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Computer-simulated experiments in high school physics and chemistry

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Computer-simulated experiments
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by

James Edward Jones

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INTRODUCTION

The potential of the computer as a means of improving educational methodology is becoming of widespread interest. The abundance of literature on computer-assisted instruction would in itself seem to be evidence of the felt importance of this mode of instruction. As access to high-speed digital computers by means of time-sharing terminals becomes more prevalent among high schools, educators must learn how to effectively utilize this product of modern technology to better meet the educational needs of today's youth.

Two general types of utilization of the computer terminal in the classroom are in evidence. Perhaps the most common is its use as a means of inputting student programs as a part of a study of the basic ideas of computer science. Another use is that of computer-assisted instruction (CAI).

The contribution that the computer can make toward an economically sound approach to individualized instruction has been noted by Suppes (1966). He pointed out that modern criticisms of individualized instruction are not directed at its intrinsic merit but rather at its economic inefficiency. He further stated:

> The single most powerful argument for computer-assisted instruction is an old one in education. It concerns the advantages . . . of individualized instruction. It is widely agreed that the more an educational curriculum can adapt in a unique fashion to individual learners — each of whom has his own characteristic initial ability, rate and even "style" of learning — the better the chance is of providing the student with a successful learning experience (pp. 207-208).

CAI may be subdivided into various modes. Stolurow (1968) listed five categories: (1) problem-solving, (2) drill and practice, (3) inquiry (responding to student questions with stored answers), (4) simulation and gaming, and (5) tutorial instruction. Blum and Bork (1970) stated, "The five modes are (1) producer, (2) administrator, (3) tutor, (4) simulator, and (5) calculator, listed roughly in order of increasing demands on the students' understanding and participation" (p. 963). According to Boblick (1970) the basic instructional techniques of CAI fall into the following five categories: (1) tutorial dialogue, (2) drill and review, (3) testing, (4) remote computing, and (5) simulation. It will be noted that, although there is some variation in the listing of categories, simulation has been included by each of the writers.

Simulation is usually distinguished from games in that a game may not represent a real situation. Stolurow (1968) contrasted games and simulation when he said:

> A simulation, on the other hand, does attempt to represent a real situation. To implement this mode of CAI the teacher must define the model sufficiently to permit it to be programmed. A computer program must be written to process the student's input so that he gets a meaningful output. The output is determined by what the student does and by the model. The student interacts by using natural language (p. 10).

Wing (1968) defined simulation in the following manner:

> For our purposes simulation may be defined as an imitation of real circumstances aimed at providing a learning environment; in other words, simulation is a technique by which the essential features of some object or process are abstracted and recombined in a model which represents the function of the original and can be manipulated for the purpose of study or instruction (p. 41).

Blum and Bork (1970) have divided simulation into two general types that they described as black box and Monte Carlo. In the first, the computer is considered a black box. The student inputs information and receives output without knowing what goes on inside the computer. The output is derived by the computer from a mathematical simulation of the physical situation. A random error of a predetermined maximum value may be included in the output if it is desired. Merrill (1971) illustrated this type of simulation with three programs from introductory optics. His illustrations included (1) size and position of an image in a thin lens or spherical mirror system, (2) tracing rays through a thick lens system, and (3) tracing rays through media where the index of refraction is a function of the position in space, such as in the case of the atmospheric phenomena of mirages and looming. The Monte Carlo method uses the concept of randomness and the generation of random numbers by the computer. A physical problem is replaced by an analogous but more readily soluble problem, and the solutions to the latter are produced and studied. An example of this Monte Carlo technique has been presented by Anger and Prescott (1970). Typical applications include such statistical models as molecular cross section, mean free path in a gas, and radioactive decay.

A method of computer utilization that would seem to be particularly appropriate for physics and chemistry instruction has been described by Showalter (1970). He referred to teaching science through inquiry using computer-simulated experiments as Computer Simulated Experimentation (CSE). He categorized CSE as a subset of the dialogue mode. This technique uses the dialogue mode to describe the experiment and to instruct the student on the method of inputting the independent variable(s). A simulation routine then computes values of the dependent variable(s). The output is displayed for the student in tabular or statement form.

We may conclude that computer-simulated experiments offer a feasible mode of individualizing instruction in physics and chemistry and that the procedure itself might have an intrinsic appeal that would motivate some students to further work in physics, chemistry, computer science, or some related field. Oettinger (1966) stressed the significance of simulation and hinted at the excitement of the technique when he said:

> In its scientific applications the computer has been cast in two quite distinct but complementary roles: as an instrument and as an actor. The computer's role as an instrument is far the more clear-cut and firmly established of the two. It is in its other role, however, as an active participant in the development of scientific theories, that the computer promises to have its most profound impact on science. A physical theory expressed in the language of mathematics often becomes dynamic when it is rewritten as a computer program; one can explore its inner structure, confront it with experimental data and interpret its implications much more easily than when it is in static form (p. 172).

Need for the Study

Several writers have pointed out a need for research into ways of implementing CAI. Boblick (1970) stated:

> Today's physics teachers must produce software programs for use on existing computer systems in order to develop the expertise in computer use which, when coupled with technical developments, will enable the fullest implementation of computer simulations as a teaching tool (p. 81).

Blum and Bork (1970) pointed out that we need to be concerned with how the computer may alter the style and content of science education and not just the way in which the computer can be a useful tool. Wing (1968) said:

> The chief implication of all of this is that considerably more study should be taking place of ways in which simulation techniques can be used in science education. Researchers on this topic should depart from traditional methods and devise improved ways to instruct students in science through the use of simulation (p. 42).

Zinn (1970) stressed that such research should consider instructional objectives and student characteristics.

Although many writers have discussed methods of using the computer in science education, there is no indication of any controlled study to determine the feasibility and effectiveness of using computer-simulated experiments in high school physics and chemistry. A search of the literature has revealed little or no research on achievement and attitudes of high school students using this mode of instruction.

The nature of much of the literature has been indicated by Seidel (1972) in his review of the proceedings of a conference on computers in undergraduate science education, held in College Park, Maryland in 1971. He stated:

> In most instances the papers are technically descriptive rather than evaluative — not even reporting the number of students and the effects upon these numbers of students that the innovation using the computer accomplished. For the most part, again with a few exceptions . . . opinions are simply given about the enthusiasm that the teacher sees from this use, or that the students, in general, seem to get a big kick out of it when approaching a portion of the curriculum in class (p. 64).

Statement of the Problem

The problem was to compare the attitudes and achievement of students using computer-simulated experiments with those of students using traditional laboratory experiments in high school physics and chemistry.

Students were evaluated with achievement tests over the experiments and with attitude measures relating to the subject, laboratory work, the computer as a laboratory aid, and using a computer terminal.

Purpose of the Study

The purpose of the study was to determine the feasibility of using computer-simulated experiments as a means of individualizing instruction in high school physics and chemistry, and to evaluate the attitudes and achievement of the students involved. Answers were sought to the following questions:

1. Does using a computer to simulate experiments influence students' attitudes toward (a) the subject, (b) laboratory work, (c) the computer as a laboratory aid, or (d) using a computer terminal?
2. Is student achievement in understanding laboratory work affected by using computer-simulated experiments?
3. Is the student's attitude toward the computer as a laboratory aid and toward using a computer terminal related to cumulative grade point or IQ?
4. Is there any difference between males and females in their attitude toward using a computer terminal?

Delimitations

The scope of this investigation was limited by a number of factors. (1) The students in the study were those enrolled in physics and chemistry classes at Ames Senior High School during the spring semester of 1972.

There were eight sections of physics and seven sections of chemistry involving a total sample size of 258. (2) Ten experiments were used in each subject. (3) Since the experiments were restricted to those that could actually be done in the laboratory as well as simulated, the results may not be generalized to the more extensive applications of the simulation technique. (4) Only four teachers were involved in the study. (5) Students worked in groups of two or three in the same laboratory at the same time.

REVIEW OF LITERATURE

The use of simulated experiments in high school physics and chemistry classes is a new approach to the individualization of science instruction. Because of this, the literature contains only an occasional reference to preliminary research on the effectiveness of this mode of instruction. The literature reviewed in this study has been divided into three categories: (1) rationale for computer-simulated experiments, (2) criteria and limitations for development and use of computer-simulated studies, and (3) related studies.

Rationale for Computer-Simulated Experiments

In the opinion of several writers (Boblick, 1970; Chesley, 1971; Showalter, 1970), computer simulation will soon become one of the most interesting and effective tools at the disposal of science teachers. Boblick (1970) stated:

> The possible uses of computers in physics instruction are limitless. But of all the myriad of uses of computers, the simulation of laboratory environments promises to be the most rewarding to both students and their teachers (p. 81).

Zinn (1970) feels that frame by frame programming with an author language is on the way out and that the greatest potential for instruction is in the areas of simulation and calculation.

From the educational theory point of view, the role of student and teacher is of interest. Bell and Linebarger (1970) remarked that too often true inductiveness and open-endedness in science learning situations is discouraged by teacher-centered activities that require a student to follow a predescribed and predetermined course of action. Boblick

(1970) pointed out, "The simulations will be characterized by learner-centered activities which will produce the individualized instruction so vital to the fullest development of the student" (p. 81). Bell and Linebarger (1970) stated:

> We feel that . . . using modeling and simulation has great potential as an educational tool, and that it represents an extremely exciting innovation in science education. It is a student-centered innovation, much more so than other methods, because of the opportunity for student interaction with a uniquely programed computer (p. 6.17).

Several advantages of using computer-simulated experiments have been indicated by a variety of authors. One reason for using a simulated experiment is that equipment may not be available because of its expense or complexity. Studies of such phenomena as satellite orbits, atomic spectroscopy, cyclotron operation, and X-ray diffraction are examples of experiments that may be carried out by simulation though, ordinarily, not by the traditional laboratory methods (Castleberry & Lagowski, 1970; Liao, 1972; Showalter, 1970).

The time needed for data collection is reduced, enabling the student to make replications or spend less time on the experiment (Castleberry & Lagowski, 1970; Craig, Sherertz, Carlton, & Ackermann, 1971; Showalter, 1970). This was emphasized by Castleberry and Lagowski (1970) when they said:

> . . . a technique may be taught in the laboratory and then belabored endlessly to show the student how it may be used to obtain experimental results directed toward a variety of ends. For example, it is not uncommon to have students perform acid-base titrations, equivalent weight determinations, oxidation-reduction titrations, complexometric titrations, etc. However, all of these experiments involve a basic titration technique and the student spends several afternoons in the laboratory carrying out essentially the same operation, but with a slightly

> different goal each time. Computer-simulated experiments can provide a student with practice in manipulating individualized experimental data after he has been exposed to an experimental technique in the laboratory (pp. 92-93).

Simulation makes possible experimentation that would ordinarily involve danger (Liao, 1972; Naylor _et al._, 1966). Liao (1972) referred to such hazards as radiation, heat, and substances that are corrosive, explosive, or toxic.

Simulated experiments may be conducted at terminals placed in media centers or study rooms apart from the laboratory. This enables students to conduct experiments beyond the laboratory period (Castleberry and Lagowski, 1970).

Since experimental error may be controlled, the student may be provided with data from which valid conclusions may be drawn. Danver (1970) referred to a common problem associated with actual laboratory experiments in stating:

> As far as demonstrating to him that the law in question is really valid, the discrepancies between his results and the theoretical results leave him with little to go on except to accept the principle on faith (p. 20).

Systems governed by nonphysical laws may be studied. Examples include negative gravity and noninverse-square gravitational forces (Liao, 1972).

Other reasons given for using simulation in the laboratory were: (1) A phenomena may be studied in real time, expanded time, or compressed time (Liao, 1972; Naylor _et al._, 1966; Showalter, 1970). (2) Immediate return of the result is obtained after the student has input the parameters which he has specified (Stannard, 1970). (3) Measurements of all variables of interest may be made without the problems often associated with disturbance of the system by the measuring instrument (Liao, 1972). (4) It serves as a pedagogical device to give students additional experience in theoretical analyses, statistical analyses, reasoning, and decision making (Bell and Linebarger, 1970; Castleberry and Lagowski, 1970; Naylor _et al._, 1966; Showalter, 1970).

