen removed.

Same as above.

Test tube #4 is still inverted in the beaker of water without a stopper. While keeping the mouth of the tube below the surface of the water, stir it around until any liquid remaining in the tube has the same color as the water surrounding it. To perform the limewater test, place your thumb over the mouth of the test tube, remove it from the water, turn it right side up, pour in some limewater, place your thumb over the open end and shake well. What do you conclude about the gas you have tested?

The gas tested should not show evidence of carbon dioxide.

Now let us return our attention to test tube #3. Fill the tube with water up to mark C. Pour this water into a graduated cylinder and measure the volume. Measure the volume up to mark B in the same way. What does this tell you about the volume of the original gas or air that was lost?

The student should come up with about 20 to 21% as the volume lost. This may lead to a guess that the gas lost was oxygen, but keep it a speculation at this point.

Equipment and Materials

- Masking tape
- 4 test tubes, 25 x 150
- 3 stoppers, #4 solid
- Pneumatic trough or battery jar or 1000 ml beaker
- Ball point pen
- 0.5 g pyrogallic acid
- 25 ml 1 M NaOH solution (40 g per liter of solution)
- Water
- Wood splints
- Matches

Limewater (prepared by mixing $Ca(OH)_2$ with water and allowing to settle overnight)
50 ml graduated cylinder

('66 ed)

V.10 - Experiment: ANOTHER COMPONENT OF AIR

V.11 - NITROGEN AND OXYGEN

V.12 - LOW TEMPERATURES

V.13 - THE FRACTIONAL DISTILLATION OF AIR

V.14 - MI TURES AND PURE SUBSTANCES

Laboratory Test

This is an optional activity but should be very meaningful for the student, especially if some of this material has been previously covered by the student.

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('67 ed)

V.8 - MIXTURES OF GASES: NITROGEN AND OXYGEN

V.9 - LOW TEMPERATURES

V.10 - MIXTURES AND PURE SUBSTANCES

Laboratory Test

This is an optional activity but should be very meaningful for the student, especially if some of this material has been previously covered by the student.

Chapter VI (IPS): Compounds and Elements

VI.1 - Experiment: DECOMPOSITION OF SODIUM CHLORATE

CAUTION: Be sure to use the glass wool plug and a clean and dry test tube. Try to identify the gas evolved.

VI.1a - Experiment: DECOMPOSITION OF POTASSIUM CHLORATE

Weigh out about 30 beads (7 gm) of potassium chlorate and 15 beads of manganese dioxide. Mix these together on a piece of paper. Heat the mixture in a test tube as shown in Fig. 6.1 (IPS text).

CAUTION: Do not grind these chemicals together. Be sure you use the glass wool plug and do not allow the material to touch the glass wool plug while heating. If the mixture moves up the tube, tap it gently or briefly remove the heat. You must use a clean, dry test tube.

Collect several test tubes of gas. Then take the stopper out of the tube you are heating and continue to heat for 10 to 15 minutes, or until no further change is noticed. To make sure all

As a logical extension, this experiment implies a relationship between these two chlorates and thus a relationship between sodium and potassium. The effect of the catalyst is further food for thought.

The ratio is 1 gm:4 beads.

Ring stand and apparatus can be substituted for pegboard.

Grinding $KClO_3$ and anything is extremely dangerous.

Safety glasses are a must. Stress safety here; there is much chance of accident.

Three or four test tubes are sufficient.

The stopper must be removed while the test tube is hot; otherwise, water will be sucked into the hot tube.

material was heated, rotate the tube while heating but be careful not to burn your fingers.

What gas did you collect?

Oxygen.

Was gas evolved after you stopped collecting?

Yes.

How does the melting point of the material (potassium chlorate) you started with compare with the material you now have? Can you regain all of the manganese dioxide you started with? How do the solubilities of the materials compare?

$KClO_3$ 368.4 decomposes at 400°; KCl 776 sublimes at 1500°.

Students should be able to regain all MnO_2.

The graph appears below.

Solub. gm/100 ml H_2O at var. T

	$KClO_3$	KCl
10°	5.	31.0
20°	7.4	34.0
30°	10.5	37.0
40°	14.0	40.0
50°	19.3	42.6
60°	24.5	45.5
70°	----	48.3
80°	38.5	51.1
90°	----	54.0
100°	57.	56.7

Make graphs of the solubilities of the two materials. Can you make a comparison between either material and a known solubility curve?

The curve for KCl appears in Ch. V.

What else can you do to identify the second material?

Determining specific gravity, density, crystal form, color, solubility in cold vs. hot H_2O, solubility in other solvents all help identify the second material.

Did you evolve pure substances?

Pure substances should have been evolved.

Equipment and Materials

Same as 6.1 in IPS Teacher's Manual except for the following:
- Potassium chlorate
- Ring stand
- Test tube clamps
- Bunsen burners
- Manganese dioxide

VI. 2 - Experiment: DECOMPOSITION OF WATER

This may be done as a demonstration.

VI. 2a - Experiment: DECOMPOSITION OF DILUTE SALT SOLUTIONS

You may want to do this as a demonstration. Here we are identifying certain salts that give the same results as the original IPS experiment. You may want one of your better students to do this with NaCl or you may prefer to do it youself. This should certainly cause some questions. If a NaCl solution is used, this must be done in a hood since chlorine will be evolved.

Use the same apparatus and collecting techniques as you used in IPS Experiment 6.2. The difference lies in the solution used. IPS 6.2 used a dilute sulfuric acid solution. You will use dilute salt solutions.

To make the solutions, take 10 g of salt used and dissolve it in 200 ml of distilled water. Your teacher will indicate which of the following salts you should use.

Let two groups use the same salt but separate these groups to minimize cooperation.

Salts: Sodium sulfate, sodium carbonate, sodium nitrate, potassium sulfate, potassium nitrate, potassium carbonate, calcium nitrate.

What gas(es) have evolved?

Oxygen and hydrogen.

How does your result compare with the results of the original IPS experiment?

Same gases.

If two gases evolve, try mixing and igniting the mixture. What do you conclude?

Same as before.

Compare your results with those using other salts. Is there a conclusion you can draw?

They should conclude is not the salt that is decomposed; it is the water.

Equipment and Materials

Same apparatus as IPS 6.2

Chemicals:
(10 g each/student pair)
Sodium sulfate
Sodium carbonate
Sodium nitrate
Potassium sulfate
Potassium nitrate
Potassium carbonate
Calcium nitrate

VI. 3 _ THE SYNTHESIS OF WATER

VI. 4 - Experiment: SYNTHESIS OF ZINC CHLORIDE

These instructions are contained in the '67 ed.

The material left in the evaporating dish should be evaporated in the following manner. Heat until the substance appears to be dry, then continue until a pool of liquid begins to form. Stop heating and weigh as soon as cool.

VI. 4a - Experiment: SYNTHESIS OF A CHLORIDE

In IPS VI. 4 you synthesized a metallic chloride. Carefully re-read this section in your IPS book since you will follow the same directions and answer the same questions. The only change will be in substituting the metal used.

Zinc was the metal you used before; now you will try the same experiment using either aluminum or magnesium. Aluminum will be supplied as foil and should be abraded to remove any surface contamination. Magnesium ribbon requires the same treatment. In both cases do this lightly so that you leave most of the metal in usable form.

If you remember the ratios that you computed for zinc-zinc chloride (or get them from your instructor), compare them with the ratios that are computed in this experiment. Do you see a pattern? If so, can you express this pattern mathematically?

Knowing that chemists write zinc chloride as $ZnCl_2$ and that the chemical

Here two additional metals are used to get at the same result. The student will not be able to melt the magnesium chloride. Some idea of reaction time is part of the overview of the experiments concerning all three metals.

6M HCl is to be used. Mix equal volumes of concentrated HCl with H_2O.

Always add acid to water, never the reverse.

The student should take care to keep the generating apparatus cool.

Emory cloth or fine steel wool works well in abrading oxidized metallic surfaces.

If you alternate metals and lab pairs, you will keep cheating at a minimum.

Vary the metal mass from .5 to 10 beads (.125 g to 2.5 g).

Here we are after definite composition.

This is a small exercise in formula writing from experimental data.

symbol for zinc is Zn; for chlorine, Cl; for aluminum, Al; and for magnesium, Mg; can you write a formula for the chlorides you produce?

Materials and Equipment

Same as in 6.4 except for magnesium ribbon and aluminum foil.

VI. 5 - THE LAW OF CONSTANT PROPORTIONS - Proust (1754-1826)

VI. 6 - Experiment: A REACTION WITH COPPER

Recording the time may be eliminated from this experiment.

Timing has been eliminated in the '67 ed.

VI. 6a - Experiment: REACTION WITH MAGNESIUM

Carefully weigh a clean, dry crucible, add 0.3 - 0.4 g magnesium ribbon cut into small pieces, and weigh again.

You should scrape or abrade the ribbon first. Why?

Put a lid on the crucible and heat it slowly, frequently lifting the lid with a pair of tongs.

What purpose does lifting the lid serve?

If the magnesium begins to burn brightly, immediately recover the crucible. Heat until all of the metal seems to have been converted to ash. Remove the cover and add a few drops of water

Here the student must take a great deal of care in his experimental procedure. If not, he will loose most of his solid. All safety precautions should be observed. This experiment should teach good technique.

The student should learn about surface contamination eventually. Perhaps he can extend this concept.