Criteria and Limitations

Various authors have identified the basic procedures and considerations in developing and utilizing computer-simulated experiments. Naylor _et al_. (1966) stated:

> Experience suggests that planning simulation experiments involves a procedure consisting of the following nine elements:
>
> 1. Formulation of the problem.
> 2. Collection and processing of real world data.
> 3. Formulation of mathematical model.
> 4. Estimation of parameters of operating characteristics from real world data.
> 5. Evaluation of the model and parameter estimates.
> 6. Formulation of a computer program.
> 7. Validation.
> 8. Design of simulation experiments.
> 9. Analysis of simulation data (p. 23).

In many of the experiments used in high school physics and chemistry, the mathematical model has already been specified; therefore, the first step would be that indicated as (4) above. Brown (1970) presented a comparable paradigm for the development of simulation programs.

The decision to simulate an experiment should be based on a careful consideration of the objectives to be attained. According to Dean (1972), simulation can provide for two types of development:

> (1) advancement of knowledge about the physical system; and
> (2) advancement of knowledge to the user, though other people such as the writer of the program already know these facts (p. 204).

He stressed that advancement of knowledge to the user should be the first consideration of education.

Liao (1972) stated three specific objectives of simulated experiments:

> The specific objectives of the individual simulations should be:
>
> (a) To improve the student's understanding of subjects treated inadequately, or not at all, in conventional laboratories.
> (b) To provide opportunities for learning by observation rather than vicariously by reading or by being lectured to.
> (c) To permit presentation in class of concepts not now possible because of limited student preparation in mathematics (p. 245).

The program should be designed in such a manner that the students can interact with the computer by answering questions and feeding in data (Fox, 1969). If the initial questions asked of the student are such that response is easily stated, the extent of computer-fright is reduced for students who are using the computer for the first time (Craig _et_ _al_., 1971). The output of the program should be restricted to numbers or a relatively small number of words (Showalter, 1970).

Showalter (1970) listed six other criteria for good topics for computer simulated experiments:

> 1. Data obtained by the student really should be realistic (i.e., they should correspond to real experimental results).
> 2. Not all controllable variables should have a systematic effect on the data obtained (i.e., the student investigator should have the chance of pursuing what ultimately will be immaterial in the general phenomenon being studied).

3. There should be an unlimited range for permitted values for each controllable variable.
4. Topics should correspond to a real referent in the investigator's experience. He should feel that he is investigating a real phenomenon.
5. Topics should go beyond that which can be done readily in the real laboratory. That is, the topics, and CSE in general, should extend, not replace, real laboratory experiences.
6. Topics should be programmed so that the investigator makes a choice of dependent variables (i.e., output) produced by the experiment as well as of values for independent variables in designing the experiment (p. 49).

In reference to the limitations of simulation experiments, several writers have stressed that the simulation technique should not be considered a substitute for real laboratory experience. Dean (1972) stated:

> Finally let us not become so engrossed with simulation programs that we forget reality. A simulation of a satellite is certain to widen learning opportunities, but to simulate a perfectly feasible school laboratory experiment is possibly a waste of time (p. 205).

Craig et al. (1971) have suggested that the introduction of computer experiments should use the computer as an instrument in its own right to enlarge the range of experiments that may be conducted. They also feel that its use should place a greater responsibility on the student experimenter for decision making. With regard to the importance of actual laboratory work, they stated, "We continue to believe that it is essential for chemistry students to have much direct experience with the behavior of matter and with the many instruments by which matter is investigated" (p. 313). Liao (1972) supported the idea that students should be exposed to real-life experiments whenever this is possible, but added that many times a student cannot perform a specific experiment, and as a consequence is deprived of a valuable learning experience. The number of experiments available for a student to do should be greatly increased by the use of computer simulations.

The ideas expressed indicate that the computer simulation should not be a substitute for laboratory work nor should it become a game played for fun (Dean, 1972). Instead, it should be a carefully developed plan of student-centered, individualized instruction leading to the realization of specific educational objectives. Oettinger (1966) summarized the overall potential of computer simulation as follows:

> In short, computers are capable of profoundly affecting science by stretching human reason and intuition, much as telescopes or microscopes extend human vision. I suspect that the ultimate effects of this stretching will be as far-reaching as the effects of the invention of writing. Whether the product is truth or nonsense, however, will depend more on the user than on the tool (p. 172).

Related Studies

The following studies were significant in forming a basis for this investigation.

The development and evaluation of a computer-assisted instruction program for introductory college chemistry has been described by Castleberry and Lagowski (1970). This study compared achievement and attitudes of college students in an introductory chemistry course using CAI for tutorial drill, simulation of experiments, and practice problems.

Extensions of this study were done by Castleberry, Montague, and Lagowski (1970). A pilot study was conducted during the fall semester of 1968 involving one section of 300 students. Of this group, 139 volunteered to participate in the pilot study by using the CAI modules.

During the spring semester of 1969, 100 subjects were randomly selected from a group of 149 who volunteered to participate in the study. Seventy-four of this group of 100 were assigned to the use of CAI, and the remainder of the group of 149 was designated as the control group. Selection of those for the control group was influenced by schedule problems and previous CAI experience. Those with no CAI experience were included in the control group. Of those designated as the experimental group, 38 were designated as fully participating and the other 36 had a more limited contact with the computer. Four simulated experiments were involved in the study. The simulated experiments used were: (1) the quantitative decomposition of potassium chloride, (2) the reaction of hydrogen with ferrous and ferric chloride, (3) a combining volumes experiment using nitric oxide and oxygen, and (4) the quantitative analysis of unknowns using spectroscopic techniques. The number of students doing the experiments ranged from three to seventeen with an average of ten.

Evaluation as described by Castleberry _et_ _al_. (1970) consisted of a final examination analyzed in relation to those items related to the CAI modules, and of an attitude pre-test and post-test. Covariates used were a chemistry placement score and SAT-Math and SAT-Verbal scores. On the achievement test, a significant difference was found in items related to the CAI modules, but there was no significant difference on those items not related to the CAI modules. Attitudes toward chemistry were not changed; however, the attitude toward CAI was significantly improved. They found no differences in attitude between males and females on either the pre-test or post-test.

Castleberry _et_ _al_. (1970) pointed out that further research is needed on the degree to which their findings may be reproducible in similar as well as more general situations, the effect of CAI on study time and habits, the long-term effects of CAI, the effect of CAI on motivation, and relationships between personality and CAI effectiveness.

A feasibility study of computer-simulated experiments in science on the secondary school level has been presented by Showalter (1970). He feels that the simulation mode is particularly significant from the practical point of view in that it ". . . may well obviate the constraints of unreasonable cost and demand for complex and extensive software" (p. 46). Showalter devised a wide range of computer-simulated experiments which he used with students in grades 6 through 12. Although he has reported no controlled studies of the relative effectiveness of this mode of instruction as compared to other currently used techniques, he has presented a number of potential benefits which he described as hypothetical. These benefits, as he gave them, are:

1. CSE gives students and teachers access to many natural phenomena that are otherwise impossible to study directly in science classes. These phenomena may be too dangerous, too small, too large, too expensive, or too extensive in time to be feasible for ordinary school procedures.
2. CSE provides a unique vehicle for students to develop skills and strategies of inquiry. Working with a computer terminal produces a printed record of everything that is done in the exact order in which it was done. This record provides a base for teacher-student interaction focused on the process of an investigation as well as on its results.
3. CSE offers a unique medium for educational research into the problems associated with how individuals learn to inquire and how their strategies of inquiry develop and change. The medium provides its own evaluation device and instrument.
4. CSE provides an ideal framework for individualization of science learning. Not only may students progress at their own rate, but they are subject to increased motivation.

5. CSE facilitates a higher efficiency in use of time in a student's learning process through investigations in which the objectives of instruction are not focused on developing manipulative skills associated with scientific apparatus. Without the time required to set up, adjust, and manipulate apparatus, a student can easily complete all stages of an investigation within a single 45-minute period.
6. CSE extends the portion of the school day available for learning beyond the time of a given class. There is a distinct possibility that lightweight portable terminals will be developed which will make any telephone an access to the computer.
7. CSE requires a minimum of soft-ware compared to other modes of CAI. This simplicity results from greatly reduced length (thus requiring smaller storage capacity) and from ease of expression in BASIC, which is easily learned (thus enabling all science teachers to construct programs).
8. CSE should enable students to develop creativity in science and to develop an interest in science beyond that of conventional techniques. CSE imposes fewer restrictions on the individual than do most laboratories in which the equipment available limits the investigation.
9. Doing CSE should provide a basis for student interest in applying computer programming and simulation to other situations.
10. CSE offers a possibility of reduced instructional costs when compared to other forms of CAI and even to "normal" instructional procedures. A fair price for a computer terminal is now about $550 per month. Assuming that 5 minutes is needed "on-line" by a student for an hour's work and there are 6 hours to the school day of which there are 21 per month, the cost of instruction is $0.36 per student hour. It costs about $0.50 per student hour for a lecturer, assuming 24 students per class and 4 lecture hours per day at a salary for the lecturer of $1,000 per month.
11. CSE offers unlimited potential for further development and application (pp. 49-50).

Other writers have referred to student response to using computer-simulated experiments. Stannard (1970) remarked that one factor that has hampered evaluation of the computer-assisted programs used at the State University of New York is the lack of student criticism. He indicated a positive response in his statement: "One of the most encouraging aspects of the entire experiment has been the enthusiasm of the students" (p. 1421). Although volunteers were used in this application of computer simulations to undergraduate physics instruction, Stannard (1970) felt the general reaction was favorable. He commented that

> . . . the fact that the use has been consistently high and that enthusiasm has been sustained in a varied cross section of the student body seems indicative of promise for student acceptance for the use of the computer for instruction (p. 1421).

The question of student response to using a teletype is of interest. In speaking of students' use of a teletype, Kelsey (1967) stated that ". . . students could experience the satisfaction of communicating with the computer themselves; this served, then, as a great motivating as well as instructional aid" (p. 120). Craig *et al.* (1971), on the other hand, referred to the need for program routines that will reduce "student fright".

The review of the literature has indicated that computer simulations have the potential of making a unique contribution to the goal of individualizing instruction in the physics and chemistry laboratory programs. Optimum utilization of this mode of instruction requires a careful analysis of the objectives to be attained, to determine the computer's role (if any) in the process. Should it seem appropriate to simulate an experiment, procedures and criteria for the development of a simulation are suggested. A need for further evaluation of computer-simulated experiments was indicated.

METHOD OF PROCEDURE

This investigation was to explore the feasibility of using computer-simulated experiments in high school physics and chemistry and to evaluate the students' attitudes and achievement as related to a series of ten laboratory experiments during the second semester of the 1971-72 school year.

Objectives

The specific objectives of this study are as follows:

1. To determine whether students do better on achievement tests over laboratory experiments when they study the experiment by means of computer simulation than when they actually do the experiment.
2. To determine student reactions to computer simulation as a mode of instruction as opposed to the traditional laboratory approach.
3. To determine if students' feelings toward using a computer terminal are changed by participation in computer-simulated experiments.
4. To determine if factors such as IQ, cumulative grade point, and sex have any relationship to the effectiveness of computer simulation as a mode of instruction.
5. To determine the feasibility of using computer simulation in existing programs and to explore its potential for further individualization of instruction.

Hypotheses

Five null hypotheses were proposed to form a basis for a statistical evaluation of the study. A difference was considered significant if the F value calculated was larger than the value required for a 2-tailed test at the 0.05 level. An F value larger than the value required for the 0.01 level was considered highly significant (Snedecor & Cochran, 1967).

The hypotheses stated for investigation were as follows:

1. There is no significant difference between the group means of the experimental and control groups as measured by a pre-test and a post-test to determine attitude toward:
    a. the subject (physics or chemistry)
    b. laboratory work
    c. the computer as a laboratory aid
2. There is no significant difference between the group means of the experimental and control groups as measured by achievement tests over the laboratory experiments.
3. There is no significant difference between the group means of the experimental and control groups as measured by a post-test on attitude toward using a computer terminal.
4. There is no significant difference between the group means of males and females as measured by a post-test on attitude toward using a computer terminal.
5. There is no significant difference in the gain-scores on group means of the experimental and control groups as measured by a pre-test and a post-test to determine attitude

toward:

a. the subject (physics or chemistry)

b. laboratory work

c. the computer as a laboratory aid

Assumptions

The following basic assumptions were made: (1) Students were normally and independently distributed in both the experimental and control group with respect to ability in chemistry or physics, cumulative grade point, IQ, and in attitude toward physics or chemistry, laboratory work, and the computer as a laboratory aid. (2) The effect of the teacher was approximately the same in all courses. (3) The effect of the teacher was approximately the same on experimental and control groups. (4) The presence of experimental and control groups in the same class had no differential effect on either group.

Selection of the Sample

The sample consisted of the students enrolled in physics and chemistry at Ames Senior High School, Ames, Iowa during the second semester of the 1971-72 school year. These students were enrolled in 15 sections of which 4 were PSSC Physics (Physics B), 4 were Project Physics (Physics A), 4 were chemistry with strong physics and mathematics backgrounds as a prerequisite (Chemistry B), and the remaining 3 were chemistry with minimal prerequisites (Chemistry A). The total number of students in the study was 258. Enrollments in the courses were as follows: Physics B, 86; Physics A, 56; Chemistry B, 66; Chemistry A, 50.

The chemistry students were all seniors and the physics students predominately juniors. Of the 258 subjects, 156 were males and 102 were females.

The size of the sections ranged from 11 to 24. The students in each of the sections were randomly divided into experimental and control groups of as nearly equal size as possible. Although withdrawals and missing test scores unbalanced the groups in each of the chemistry courses, the entire sample was evenly divided with 129 in the experimental group and 129 in the control group. (See Table 1.) At the time the attitude pre-test was given early in the first semester, the total enrollment was 297. The loss of students was primarily at the end of the first semester and would not have affected the study which was conducted during the second semester.

Table 1. Distribution of the sample

	Experimental		Control		Total	
	Male	Female	Male	Female	Male	Female
Physics A	16	12	19	9	35	21
Physics B	29	14	34	9	63	23
Subtotal	45	26	53	18	98	44
Chemistry A	11	16	7	16	18	32
Chemistry B	22	9	18	17	40	26
Subtotal	33	25	25	33	58	58
Total	78	51	78	51	156	102

Selection of Experiments

Several guidelines were observed in the selection of the experiments to be used in the study.

First, the experiment had to be closely related to the course of study for the second semester's work in physics or chemistry at Ames Senior High School. This restriction minimized the disruption caused by the research and also added validity to the study, since one of the objectives of the study was to determine the feasibility of using computer simulations in existing programs as well as to explore its potential for further individualization of instruction.

Second, only those experiments that could actually be done in the laboratory as well as simulated were used. Although one of the greatest potentials of the simulation technique is in extending the scope of the inquiry approach in science education, this study had to include those experiments that could be done both ways so that comparisons could be made.

Third, it was felt that the experiments should be representative of those that are widely used in high school physics and chemistry. The committee developed materials, such as PSSC Physics, Project Physics, and CHEM Study, and traditional experiments were included to give as much generality as possible.

Fourth, wherever possible, experiments were picked and scheduled so that the student would not know the expected outcome of the laboratory or have a readily available source from which to obtain the information.

The experiments used for chemistry were adaptations of those in introductory chemistry laboratory manuals such as those by Anderson and Hawes (1967); Bickel and Hogg (1971); Davis, MacNab, Haenisch, McClellan, and O'Connor (1968); Ferguson, Schmuckler, Caro, and Siegelman (1970); Greenstone (1966); Harper and Lloyd (1968); Sienko and Plane (1968); and Spritzer and Markham (1969). The following chemistry experiments were selected for the study:

1. Equivalent weight of an acid — This was a titration experiment using a polyprotic, solid acid as an unknown and a standardized base. The students were asked to determine the number of ionizable hydrogens in the acid and to determine the equivalent weight of the acid.
2. Analysis of a potassium chlorate - potassium chloride mixture — This was a thermal decomposition experiment in which the students determined the percent of potassium chlorate in a sample.
3. Reduction of permanganate — The reduction of the permanganate ion in acidic, basic, and neutral solutions was studied by a titration experiment. Students were asked to calculate the number of electrons furnished by a reducing agent and assign an oxidation number to the reduced ion.
4. Heat of solution — Sulfuric acid was added to water in a calorimeter and the energy change per mole of acid determined.
5. Molecular weight by the Dumas Method — An unknown volatile compound was heated above its boiling point, and volume, temperature, and pressure measurements made on the vapor produced.

The vapor was then condensed and the molecular weight of the compound determined from the weight of the resulting liquid.

6. Combining weight of a metal — A known mass of metal was reacted with nitric acid. The resulting compound was decomposed by heat to form an oxide of the metal. From the mass relationships obtained, the combining weight (or equivalent weight) of the metal was determined.
7. Formula of a precipitate — Solutions of lead nitrate and sodium iodide were mixed and the mass of the precipitate obtained. The mole relation between reactants and products was used to determine the formula of the precipitate.
8. Specific heat of a metal — A heated metal sample was placed in a calorimeter containing cold water. Measurements of the mass of metal and water and the final temperature were used to calculate the specific heat of the metal sample.
9. Heat of reaction — An exothermic reaction was studied by calorimetric methods to determine the number of kilocalories per mole released in the reaction.
10. Water of hydration — Crystals of a material containing water of hydration were heated to drive off the water. From the mass of the anhydrous compound and the original mass, the percentage of water in the original material was determined.
11. Solubility product of lead chloride — A saturated solution

of lead chloride was evaporated to dryness. The solubility product was calculated from the mass of the dry residue and the original volume of the solution.

12. Gas laws — A J-tube apparatus was used to study the pressure-volume relationship for a gas at constant temperature. The temperature-volume relationship at constant pressure was studied using a plastic syringe and manometer.
13. Equivalent weight of copper — Faraday's laws of electrolysis were applied to determine the equivalent weight of copper and the oxidation state of the metal ion.

The experiments used for physics were adaptations of those in introductory physics laboratory manuals such as those by Jensen and Stebbins (1953); Physical Science Study Committee (1965); Rutherford, Holton, and Watson (1970); Stollberg and Hill (1965); Verwiebe, Van Hooft, and Saxon (1970); and Wall and Levine (1962). The following physics experiments were selected for the study:

1. Boyle's Law — A commercial J-tube apparatus was used to determine the relationship between the pressure and volume of a gas at constant temperature.
2. Magnetic field at the center of a loop — The strength of the magnetic field at the center of a rectangular loop was measured by a comparison with the earth's field. The effect of the current in the loop and number of turns of wire in the loop were determined.
3. Forces on currents — A current balance was used to determine

how the force on current-carrying conductors depends upon (a) the current in the wires, (b) the distance between the wires, and (c) the length of one of the wires.

4. Currents, magnets and forces — A current balance was used to determine: (a) how the force between a current and a magnet depends upon the magnitude of the current, (b) how the force between a magnet and a current depends on the length of the region of interaction, and (c) how a current interacts with the magnetic field of the earth.
5. Electrical circuits — Measurements of potential difference and current in a circuit containing a single resistance and two resistances in combination were used to discover Ohm's Law and the rules for combining resistances in series and parallel.
6. Coulomb's Law — A balance constructed from a soda-straw and pin was used to determine the relationship between force and separation for point, electrostatic charges.
7. Electric calorimeter — An electric heating unit was submerged in cold water in a calorimeter cup. Measurements of mass of water, time, temperature, and current were used to determine the potential difference applied to the heating element.
8. Radiation from a point source — A miniature lamp and silicon, solar cell were used to determine the relationship between intensity of the radiation and the distance from the source.

9. The magnetic field near a long, straight wire — The relationship between magnetic field strength and distance from a long, straight wire was determined. The field produced by the wire was determined by comparison with the earth's magnetic field.
10. Convex lens — The relationship between image position and object position was determined for a convex lens. The nature of the image and the size of the image were related to object position.

Computer Programs

The computer programs used were written, debugged, and stored in the computer memory (library) prior to the laboratory period. Specimen data sets were always pre-run so that laboratories could proceed during computer down-time. This precaution also guarded against delays that might occur due to terminal malfunction or instances where several students might wish to obtain data from the terminal at the same time.

All programs were written to include a random error in the output data comparable in maximum percentage to the errors that a careful experimenter might find in his data obtained from working with the real laboratory equipment.

From the standpoint of student interaction with the terminal, two types of programs were used. In one type of program, the student was required to input the independent variable(s) singly and the terminal then provided the dependent variable as output. The limitations on each of the variables were similar to the restrictions imposed by the actual laboratory apparatus. For example, if an ammeter of maximum range of 5 amperes was used in the actual experiment, in the simulated experiment the computer was programmed to warn the student if he exceeded this value by a slight amount. If he exceeded a permissible range by a great amount, he might be informed that he damaged the instrument and the execution of the program would be halted. This type of program demanded a high degree of student involvement.

In the second type of program, the student selected the initial set of circumstances to be utilized, and the computer then generated a data set including an appropriate range of values on both the dependent and independent variables. In this case, random selection of the independent variable(s) and/or random error of the output insured data sets that were not identical. This type of program was used whenever the range and increment of the independent variable was specified in the laboratory instructions. It was also a convenient method of pre-running data sets to have available as needed.

The PL/1 language was used with the Conversational Programming System (CPS) used at Iowa State University. This language is described in the IBM *Conversational Programming System Terminal User's Manual* (1970).

A Model 33ASR Teletypewriter was used to communicate with the IBM 360/65 computer at Iowa State University.

Classroom Procedure

Prior to the beginning of each of the laboratory experiments, the experimental and control groups were given the same background information and instructions. Within each section of physics or chemistry, both experimental and control groups worked in the same laboratory at the same time. The teachers monitored the laboratories and discouraged the sharing of information between experimental and control groups. Students in the experimental group were encouraged to look at the equipment, but they were not allowed to use it to take data. Students in the control group were not allowed to use computer generated data. The teachers were on hand to give assistance in operation of the equipment and the computer terminal. Advice was provided in the methods of data analysis; however, clues to indicate whether conclusions were right or wrong were avoided. Laboratory work was carried out in small groups of two or three students. During the first laboratory session, all students in the experimental group were required to personally operate the terminal to obtain some data. In later sessions, the teachers urged all students in the experimental group to share in the actual operation of the terminal and prevented the monopolization of the terminal by those who were particularly desirous to use it.

A laboratory quiz was given at the end of the session or at the beginning of the next session. Any follow-up discussion of the experiments was postponed until after the quiz. Other aspects of the classroom procedure were carried out in the manner that each teacher ordinarily used in conducting his or her classes.

In a typical laboratory session, the teacher would first briefly review the objectives or plan of the experiment and comment on special problems or precautions. Both experimental and control groups were treated identically in this respect. Any additional guide sheets or sheets needed to supplement the experiment directions were given to both groups. Students then divided into experimental and control groups. A given student was always in the same group. Those doing the experiment in the traditional manner proceeded to carry out the investigation in groups of two or three students. Those in the experimental group obtained their data from the computer simulation. During the time that the students in the first groups to use the terminal were gathering data, others were encouraged to utilize the waiting time to thoroughly familiarize themselves with the experiment and to organize their plan of data analysis.

Data Collection

During the first semester of the 1971-72 school year, all students in physics and chemistry were assigned a subject identification number. At this time they were told that they would be participating in an experimental study involving the computer terminal and were asked to respond to an attitude survey. This test was an adaptation of a scale used by Castleberry and Lagowski (1970) and consisted of 18 descriptive terms organized in the semantic differential format (Osgood _et al._, 1969). Students were asked to express their reaction to the subject (physics or chemistry), to laboratory work, and to the computer as a laboratory aid. A 7-point scale was used for each of the descriptors resulting in a neutral score of 72. At the time of this survey, student contact with the computer terminal ranged from none to two years of intensive work in programming. The latter was an exception. Most of them had seen the terminal and some had seen a demonstration of its use, but had not used it themselves.

At the end of each experiment a 10-point quiz was administered by the classroom teacher. These quizzes covered only the specific material involved in the experiment and were mostly multiple choice. Some items were in the form of short answers and problems. All tests were teacher-made.