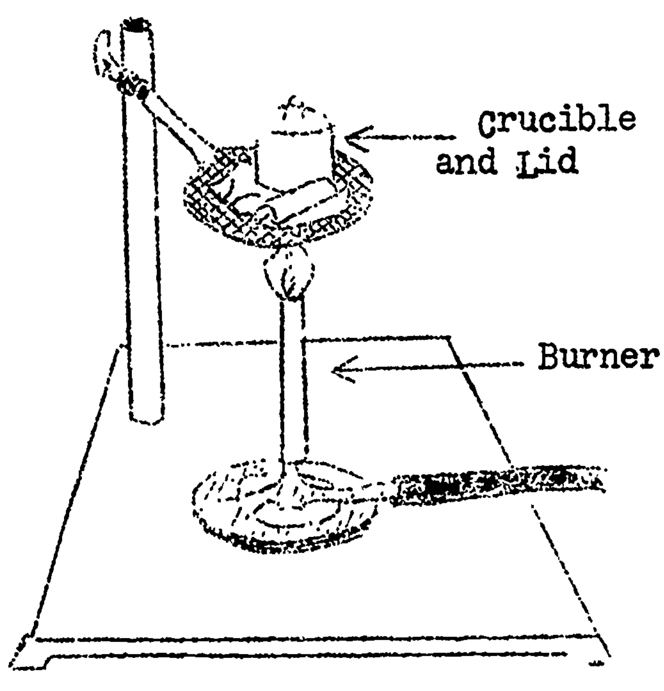

FIG. VI.1

while the crucible is still warm, gradually, heat the crucible to the maximum degree allowed by the burner. Allow the crucible to cool, them weigh it. Again heat the crucible, cool, weigh again. If the weight changed after the last weighing, heat and weigh again until no further weight change is observed.

Is there a difference between your first weight of the crucible and ribbon and your last weight? How do you explain this?

An alternate procedure: Gently warm the crucible, gradually increasing the heat supplied while leaving the lid on. After 10 minutes prop the lid slightly open and continue to heat for 15 minutes, making sure not to ignite the magnesium. Lifting the lid allows oxygen to get to the metal. There should be a weight gain because of the formation of a new compound which contains all of magnesium plus an added fraction from the air (oxygen).

Magnesium oxide is very refractory.

Equipment and Materials

- Ring stand
- Ring
- Clay triangle
- 00 crucible with lid
- Tongs
- Bunsen burner
- Magnesium ribbon
- Steel wool or emory cloth

VI. 7 - Experiment: REDUCTION OF COPPER OXIDE

The ratio of copper oxide to charcoal is 10 beads CuO to 1 bead charcoal.

You should heat the mixture until it begins to glow. Continue to heat for about 1 minute, then allow the tube to cool and proceed as directed.

Be sure that you do not supply bone charcoal.

VI. 7a - Experiment: OXIDATION-REDUCTION

When you did Experiments VI. 6 and VI. 7 in your IPS course work, you heated copper powder and it combined with oxygen from the air. It was thus oxidized. You then reduced the copper oxide and regained the copper you started with.

Set up a bunsen burner and look at the flame. You will find two general regions within the flame itself, the outer or apparent boundary of the flame, and an inner cone just above the barrel of the burner. Hold a strip of copper metal (don't hold it directly by hand or you will burn yourself) just above the tip of the outer region of the flame. Record the changes that take place. Now move the changed region so that the tip of the inner cone just touches it. Record any changes that occur.

The outer flame is called the oxidizing flame and the inner is called the reducing flame. In the light of this information, how would you describe what you have observed?

This is a simple yet complex approach to oxidation-reduction reactions. For the advanced student, you can suggest supplementary reading starting with the May 1967 issue of the Journal of Chemical Education. This article contains many references that will take the student as far as he wants to go.

Sections VI. 6, VI. 7 IPS should be re-read as a lead into this experiment.

There are, of course, other zones. It is unlikely the student will recognize more than two. This could be an excellent challenge to the student who does see more than two.

Make sure the metal is no thinner than 18 guage.

Oxidation ---- Reduction

This could provoke some research or just ideas. The tip of the inner cone is rich in H_2 and CO, both strong reducers, while the outer flame tip is hot and open to oxygen from the air.

What difference in these regions would lead to the difference in their chemical activity?

VI. 8 - ELEMENTS

VI. 9 - TWO SPECIAL CASES: LIME AND OXYMURIATIC ACID

VI. 10 - Experiment: FLAME TESTS OF SOME ELEMENTS

VI. 11 - Experiment: SPECTRA OF SOME ELEMENTS

VI. 12 - SPECTRAL ANALYSIS

Equipment and Materials

Bunsen burner
Tongs
Copper sheet, 18 ga.

You might select other compounds to supplement. This experiment should be done as a demonstration.

See the above comment.

To extend this material, you might refer to the book by Barrow, The Structure of Molecules, published by Benjamin in 1963. This book is an introduction to molecular spectroscopy and could give you information of another type of spectra.