At the conclusion of the study two attitude scales were used. The first was the same semantic differential scale used during the first semester to determine attitude toward the subject, laboratory work, and the computer as a laboratory aid. The second was an adaptation of a scale used by Wisnieski (1970) and previously by Aiken and Dreger (1961). This consisted of 26 items arranged in the Likert (1932) format and was used to determine the student's attitude toward using the computer terminal. Half of the questions were worded positively and half were worded negatively, and the students were asked to agree or disagree and to indicate the strength of their reaction on a 5-point scale with "5" indicating the strongest feeling. To facilitate analysis, all answers were converted to a positive number so that a range of from 1 to 261 resulted. A score of 131 would indicate a neutral reaction.

The additional measures used were obtained from the students' permanent records obtained from the guidance department at Ames Senior High School. The measures used included the cumulative grade point, the Otis-Lennon IQ score, and the average of the first- and second- semester grades in physics or chemistry for the 1971-72 school year.

The total number of measures obtained for each student included 7 attitude measures, an achievement test score representing the sum of 10 separate tests, and 3 scores from the student's permanent records.

Statistical Design

In addition to comparing the mean scores on all measures for the entire experimental and control groups, this study was also considered as four separate experiments — one in each of the four subjects identified previously as Physics A, Physics B, Chemistry A, and Chemistry B.

The pre-test - post-test control group design (Campbell & Stanley, 1963) was used to study student attitudes toward the subject (physics or chemistry), laboratory work, and the computer as a laboratory aid. To measure attitudinal changes, a pre-test - post-test gain score was calculated.

Achievement and attitude toward using a computer terminal were studied by the post-test only control group design (Campbell & Stanley, 1963).

Data were coded on 80 column IBM code sheets and data cards punched from the code sheets. The field designations for the data card deck are shown in Table 2. Calculations of values for statistical analysis were done by computer. Gain-scores were obtained by the computer in processing the data and, therefore, do not appear as separate fields on the data deck.

A covariance analysis, using IQ as the covariate, was used as a test for significance on all measures in the analysis of the experiment by separate subjects. Mean scores on all measures for the entire experimental and control groups were compared using t-tests and correlation matrices.

Table 2. Key to field sizes of master data deck

Field	Significance
1- 4	Job number identification
5- 6	Card number
7-10	Subject identification number
11-14	Attitude pre-test: subject
15-18	Attitude pre-test: laboratory work
19-22	Attitude pre-test: computer as laboratory aid
23-26	Attitude post-test: subject
27-30	Attitude post-test: laboratory work
31-34	Attitude post-test: computer as laboratory aid
35-38	Attitude post-test: using a computer terminal
39-42	Achievement post-test on experiments
43-46	Grade point — implied decimal between 44 and 45
47-50	IQ
51-54	Course grade — implied decimal between 53 and 54
55-58	Experimental or control group Experimental = 1 Control = 2
59-62	Course Physics A = 1 Physics B = 2 Chemistry A = 3 Chemistry B = 4
63-66	Sex Male = 1 Female = 2

The following model was used for the covariance analysis:

$$Y_{ijk} = \mu + A_i + B_j + AB_j + \beta(X_{ijk} - \bar{X}\cdots) + E_{ijk}$$

where

$i = 1, 2,$

$j = 1, 2,$

$k = 1, 2, \cdots, n,$

Y_{ijk} = the test score for the k^{th} person of the j^{th} sex in the i^{th} group,

μ = the overall mean for a course,

A_i = the effect of the i^{th} treatment,

B_j = the effect of the j^{th} sex,

AB_{ij} = the interaction of the i^{th} treatment with the j^{th} sex,

β = the regression coefficient of Y on X,

X_{ijk} = the IQ score of the k^{th} person of the j^{th} sex in the i^{th} group,

$\bar{X}\cdots$ = the overall mean on the IQ test,

E_{ijk} = the residual associated with the test score of the k^{th} person of the j^{th} sex in the i^{th} group, and

n = the number of persons of the j^{th} sex in the i^{th} group.

FINDINGS

The experimental and control groups were first compared on the basis of mean scores for all measures and the correlation of all measures within these groups.

The group means, variances, and values of t are shown in Table 3. The values of t were computed using the separate variance t model with 128 degrees of freedom. No significant differences were found among any of the pre-test attitude scores, cumulative grade points, IQ scores, or grade points for physics or chemistry. This would lend support to the assumption that random assignment had resulted in equivalent groups. There was no significant difference between the mean scores on achievement tests; however, the control group mean score was slightly higher than that of the experimental group. Differences between the means of the post-test scores measuring attitude toward the computer as a laboratory aid and attitude toward using a computer terminal were significant beyond the 0.05 level. In both cases the experimental group means were higher, indicating a more positive attitude for the experimental group than for the control group.

The correlation matrices for the experimental and control groups are shown in Tables 4 and 5. Correlations significantly different from zero are indicated by either a single or double asterisk. A single asterisk was used to indicate a correlation equal to or exceeding the 0.05 level of 0.17. Those equal to or exceeding the 0.01 level of 0.23 were denoted by a double asterisk.

The correlation matrices were analyzed to determine if attitude

Table 3. Comparison of experimental and control group means on all measures

	$\bar{X}_1$	S_1^2	$\bar{X}_2$	S_2^2	
	Experimental group		Control group		
Variable	Mean	Variances	Mean	Variances	t
Attitude pre-test, Subject	82.02	211.81	82.05	270.75	-0.0155
Attitude pre-test, Laboratory work	87.29	239.29	87.76	279.87	-0.2343
Attitude pre-test, Computer as aid	89.54	235.30	88.40	354.43	0.5332
Attitude post-test, Subject	82.31	218.47	80.54	266.14	0.9132
Attitude post-test, Laboratory work	84.88	243.38	81.59	284.73	1.6260
Attitude post-test, Computer as aid	90.88	379.05	85.08	380.92	2.3896*
Attitude post-test, Using computer	184.81	1,627.00	170.09	2,492.80	2.6047*
Achievement	63.14	205.84	64.80	254.72	-0.8785
Grade point average	3.02	0.346	3.12	0.465	-1.2612
IQ	122.09	111.26	123.37	121.69	-0.9525
Course grade point	2.77	0.779	2.79	1.08	-0.1666

*P > 0.05.

Table 4. Correlation matrix for all measures; control group

	Attitude pre-test		
	Subject	Laboratory work	Computer as aid
1. Attitude pre-test, Subject	1.00		
2. Attitude pre-test, Laboratory work	0.48**	1.00	
3. Attitude pre-test, Computer as aid	0.25**	0.35**	1.00
4. Attitude post-test, Subject	0.49**	0.26**	0.30**
5. Attitude post-test, Laboratory work	0.20*	0.53**	0.23**
6. Attitude post-test, Computer as aid	0.21*	0.31**	0.37**
7. Attitude post-test, Using computer	0.30**	0.35**	0.48**
8. Achievement	0.30**	0.03	0.04
9. Grade point average	0.15	-0.03	0.02
10. IQ	0.18*	-0.02	-0.05
11. Course grade point	0.24**	-0.08	-0.03

*P > 0.05.

**P > 0.01.

Attitude post-test							
Subject	Laboratory work	Computer as aid	Using computer	Achievement	Grade point average	IQ	Course grade point
1.00							
0.47**	1.00						
0.16	0.32**	1.00					
0.30**	0.30**	0.46**	1.00				
0.44**	0.20*	-0.12	0.10	1.00			
0.30**	0.05	-0.16	0.07	0.65**	1.00		
0.20*	0.10	-0.05	0.21*	0.58**	0.67**	1.00	
0.46**	0.11	-0.10	0.03	0.67**	0.70**	0.48**	1.00

Table 5. Correlation matrix for all measures; experimental group

		Attitude pre-test		
		Subject	Laboratory work	Computer as aid
1.	Attitude pre-test, Subject	1.00		
2.	Attitude pre-test, Laboratory work	0.49**	1.00	
3.	Attitude pre-test, Computer as aid	0.23**	0.25**	1.00
4.	Attitude post-test, Subject	0.51**	0.27**	0.15
5.	Attitude post-test, Laboratory work	0.31**	0.40**	0.06
6.	Attitude post-test, Computer as aid	0.22*	0.10	0.39**
7.	Attitude post-test, Using computer	0.26**	0.29**	0.36**
8.	Achievement	0.25**	0.10	0.13
9.	Grade point average	0.19*	0.00	0.03
10.	IQ	0.12	0.09	0.02
11.	Course grade point	0.17*	-0.07	-0.05

*P > 0.05.

**P > 0.01.

Attitude post-test							
Subject	Laboratory work	Computer as aid	Using computer	Achievement	Grade point average	IQ	Course grade point
1.00							
0.48**	1.00						
0.36**	0.21*	1.00					
0.31**	0.26**	0.57**	1.00				
0.39**	0.21*	0.10	0.13	1.00			
0.21*	0.04	-0.07	-0.03	0.65**	1.00		
0.08	0.03	-0.07	0.08	0.53**	0.45**	1.00	
0.44**	0.00	0.06	0.01	0.62**	0.61**	0.27*	1.00

measures relative to the use of the computer correlated with either cumulative grade point, IQ, or grade received in physics or chemistry. For the experimental group, no correlations significantly different from zero were found among any of these measures. A correlation significantly different from zero was found between IQ and attitude toward using the computer terminal for the subjects in the control group.

The data were further analyzed as four separate experiments — Physics A, Physics B, Chemistry A, and Chemistry B. To determine if there were differences between the courses or between sexes, an analysis of covariance was used. The correlation between IQ and attitude indicated on the control group matrix suggested the use of IQ as a covariate in the analysis. In addition to comparing the means on the seven measured of attitude and achievement, pre-test and post-test gain scores on attitude toward the subject, toward laboratory work, and toward the computer as a laboratory aid were compared.

Each of the null hypotheses was then tested with combined results of the overall analysis and the analysis as four separate experiments.

Null hypothesis number 1: There is no significant difference between the group means of the experimental and control groups as measures by a pre-test and post-test to determine attitude toward the subject (physics or chemistry), laboratory work, and the computer as a laboratory aid.

On the basis of the analysis of the overall group, this hypothesis is rejected because of significant differences on the post-test measure of attitude toward the computer as a laboratory aid. On this measure, the means for the experimental and control groups were 90.88 and 85.08 respectively. (See Table 3.) Analysis by courses (see Tables 6-12) indicated that this difference was significant only in Chemistry A. (See Table 11.) The experimental group mean was 92.70 and the control group mean was 80.97. Tables 8 and 12 also indicate a significant interaction in Physics A between group and sex on the pre-test measuring attitude toward the computer as a laboratory aid.

Null hypothesis number 2: There is no significant difference between the group means of the experimental and control groups as measured by achievement tests over the laboratory experiments.

The mean for the experimental group was 63.14 and for the control group, 64.80 (see Table 3); however, this difference was not significant and the null hypothesis can not be rejected. In Physics A, Physics B, and Chemistry B, significant differences were found between means on achievement for males and females. (See Table 13.) For Physics A, although males averaged 49.63, females averaged 47.48. For Physics B, the difference between the mean for males of 75.40 and the mean for females of 70.78 was highly significant. Chemistry B averages were: males, 73.92 and females, 71.92. In Physics A, the experimental group mean of 50.00 on achievement was significantly higher than the control group mean of 47.64. In Chemistry B a significant interaction was present between group and sex. (See Table 13.) The mean for males in the experimental group was 69.00, whereas for the males in the control group, the mean was 79.94. For the females the experimental group mean was 75.11 and the control group mean, 70.24. (See Table 12.)

Table 6. Analysis of covariance of pre-test on attitude toward subject

Source	df	Residuals Sum of squares	Residuals Mean squares	F
Physics A				
Group	1	201.19	201.19	0.78
Sex	1	193.44	193.44	0.75
Group x sex	1	860.63	860.63	3.33
Error	51	13,186.50	258.56	
Total	55	14,778.00		
Physics B				
Group	1	22.44	22.44	0.09
Sex	1	45.25	45.25	0.19
Group x sex	1	299.50	299.50	1.24
Error	81	19,576.38	241.68	
Total	85	20,213.44		
Chemistry A				
Group	1	295.00	295.00	1.44
Sex	1	187.00	187.00	0.91
Group x sex	1	99.25	99.25	0.48
Error	45	9,242.06	205.38	
Total	49	10,251.31		
Chemistry B				
Group	1	0.69	0.69	0.003
Sex	1	251.88	251.88	1.26
Group x sex	1	282.69	282.69	1.42
Error	61	12,157.25	199.30	
Total	65	12,930.00		

Table 7. Analysis of covariance of pre-test on attitude toward laboratory work

		Residuals		
Source	df	Sum of squares	Mean squares	F
Physics A				
Group	1	67.63	67.63	0.17
Sex	1	35.25	35.25	0.09
Group x sex	1	221.25	221.25	0.56
Error	51	20,127.19	394.65	
Total	55	20.425.88		
Physics B				
Group	1	200.19	200.19	0.91
Sex	1	4.63	4.63	0.02
Group x sex	1	333.31	333.31	1.53
Error	81	17,685.25	281.34	
Total	85	18,095.31		
Chemistry A				
Group	1	9.38	9.38	0.04
Sex	1	2.00	2.00	0.01
Group x sex	1	2.94	2.94	0.01
Error	45	9,398.13	208.85	
Total	49	9,635.81		
Chemistry B				
Group	1	160.44	160.44	0.67
Sex	1	660.63	660.63	2.74
Group x sex	1	429.19	429.19	1.78
Error	61	14,683.06	240.71	
Total	65	16,414.50		

Table 8. Analysis of covariance of pre-test on attitude toward the computer as a laboratory aid

		Residuals		
Source	df	Sum of squares	Mean squares	F
Physics A				
Group	1	2.44	2.44	0.01
Sex	1	217.19	217.19	0.88
Group x sex	1	1,258.13	1,258.13	5.09*
Error	51	12,596.81	247.00	
Total	55	14,598.31		
Physics B				
Group	1	183.38	183.38	0.76
Sex	1	657.75	657.75	2.73
Group x sex	1	205.31	205.31	0.85
Error	81	19,550.44	241.36	
Total	85	21,144,69		
Chemistry A				
Group	1	440.94	440.94	1.66
Sex	1	363.19	363.19	1.35
Group x sex	1	83.13	83.13	0.31
Error	45	12,062.00	268.04	
Total	49	13,460.69		
Chemistry B				
Group	1	692.63	692.63	2.13
Sex	1	555.56	555.56	1.71
Group x sex	1	26.13	26.13	0.08
Error	61	19,863.88	325.64	
Total	65	21,092.56		

*P > 0005.

Table 9. Analysis of covariance of post-test on attitude toward subject

		Residuals		
Source	df	Sum of squares	Mean squares	F
Physics A				
Group	1	121.81	121.81	0.62
Sex	1	244.19	244.19	1.25
Group x sex	1	276.63	276.63	1.41
Error	51	9,971.06	195.51	
Total	55	10,676.00		
Physics B				
Group	1	5.94	5.94	0.03
Sex	1	43.44	43.44	0.23
Group x sex	1	78.75	78.75	0.43
Error	81	14,985.56	185.01	
Total	85	16,582.94		
Chemistry A				
Group	1	1.098.13	1,098.13	3.31
Sex	1	7.06	7.06	0.02
Group x sex	1	2.75	2.75	0.08
Error	45	14,948.31	332.19	
Total	49	16,136.44		
Chemistry B				
Group	1	2.31	2.31	0.01
Sex	1	73.44	73.44	0.32
Group x sex	1	2.00	2.00	0.01
Error	61	13,793.88	226.13	
Total	65	14,210.31		

Table 10. Analysis of covariance of post-test on attitude toward laboratory work

Source	Residuals			
	df	Sum of squares	Mean squares	F
Physics A				
Group	1	36.06	36.06	0.16
Sex	1	85.50	85.50	0.37
Group x sex	1	46.00	46.00	0.20
Error	51	11,831.69	231.99	
Total	55	12,197.88		
Physics B				
Group	1	147.69	147.69	0.64
Sex	1	0.31	0.31	0.00
Group x sex	1	4.75	4.75	0.02
Error	81	18,642.81	230.16	
Total	85	19,164.56		
Chemistry A				
Group	1	1,101.38	1,101.38	3.56
Sex	1	529.63	529.63	1.71
Group x sex	1	1,078.25	1,078.25	3.49
Error	45	13,916.69	309.26	
Total	49	17,792.75		
Chemistry B				
Group	1	4.75	4.75	0.02
Sex	1	91.25	91.25	0.36
Group x sex	1	98.56	98.56	0.39
Error	61	15,569.06	255.23	
Total	65	16,198.50		

Table 11. Analysis of covariance of post-test on attitude toward the computer as a laboratory aid

Source	Residuals			
	df	Sum of squares	Mean squares	F
Physics A				
Group	1	171.69	171.69	0.38
Sex	1	345.31	345.31	0.77
Group x Sex	1	154.31	154.31	0.34
Error	51	22,913.50	449.28	
Total	55	23,627.44		
Physics B				
Group	1	501.06	501.06	1.59
Sex	1	45.56	45.56	0.14
Group x Sex	1	397.44	397.44	1.26
Error	81	25,504.50	314.87	
Total	85	26,287.31		
Chemistry A				
Group	1	1,269.25	1,269.25	5.14*
Sex	1	457.69	457.69	1.85
Group x Sex	1	807.06	807.06	3.27
Error	45	11,115.69	247.02	
Total	49	15,328.69		
Chemistry B				
Group	1	1,331.00	1,331.00	3.06
Sex	1	477.81	477.81	1.10
Group x Sex	1	708.25	708.25	1.63
Error	61	26,522.94	434.80	
Total	65	29,857.13		

*$P > 0.05$.

Table 12. Means of variables where significant differences exist

Variable	Course	Experimental group		Control group	
		Males	Females	Males	Females
Attitude pre-test, Computer as aid	Physics A	85.69	101.00	95.95	91.11
Attitude post-test, Computer as aid	Chemistry A	85.82	97.44	84.14	79.56
Attitude post-test, Using computer	Chemistry A	166.64	189.00	174.00	131.69
Attitude post-test, Using computer	Chemistry B	185.36	146.78	171.39	139.00
Achievement	Physics A	50.63	49.17	48.79	45.22
Achievement	Physics B	75.48	71.57	75.32	69.56
Achievement	Chemistry B	69.00	75.11	79.94	70.24
Pre-test - post-test gain scores on attitude toward laboratory work	Chemistry B	0.95	-3.78	-10.72	1.76
Pre-test - post-test gain scores on attitude toward computer as aid	Chemistry A	-2.45	13.44	-0.71	4.19
Pre-test - post-test gain scores on attitude toward computer as aid	Chemistry B	5.91	2.89	-15.00	-8.18

Table 13. Analysis of covariance of achievement

Source	df	Residuals		F
		Sum of squares	Mean squares	
Physics A				
Group	1	195.63	195.63	4.58*
Sex	1	212.75	212.75	4.98*
Group x Sex	1	6.88	6.88	1.61
Error	51	2,177.63	42.70	
Total	55	2,876.25		
Physics B				
Group	1	9.69	9.69	0.15
Sex	1	515.69	515.69	8.24**
Group x Sex	1	34.50	34.50	0.55
Error	81	5,068.81	62.58	
Total	85	7,367.81		
Chemistry A				
Group	1	25.81	25.81	0.23
Sex	1	54.94	54.94	0.50
Group x Sex	1	87.25	87.25	0.79
Error	45	4,993.31	110.96	
Total	49	6,186.50		
Chemistry B				
Group	1	31.81	31.81	0.39
Sex	1	343.69	343.69	4.24*
Group x Sex	1	482.88	482.88	5.96*
Error	61	4,943.50	81.04	
Total	65	7,341.94		

*$P > 0.05$.

**$P > 0.01$.

Null hypothesis number 3: There is no significant difference between the group means of the experimental and control groups as measured by a post-test on attitude toward using a computer terminal.

This hypothesis is rejected. The difference between the experimental group mean of 184.81 and the control group mean of 170.09 was significant. (See Table 3.) In the analysis by courses, in Chemistry A a significant difference was found between the experimental and control groups and a highly significant interaction between the group and sex. In Chemistry B, there was a highly significant difference related to sex. (See Table 14.)

Null hypothesis number 4: There is no significant difference between group means of males and females as measured by a post-test on attitude toward using a computer terminal.

The mean score of this measure for males was 184.69 and for females was 166.39. (See Table 15.) This difference was highly significant; therefore, it is possible to reject this hypothesis. Analysis of the results on this measure by courses (see Table 14) indicated a highly significant difference related to sex in Chemistry B and a significant interaction between group and sex in Chemistry B.

Null hypothesis number 5: There is no significant difference in the gain-scores on group means of the experimental and control groups as measured by a pre-test and a post-test to determine attitude toward the subject (physics or chemistry), laboratory work, and the computer as a laboratory aid.

This hypothesis is rejected on the basis of significant differences

Table 14. Analysis of covariance of post-test on attitude toward using a computer terminal

Source	df	Residuals Sum of squares	Residuals Mean squares	F
Physics A				
Group	1	136.00	136.00	0.06
Sex	1	1,121.00	1,121.00	0.51
Group x Sex	1	1,750.00	1,750.00	0.80
Error	51	111,391.00	2,184.14	
Total	55	114,802.00		
Physics B				
Group	1	3,701.00	3,701.00	3.06
Sex	1	329.00	329.00	0.27
Group x Sex	1	1,287.00	1,287.00	1.06
Error	81	98,116.00	1,211.31	
Total	85	102,986.00		
Chemistry A				
Group	1	7,933.00	7,933.00	4.76*
Sex	1	165.00	165.00	0.10
Group x Sex	1	12,223.00	12,223.00	7.33**
Error	45	75,048.00	1,667.73	
Total	49	108,124.00		
Chemistry B				
Group	1	2,933.00	2,933.00	1.22
Sex	1	23,499.00	23,499.00	9.78**
Group x Sex	1	814.00	814.00	0.34
Error	61	146,520.00	2,401.97	
Total	65	175,927.00		

*$P > 0.05$.

**$P > 0.01$.

Table 15. Group means for males and females on attitude toward using a computer terminal

	$\bar{X}_1$	s_1^2	$\bar{X}_2$	s_2^2	
	Male (n = 156)		Female (n = 102)		
Variable	Mean	Variance	Mean	Variance	t
Attitude post-test, Using computer	184.69	2,029.53	166.39	2,040.54	3.66**

$^{**}P > 0.01$.

found in chemistry on gain-scores related to laboratory work and the computer as a laboratory aid.

Pre-test - post-test gain scores were analyzed by courses. No significant differences were found in the gain scores related to attitude toward the course. (See Table 16.) On the measure related to attitude toward laboratory work (see Table 17), a significant interaction between group and sex was indicated in Chemistry B. For the experimental group in Chemistry B, the mean gain for males was 0.95 and for females, -3.78. In contrast, the control group mean gains on this measure were -10.72 for males and 1.76 for females.

Significant differences in gain scores on attitude toward the computer as a laboratory aid were found in both Chemistry A and Chemistry B. (See Table 18.) In Chemistry A the difference was related to sex. The mean gains in the experimental group were -2.45 for males and 13.44 for females. On the same measure, the control group mean gains were -0.71 for males and 4.19 for females. In Chemistry B a highly significant

Table 16. Analysis of covariance of pre-test - post-test gain scores on attitude toward subject

Source	df	Residuals Sum of squares	 Mean squares	F
Physics A				
Group	1	9.89	9.89	0.05
Sex	1	2.94	2.94	0.02
Group x Sex	1	161.43	161.43	0.88
Error	51	9,330.39	182.95	
Total	55	9,593.71		
Physics B				
Group	1	5.39	5.39	0.03
Sex	1	176.79	176.79	0.86
Group x Sex	1	71.17	71.17	0.35
Error	81	16,598.63	204.92	
Total	85	17,267.53		
Chemistry A				
Group	1	254.70	254.70	0.59
Sex	1	121.34	121.34	0.28
Group x Sex	1	68.84	68.84	0.16
Error	45	19,572.96	434.96	
Total	49	20,596.18		
Chemistry B				
Group	1	5.28	5.28	0.02
Sex	1	53.37	53.37	0.23
Group x Sex	1	237.61	237.61	1.05
Error	61	13,843.63	226.95	
Total	65	14,315.95		

Table 17. Analysis of covariance of pre-test - post-test gain scores on attitude toward laboratory work

Source	df	Residuals Sum of squares	Mean squares	F
Physics A				
Group	1	202.43	202.43	0.65
Sex	1	10.94	10.94	0.04
Group x Sex	1	65.45	65.45	0.21
Error	51	15,795.73	309.72	
Total	55	16,095.36		
Physics B				
Group	1	3.98	3.98	0.02
Sex	1	8.16	8.16	0.04
Group x Sex	1	418.21	418.21	1.99
Error	81	17,023.01	210.16	
Total	85	17,637.81		
Chemistry A				
Group	1	1,316.01	1,316.01	4.00
Sex	1	598.20	598.20	1.82
Group x Sex	1	1,194.98	1,194.98	3.63
Error	45	14,809.91	329.11	
Total	49	19,104.58		
Chemistry B				
Group	1	109.09	109.09	0.49
Sex	1	260.76	260.76	1.17
Group x Sex	1	939.64	939.64	4.23*
Error	61	13,538.36	221.94	
Total	65	15,378.66		

*$P > 0.05$.

Table 18. Analysis of covariance of pre-test - post-test gain scores on attitude toward the computer as a laboratory aid

Source	df	Residuals Sum of squares	 Mean squares	F
Physics A				
Group	1	214.88	214.88	0.46
Sex	1	14.81	14.81	0.03
Group x Sex	1	531.23	531.23	1.15
Error	51	23,604.00	462.82	
Total	55	24,711.93		
Physics B				
Group	1	78.22	78.22	0.20
Sex	1	1,050.03	1,050.03	2.72
Group x Sex	1	1,174.37	1,174.37	3.04
Error	81	31,318.80	386.65	
Total	85	34,350.75		
Chemistry A				
Group	1	213.96	213.96	0.81
Sex	1	1,636.79	1,636.79	6.18*
Group x Sex	1	371.98	371.98	1.40
Error	45	11,923.21	264.96	
Total	49	14,632.00		
Chemistry				
Group	1	3,944.06	3,944.06	8.61**
Sex	1	2.93	2.93	0.01
Group x Sex	1	462.26	462.26	1.01
Error	61	27,931.54	457.89	
Total	65	33,165.16		

*P > 0.05.

**P > 0.01.

difference between experimental and control groups was found. In the experimental group, the mean gain score for males was 5.91 and for females, 2.89. The control group mean gains were -15.00 and -8.18 for males and females, respectively. (See Table 12.)

DISCUSSION AND RECOMMENDATIONS

The general objectives of this study were to determine the feasibility of using computer-simulated experiments in high school physics and chemistry, to determine the effect of this mode of instruction on student attitudes, and to determine if students who have studied experiments by simulation do as well on tests over those experiments as do students who actually do the experiment.

No major problems were encountered in implementing the simulated experiments. Programming in the CPS PL/1 language is relatively simple and a simulation program may often be quite short. Students readily learned the procedures of operating the terminal and did not need any knowledge of how the computer carried out the simulation or how to write programs. Students only needed to know how to log in the terminal, load and execute the program, and log out when finished. Although the time needed at the terminal was typically five to ten minutes, some students tended to spend excessive time simply because they enjoyed using it. This may pose a problem when many people must share a terminal.

The potential for individualizing instruction and extending the scope of inquiry type of investigations is great. Students were able to investigate such things as the effect of a change of atmospheric pressure on the results of a gas law experiment or the effect of using different components in an electrical circuit, quickly and without concern about damage to equipment. Students were not only able to explore beyond the limitations of the actual laboratory equipment, but could also re-run the experiment without need for access to the laboratory and equipment. The portability of the terminal allowed it to be used in any one of several rooms.

Because values obtained for variables differ from trial to trial in the simulations, individual work is encouraged. The expected result may often be part of the output to simplify grading of reports. This may be in a coded form, if desired, so that the student will not recognize the answer.

The attitude scales indicated that there was no significant change in attitude toward the course or toward laboratory work; however, there was a positive change in attitude toward the computer as a laboratory aid and toward using a computer terminal. In the analysis of attitudes by courses, only 7 F values were significant out of 120 F values related to attitude. No further generalization was possible from these comparisons.

The mean scores on all attitude measures were higher than might have been expected. Castleberry _et al_. (1970) reported means of 43.6 on the pre-test and 43.5 on the post-test measuring attitude toward chemistry as a subject. On the basis of the 70-point scale they used, these scores represent about 62%. On the same measure, Ames High School physics and chemistry students averaged 82.0 on the pre-test and 81.4 on the post-test. Based on the 126-point scale used in this study, these scores represent about 65%. The high school students in this study had at least as positive an attitude as the college chemistry students studied by Castleberry _et al_. (1970). Attitudes toward the computer as a laboratory aid were more positive than attitudes toward either the subject or laboratory work as measured by both the pre-tests and post-tests. (See Table 3.)

The second of the two aspects of attitudes pertaining to the use of computer-simulated experiments was not studied by Castleberry _et al._ (1970). This measure attempted to evaluate students' feelings about actually using a terminal themselves as opposed to whether or not they felt it was a useful technique. A degree of anxiety on the part of many students was observed by the teachers involved in the study. On this measure, significant differences were noted between the experimental and control groups and between males and females. The data indicated that the females were less enthusiastic toward using the terminal. On this measure the group mean for males was 184.69 and for females, 166.39. A neutral reaction would be represented by a score of 131, so both male and female reactions were quite positive. Expressed as percentages, these values represent 71 and 64, respectively. Even though the post-test results show a positive attitude toward using a terminal, observational evidence of the teachers involved in the study indicated a need for introducing the student to terminal usage by requiring some simple exercise that would be non-threatening and, if possible, enjoyable. Games and simulated "conversations" between the computer and the student have been found effective techniques. Students have seemed to be particularly pleased with pseudo-dialogues initiated by the student typing in his or her name and then having the computer respond to them using their name.

No significant difference was found in the achievement of the experimental and control groups. The fact that achievement was not improved tends to discount the value of computer use as a motivation to study in another area such as physics or chemistry. Although this may be true in a comparison of group means, it was evident to the teachers using the simulations that several individual students were strongly motivated by the computer utilization. As a tool for further individualization of instruction, computer simulation of experiments would serve as a motivational device for certain individuals. Further research is recommended to determine the type of student who responds to this stimulus and to specifically evaluate the contribution that computer simulation of experiments can make to a program of individualized instruction.

No comparison between physics and chemistry achievement could be made, since the tests were not the same and there was no way of equating them. In Physics A, Physics B, and Chemistry B, a significant interaction between sex and achievement was noted. In these courses the mean scores for males were higher than for females. This did not seem to be related to the use of the computer.

A problem common to laboratory teaching by the inquiry or discovery method is the inability of the student to draw valid conclusions from the interpretation of highly unreliable data. Often the lack of accuracy and/or precision in the data leads the student to an erroneous conclusion. Further research using only experiments that frequently yield unreliable results is recommended. Such a study might reveal the extent of such misconceptions and determine if a computer simulation might be preferred to the actual laboratory work in such instances.

In this study each course was taught by a different teacher. This confounding makes it impossible to state which effects are related to the teacher and which are related to the course. Also, the physics students were juniors and the chemistry students, seniors. This further confounding makes it impossible to draw valid conclusions about the effect of either course, teacher, or grade level. Further replications of the study would be needed to answer these questions.

In some experiments it was difficult for students to visualize the meaning of the output data unless they had actually worked some with the particular type of equipment involved in that experiment. It would be preferable to give the student some opportunity to actually use the kind of equipment involved in the simulation or, if this is not possible, combine the simulation with other media. A combination of tape cassette instructions, visuals (such as drawings, photographs, slide sets, models, or single-concept films) would help provide the context for simulated experiments.

The interaction of the experimental and control groups in the same laboratory is another factor that could influence results. The opportunity to watch students actually doing the same experiment undoubtedly made the simulations much easier to comprehend. On the other hand, it was possible that those in the control group were able to pick up clues about the expected results from seeing computer-simulated data tables. Replication of the study with isolated experimental and control groups is recommended.

The potential of the computer simulation as a component in a multimedia approach suggests a need for further research and development in this area.

This study was purposefully restricted to experiments that could actually be done in a high school laboratory, as well as simulated. It was also restricted by time and the courses of study. Further study should be made of the effectiveness of computer simulations that go beyond that which can be done in the laboratory.

SUMMARY

This study investigated the feasibility of using computer-simulated experiments in high school physics and chemistry and compared the effect of this technique to that of actually doing the experiment. Evaluation was based on achievement tests and attitude scales.

All 258 students enrolled in physics and chemistry at Ames High School during the second semester of the 1971-72 school year were randomly divided into experimental and control groups within each of the 15 sections. A series of ten experiments was done by use of computer simulation in the experimental group; whereas, the control group carried out the investigation with regular laboratory equipment.

A pre-test was given to determine attitude toward the subject (physics or chemistry), laboratory work, and the computer as a laboratory aid. The same instrument was used as a post-test. Achievement tests were given over each of the ten experiments immediately after the experiment. A post-test was used to determine attitude toward using a computer terminal. Cumulative grade point, IQ, and grade in the subject were obtained from the students' permanent records in the guidance office of the school.

The following hypotheses were tested: (1) There is no significant difference between the group means of the experimental and control groups as measured by a pre-test and a post-test to determine attitude toward the subject (physics or chemistry), laboratory work, and the computer as a laboratory aid. This hypothesis was rejected. (2) There is no significant difference between the group means of the experimental and control

groups as measured by achievement tests over the laboratory experiments. There was insufficient evidence to reject this hypothesis. (3) There is no significant difference between the group means of the experimental and control groups as measured by a post-test on attitude toward using a computer terminal. This hypothesis was rejected. (4) There is no significant difference between the group means of males and females as measured by a post-test on attitude toward using a computer terminal. This hypothesis was rejected. (5) There is no significant difference in the gain-scores on group means as measured by a pre-test and a post-test to determine attitude toward the subject, laboratory work, and the computer as a laboratory aid. This hypothesis was rejected.

The means of the experimental groups were first compared with those of the control groups by use of a t-test. The results were further analyzed as four separate experiments using analysis of covariance. The IQ score was used as a covariate. On the three scales measuring attitude toward the subject, laboratory work, and the computer as a laboratory aid, F values were obtained for comparisons of pre-tests, post-tests, and pre-test - post-test gain scores. F values were also obtained for post-tests on achievement and on attitude toward using a computer terminal.

Findings of the study included: (1) The attitudes of the experimental and control groups toward the subject (physics and chemistry) and toward laboratory work were not significantly different before the experiment or after the experiment. (2) At the start of the experiment, the experimental group's attitude toward the computer as a laboratory aid was not significantly different from the attitude of the control group. (3) At the close of the experiment, the experimental group's attitude toward the computer as a laboratory aid and toward using a computer terminal was significantly more positive than the attitude of the control group. (4) On the achievement tests given over the laboratory experiments, the group mean scores of the experimental group were not significantly different from the group mean scores of the control group. (5) The males indicated a significantly more positive attitude than the females as measured by the post-test on attitude toward using a computer terminal.

The use of computer-simulated experiments in high school physics and chemistry was found to be an effective way of extending the scope of laboratory work and of providing a means of individualizing instruction in this area. Attitudes toward the computer as a laboratory aid and toward using a computer terminal were improved. No significant difference was found between the achievement of the experimental and control groups. Attitudes toward the subject (physics or chemistry) and toward laboratory work were not significantly changed.

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APPENDIX A. COMPUTER PROGRAMS

Chemistry Computer Programs

Simulation of solid acid titration

```
 3.   PUT LIST('    SIMULATION OF SOLID ACID TITRATION')
 5.   PUT LIST('IF YOU WISH TO ALSO STANDARDIZE THE BASE WITH')
 7.   PUT LIST('HYDROCHLORIC ACID TYPE "YES".  IF YOU')
 9.   PUT LIST('ALREADY KNOW THE CONCENTRATION OF THE BASE TYPE "NO".')
11.   READ INTO(ANS)
12.   IF ANS='NO' THEN PUT LIST('ENTER CONCENTRATION OF BASE.')
12.5  IF ANS='NO' THEN GET LIST(CBASE)
13.   DECLARE ANS CHAR(3) VAR
15.   PUT LIST('ENTER THE NUMBER OF SETS OF DATA DESIRED.')
17.   GET LIST(N)
19.   DO I=1 TO N
21.   PUT LIST('
               DATA SET',I,'
                          ')
25.   IF ANS='NO' THEN GO TO UNK
27.   STD:  PUT LIST('STANDARDIZATION OF BASE
                                             ')
28.   CACID=.19+RANDOM*.02
29.   PUT EDIT('CONCENTRATION OF ACID = ',CACID,'M')(A,F(6,4),X(1),
      A(1))
31.   PUT LIST('
               VOL ACID     INI VOL BASE     FINAL VOL BASE')
35.   CBASE=.19+RANDOM*.02
36.   DO J=1 TO 3
37.   IF RANDOM<.5 THEN SG=-1; ELSE SG=1
43.   VACID=20+RANDOM*10
44.   INI=RANDOM*.5
45.   VBASE=VACID*CACID/CBASE
46.   VBASE=VBASE+VBASE*SG*RANDOM*.02
46.5  VBASE=VBASE+INI
47.   PUT IMAGE(VACID,INI,VBASE)(IM)
49.   IM:  IMAGE
--.-- ML      --.-- ML      --.-- ML
51.   END
53.   PUT LIST('
               ')
57.   UNK:  PUT LIST('UNKNOWN ACID')
59.   K=TRUNC(RANDOM*5)+1
61.   DECLARE FORM(5)  CHAR(8)  VAR, FW(5)
62.   IF V THEN GO TO NEXT
63.   DO KK=1 TO 5
64.   DECLARE FOR CHAR(8) VAR
64.5  READ INTO(FOR)
```

```
64.6  FORM(KK)=FOR
64.7  GET LIST(FW(KK))
65.   END
67.   FW=FW/1000
69.   NEXT:  PUT LIST('EMPIRICAL FORMULA IS',FORM(K))
71.   PUT LIST('
                MASS UNKNOWN     INI VOL BASE     FINAL VOL BASE')
73.   DO II=1 TO 3
75.   MUNK=.3+RANDOM*.3
77.   EQUNK=MUNK/FW(K)
78.   INI=RANDOM*.5
79.   VBASE=EQUNK/CBASE
81.   IF RANDOM<.5 THEN SG=-1; ELSE SG=1
83.   VBASE=VBASE+SG*VBASE*RANDOM*.03
84.   VBASE=VBASE+INI
85.   PUT IMAGE(MUNK,INI,VBASE)(IMI)
87.   IMI:  IMAGE
-.--- G     -.-- ML      --.-- ML
89.   END
91.   END
92.   PUT LIST('
               ')
93.   STOP
```

Simulation of $KClO_3$-KCl mixture

```
 4.   PUT LIST('     SIMULATION OF KCLO3-KCL MIXTURE')
 6.   PUT LIST('ENTER THE NUMBER OF SETS OF DATA DESIRED.')
 8.   GET LIST(N)
16.   DO I=1 TO N
18.   PUT LIST('
               ')
20.   PUT EDIT('DATA SET ',I,'DATA SET ',I)(A(9),F(2),COLUMN(60),A(9),
      F(2))
20.5  DO L=1,2
21.   MT=2*RANDOM+10
21.1  PCT=25+50*RANDOM
21.2  DO K=1 TO 2
21.3  MIT=MT+.1+.1*RANDOM
22.   PUT LIST('  ')
24.   MSAMP=1+RANDOM*.5
30.   MO2=96*MSAMP/2/122.6
31.   IF L=2 THEN MO2=MO2*PCT/100
32.   IF RANDOM<.5 THEN SG=-1; ELSE SG=1
34.   MO2=MO2+SG*RANDOM*MO2*.03
40.   IF L=1 THEN PCT=100
54.   PUT EDIT('MASS OF TEST TUBE AND CATALYST',MIT,' G',PCT)(A,COLUMN
      (45),F(6,3),A(2),COLUMN(60),F(5,1))
55.   DECLARE WORD CHAR(7) VAR
55.1  IF L=1 THEN WORD='KCLO3'; ELSE WORD='MIXTURE'
```

```
56.   PUT EDIT('MASS OF TEST TUBE, CATALYST AND ',WORD,MIT+MSAMP,' G')
      (A,A,COLUMN(45),F(6,3),A)
58.   PUT EDIT('MASS OF TEST TUBE, CATALYST AND RESIDUE',MIT+MSAMP-MO2,'
      G')(A,COLUMN(45),F(6,3),A)
60.   END
62.   PUT LIST('
                 ')
63.   END
64.   END
66.   STOP
```

Simulation of reduction of permanganate ion

```
 4.   PUT LIST('SIMULATION REDUCTION OF PERMANGANATE ION')
 5.   PUT LIST('ENTER THE CONCENTRATION OF THE PERMANGANATE AND
      BISULFITE.')
 6.   K=1
 8.   GET LIST(MNO4,HSO3)
10.   IF K THEN GO TO NXT
12.   DECLARE RAT(3)  WORD(3)  CHAR(7)  VAR
14.   GET LIST(RAT,WORD)
16.   NXT:  PUT LIST('ENTER THE NUMBER OF SETS OF DATA DESIRED.')
18.   GET LIST(N)
20.   DO I=1 TO N
22.   PUT LIST('
                 ')
24.   PUT LIST('DATA SET',I)
25.   VMNO4=RANDOM
26.   DO K=1 TO 3
28.   PUT LIST('  ')
30.   PUT LIST(WORD(K))
31.   IF K=3 THEN GO TO AA
32.   PUT LIST('VOLUME OF NAHSO3 = 25.00 ML')
34.   PUT LIST('      INI VOL KMNO4      FIN VOL KMNO4')
36.   DO L=1,2
36.5  IF VMNO4>35 THEN VMNO4=RANDOM
37.   INIT=VMNO4
38.   MHSO3=25*HSO3
40.   MMNO4=MHSO3*RAT(K)
42.   VMNO4=MMNO4/MNO4
46.   VMNO4=INIT+VMNO4
48.   IF RANDOM<.5 THEN SG=-1; ELSE SG=1
50.   VMNO4=VMNO4+SG*VMNO4*RANDOM*.02
52.   PUT EDIT('TRIAL ',L,INIT,'ML',VMNO4,'ML')(A,F(1),COLUMN(12),
      F(5,2),A,COLUMN(31),F(5,2),A)
54.   END
55.   GO TO AB
56.   AA:  PUT LIST('     INI NAHSO3      FIN NAHSO3      INI KMNO4
      FIN KMNO4')
```

```
60.   IF VMNO4>35 THEN VMNO4=RANDOM
62.   VHSO3=RANDOM
66.   DO L=1,2
66.5  IF VMNO4>35 THEN VMNO4=RANDOM
67.   INITA=VMNO4
67.5  INITB=VHSO3
68.   VMNO4=9.5+RANDOM
72.   VHSO3=VMNO4*MNO4/HSO3/RAT(3)
74.   VMNO4=INITA+VMNO4
78.   IF RANDOM>.5 THEN SG=-1; ELSE SG=1
79.   VHSO3=INITB+VHSO3+VHSO3*SG*RANDOM*.02
80.   PUT EDIT('TRIAL ',L,INITB,'ML',VHSO3,'ML',INITA,'ML',VMNO4,'ML')
      (A,F(1),COLUMN(12),F(5,2),A,COLUMN(26),F(5,2),A,COLUMN(40),
      F(5,2),A,COLUMN(54),F(5,2),A)
82.   END
90.   AB:  END
92.   end
94.   PUT LIST('
                ')
96.   STOP
```

Simulation of heat of solution

```
 4.   PUT LIST('     SIMULATION - HEAT OF SOLUTION')
 6.   PUT LIST('ENTER NUMBER OF SETS OF DATA DESIRED.')
 8.   GET LIST(N)
10.   DO I=1 TO N
12.   PUT LIST('
                ')
14.   PUT LIST('DATA SET',I)
16.   PUT LIST('  ')
18.   MACID=.003*18
20.   IF RANDOM<.5 THEN SG=-1; ESLE SG=1
22.   HSOL=17.85+17.85*SG*RANDOM*.05
24.   HEAT=HSOL*MACID*1000
26.   DT=HEAT/170.02
28.   INIT=15+RANDOM*10
30.   PUT EDIT('CALORIMETER CONSTANT','14.5 CAL/DEG')(A,COLUMN(40),A)
32.   PUT EDIT('INITIAL TEMPERATURE OF WATER',INIT,' C')(A,COLUMN(40),
      F(4,1),A)
34.   PUT EDIT('FINAL TEMPERATURE OF WATER',INIT+DT,' C')(A,COLUMN(40),
      F(4,1),A)
36.   END
38.   PUT LIST('
                ')
40.   STOP
```

Simulation of molecular weight by the Dumas Method

```
 1.   PUT LIST('THIS GENERATES RANDOM DATA FOR CONCEPTS')
 2.   PUT LIST('EXPERIMENT 10.  N=NUMBER OF SETS OF DATA DESIRED.')
 4.   MWT=97
 5.   DO I=1 TO N
 6.   E=RANDOM
 6.1  IF E>.5 THEN SG=-1; ELSE SG=1
 7.   IF E>.5 THEN E=E-.5
 8.   IF .25<E<.5 THEN E=E-.25
10.   AGAIN:  STP=RANDOM*1000
11.   IF STP>500 THEN STP=STP-500
11.1  IF STP>250 THEN STP=STP-250
11.2  IF STP<125 THEN STP=STP+125
11.3  IF STP<175 THEN STP=STP+50
12.   WLIQ=EMWT/22400*STP
13.   CORR=STP
14.   CORR=STP/10
15.   WFS=4*CORR+SG*CORR*E
16.   WFSV=WFS+WLIQ
17.   PRESS=RANDOM*1000
18.   IF PRESS>750 THEN PRESS=PRESS-250
18.1  IF PRESS<350 THEN PRESS=PRESS+350
18.2  IF PRESS<500 THEN PRESS=PRESS+250
18.3  IF PRESS<650 THEN PRESS=PRESS+150
19.   VOL=STP*760/PRESS*373/273
19.1  PUT LIST('  ')
20.   PUT LIST('WT FLASK,STOPPER     WT FLASK      VOLUME      ATM')
21.   PUT LIST('AND VAPOR      AND STOPPER      OF VAPOR      PRESSURE')
21.1  PUT LIST('  ')
22.   PUT IMAGE(WFSV,WFS,VOL,PRESS)(OUTPUT)
23.   OUTPT:  IMAGE
---.-- G     ---.-- G      ---.- ML   --- MM  100 C
25.   PUT LIST('  ')
26.   PUT LIST('  ')
27.   END
28.   STOP
```

Combining weight of a metal

```
 3.   K=1
 5.   PUT LIST('SIMULATION - COMBINING WEIGHT OF A METAL')
 7.   PUT LIST('ENTER NUMBER OF SETS OF DATA DESIRED.')
 9.   GET LIST(N)
11.   DECLARE SAMP(8,3)  DEC(6)
13.   /*SAMP(A,1)=METAL/OXYGEN RATIO; SAMP(A,2)=SPECIFIC HEAT*/
15.   /*SAMP(A,3)=ATOMIC WEIGHT*/
17.   IF K THEN GO TO DOIT
19.   GET LIST(SAMP)
```

```
21.   DOIT:  DO I=1 TO N
22.   CODE=0
23.   PUT LIST('
                 ')
24.   PUT EDIT('DATA SET ',I,'DATA SET ',I)(A(9),F(2),COLUMN(60),A(9),
      F(2))
25.   PUT LIST('  ')
27.   A=TRUNC(RANDOM*8+1
29.   IF RANDOM>.5 THEN SG=-1; ELSE SG=1
31.   ATWT=SAMP(A,3)+SG*RANDOM*.05*SAMP(A,3)
33.   ZIP:  MMETAL=.95+RANDOM/10
35.   MO2=MMETAL/SAMP(A,1)
37.   MCRU=15+RANDOM*5
39.   CRUMET=MCRU+MMETAL
41.   CRUO2=MO2+CRUMET
41.2  IF CODE THEN GO TO OUT
41.4  AMCRU=MCRU
41.6  ACRUME=CRUMET
41.8  ACRUO=CRUO2
42.   CODE=1
42.2  GO TO ZIP
42.4  OUT:  CODE=0
43.   PUT IMAGE(MCRU,AMCRU,A)(IMA)
45.   IMA:  IMAGE
MASS OF CRUCIBLE AND COVER     --.--- G  --.--- G     SAMPLE --
47.   PUT LIST('  ')
49.   PUT IMAGE(CRUMET,ACRUME)(IMB)
51.   IMB:  IMAGE
MASS OF CRUCIBLE, COVER & METAL     --.--- G  --.--- G
53.   PUT LIST('  ')
55.   PUT IMAGE(CRUO2,ACRUO)(IMC)
57.   IMC:  IMAGE
MASS OF CRUCIBLE, COVER & OXIDE     --.--- G  --.--- G
59.   PUT LIST('  ')
61.   PUT IMAGE(SAMP(A,2))(IMD)
63.   IMD:  IMAGE
SPECIFIC HEAT OF METAL     -.----- CAL/G DEG
65.   END
67.   PUT LIST('
                 ')
69.   STOP
```

Formula of a precipitate

```
10.   PUT LIST('FORMULA OF A PRECIPITATE CHEMS EXP 16')
12.   PUT LIST('TYPE "BATCH" IF YOU WANT TO PRODUCE MULTIPLE')
14.   PUT LIST('SETS OF DATA.  TYPE "STUDENT" IF YOU WANT EACH')
16.   PUT LIST('STUDENT TO GET HIS OWN DATA.')
18.   GET EDIT(HOW)(A(7))
```

```
20.   DECLARE HOW CHAR(7), M(8), HT(8)
22.   I=1
24.   N=0
26.   IF HOW='BATCH' THEN GO TO AA
28.   AD:  GET LIST(MPBNO3,MNAI)
30.   GO TO AC
32.   AA:  MPBNO3=8.28
34.   MNAI=3.75
36.   PUT LIST('ENTER NUMBER OF SETS OF DATA DESIRED.')
38.   GET LIST(N)
40.   IF I>N THEN STOP
42.   PUT EDIT('DATA SET ',I)(A(9),F(2))
44.   AC:  MOLPB=MPBNO3/331/50
46.   MOLNAI=MNAI/150/50
47.   RATIO=.5
48.   DO K=1 TO 8
50.   J=9-K
52.   M(K)=MIN(K*MOLPB,J*RATIO*MOLNAI)
54.   IF RANDOM>.5 THEN SG=1; ELSE SG=-1
56.   M(K)=M(K)+SG*M(K)*(RANDOM*.05)
58.   M(K)=M(K)*461
60.   /*1 MM= .02 G*/
62.   HT(K)=M(K)/.02
64.   END
64.5  IF RANDOM<.5 THEN SG=1; ELSE SG=-1
65.   RR=.69+SG*RANDOM*.02*.69
65.5  M=M+RR
66.   PUT LIST('  ')
68.   PUT LIST('TUBE NUMBER    I    II    III    IV    V    VI    VII    VIII')
70.   PUT LIST('  ')
72.   PUT IMAGE(HT(1),HT(2),HT(3),HT(4),HT(5),HT(6),HT(7),HT(8))(IM)
73.   IM:  IMAGE
HT OF PPT(MM)      ---  ---  ---  ---  ---  ---  ---  ---
74.   PUT LIST('  ')
76.   PUT IMAGE(M(1),M(2),M(3),M(4),M(5),M(6),M(7),M(8))(IMG)
78.   IMG:  IMAGE
MASS OF PPT        -.-- -.-- -.-- -.-- -.-- -.-- -.-- -.--
79.   PUT LIST('AND FILTER')
79.5  PUT LIST('  ')
79.6  PUT EDIT('MASS OF FILTER PAPER = ',RR,' G')(A(23),F(5,3),A(2))
80.   PUT LIST('  ')
82.   PUT LIST('  ')
84.   PUT LIST('  ')
86.   I=I+1
88.   IF HOW='STUDENT' THEN GO TO AD; ELSE GO TO AB
```

Specific heat of a metal

```
 2.   PUT LIST('SIMULATION OF HEAT CAPACITY OF A SOLID')
 3.   PUT LIST('THIS EXPERIMENT WILL SIMULATE WITHIN')
 4.   PUT LIST('CERTAIN EXPERIMENTAL ERRORS, A')
 5.   PUT LIST('HEAT CAPACITY EXPERIMENT.  IT WILL BE POSSIBLE')
 6.   PUT LIST('FOR THE STUDENT TO CALCULATE THE SPECIFIC')
 7.   PUT LIST('HEAT FROM THE DATA PRODUCED')
 8.   PUT LIST('ENTER THE NUMBER OF SETS OF DATA DESIRED')
 9.   DECLARE LAB LABEL
13.   GET LIST(N)
14.   DO I=1 TO N
14.5  PUT LIST('DATA SET ',I)
15.   PUT LIST('CALORIMETER CONSTANT')
16.   PUT LIST('  ')
17.   PUT LIST('MASS HOT     TEMP HOT     MASS COOL     TEMP COOL
      MAX')
18.   PUT LIST(' WATER        WATER         WATER         WATER
      TEMP')
19.   PUT LIST('  ')
19.4  LAB=AA
19.5  K=0
20.   GO TO START
21.   AA:  CC=3+3*SG*R
22.   TM=(TI*100+TS*100*TI*CC)/(CC+200)
23.   PUT IMAGE(100,TS,100,TI,TM)(IM)
24.   IM:  IMAGE
--- G     --.- C     --- G     --.- C     --.- C
25.   PUT LIST('  ')
26.   PUT LIST('SPECIFIC HEAT OF WASHERS')
27.   PUT LIST('  ')
28.   PUT LIST('MASS      TEMP     MASS      TEMP      MAX')
29.   PUT LIST('WATER     WATER     WASHERS     WASHERS     TEMP')
30.   PUT LIST('  ')
31.   K=1
31.2  LAB=AB
31.5  GO TO START
31.7  AB:
32.   SHW=.11+.11*SG*R
33.   MW=80+30*RANDOM
33.5  TM=(SHW*MW*TS+100*TI+CC*TI)/(100+CC+SHW*MW)
34.   PUT IMAGE(100,TI,MW,TS,TM)(IM)
35.   PUT EDIT('DATA SET ',I)(SKIP(3),A(9),F(2))
36.   PUT LIST('CAL CONST =',CC)
37.   PUT LIST('SPECIFIC HEAT OF WASHERS =',SHW)
38.   PUT LIST('  ')
39.   PUT LIST('  ')
40.   PUT LIST('  ')
41.   GO TO DONE
42.   STOP
```

```
50.   START:
51.   TI=RANDOM*10+20
52.   R=RANDOM*.05
54.   IF RANDOM>.5 THEN SG=1; ELSE SG=-1
55.   IF K THEN TS=100-RANDOM*10; ELSE TS=TI+12+TRUNC(5*RANDOM)
56.   GO TO LAB
57.   DONE:  END
58.   STOP
```

Heat of reaction

```
 2.   PUT LIST('HEAT OF REACTION FOR THE COMBUSTION OF MG')
 3.   PUT LIST('THIS PROGRAM WILL SIMULATE WITHIN CERTAIN EXPERIMENTAL')
 4.   PUT LIST('ERRORS THE EXPERIMENT FOR THE HEAT OF COMBUSTION')
 5.   PUT LIST('OF MG.  DATA WILL BE GIVEN FOR THE HEAT PRODUCED')
 6.   PUT LIST('WHEN A CERTAIN MASS OF MG REACT WITH AN EXCESS OF 1M')
 7.   PUT LIST('HCL ACID.  ALSO DATA WILL BE GENERATED FOR THE HEAT')
 8.   PUT LIST('RELEASED WHEN A CERTAIN MASS OF MGO REACTS WITH')
 9.   PUT LIST('AN EXCESS OF 1M HCL ACID.  FROM THE DATA THE STUDENT')
 9.5  PUT LIST('WILL BE ABLE TO CALCULATE THE HEAT OF REACTION')
 9.8  PUT LIST('FOR BOTH REACTIONS.  FROM THE SIMULATED HEATS OF')
10.   PUT LIST('REACTIONS AND LAW OF CONSTANT HEAT SUMMATION,')
11.   PUT LIST('ONE CAN DETERMINE THE HEAT OF COMBUSTION FOR MG')
11.5  GET LIST(N)
11.6  PUT LIST('  ')
11.7  PUT LIST('  ')
11.8  DO I=1 TO N
11.9  PUT LIST('  ')
12.   PUT LIST('HEAT OF REACTION OF MG WITH HCL')
13.1  PUT LIST('INITIAL HCL      MASS      MASS      MAX-TEMP')
13.2  PUT LIST('TEMPERATURE      HCL        MG         HCL')
13.25 PUT LIST('  ')
13.3  CALL CALCU(108000,24.3)
13.31 PUT LIST('HEAT OF REACTION OF MGO WITH HCL')
13.32 PUT LIST('INITIAL HCL      MASS      MASS      MAX-TEMP')
13.33 PUT LIST('TEMPERATURE      HCL       MGO         HCL')
13.34 PUT LIST('  ')
13.35 CALL CALU(33000,40.3)
13.4  PUT LIST('  ')
13.45 END
13.5  STOP
14.   CALCU:  PROCEDURE(A,B)
14.2  TI=RANDOM*10
14.3  TI=20+TI
14.4  R=RANDOM*.025
14.7  S=RANDOM
14.8  IF S>.5 THEN SG=1; ELSE SG=-1
14.9  W=.4+.2*RANDOM
15.5  HR=A*SG*R
```

```
16.6  HR=A+HR
18.   MW=100-RANDOM*10
19.   TM=HR*W/B/(MW+3)+TI
20.   PUT IMAGE(TI,MW,W,TM)(IM)
21.   IM:  IMAGE
--.--C     --.-G  --.--G    --.--C      CAL CONST =3.0CAL/GDEGREE
22.   PUT LIST('  ')
25.   QUIT:  END CALCU
```

Water of hydration

```
 4.   PUT LIST('SIMULATION OF WATER OF HYDRATION')
 6.   PUT LIST('THIS PROGRAM SIMULATES THE DATA FOR DETERMINING')
 8.   PUT LIST('THE % OF WATER OF HYDRATION OF A COMPOUND.')
10.   PUT LIST('ENTER THE NUMBER OF SETS OF DATA DESIRED.')
12.   GET LIST(N)
14.   DECLARE HYD(2)  CHAR(17) VAR
16.   HYD(1)='BARIUM CHLORIDE'
18.   HYD(2)='MAGNESIUM SULFATE'
19.   PUT LIST('
                ')
20.   DO I=1 TO N
22.   IF RANDOM<.5 THEN K=1; ELSE K=2
24.   IF K=1 THEN HYDPC=.147; ELSE HYDPC=.51
26.   MCRU=12+RANDOM*5
28.   MSMPL=3+RANDOM*2
30.   MANHY=MSMPL*(1-HYDPC)
32.   IF RANDOM<.5 THEN SG=-1; ELSE SG=1
34.   MANHY=MANHY+SG*MANHY*RANDOM*.05
38.   PUT EDIT('DATA SET',I)(A(8),X(1),F(2))
40.   PUT LIST('  ')
42.   PUT EDIT('MASS OF CRUCIBLE & COVER',MCRU,'G')(A,COLUMN(40),F(5,2),
      X(1),A)
44.   PUT EDIT('MASS OF CRUCIBLE & COVER & HYDRATE',MCRU+MSMPL,G')
      (A,COLUMN(40),F(5,2),X(1),A)
46.   PUT EIDT('MASS OF CRUCIBLE & COVER & ANHYD',MCRU+MANHY,'G',' ')
      (A,COLUMN(40),F(5,2),A,SKIP(3),A)
48.   END
50.   STOP
```

Solubility product of lead chloride

```
 2.   PUT LIST('SIMULATION:  DATA FOR SOLUBILITY PRODUCT OF PBCL2')
 3.   PUT LIST('ENTER NUMBER OF SETS OF DATA DESIRED')
 4.   GET LIST(N)
 5.   PUT LIST('  ')
 6.   START:  DO I=1 TO N
 7.   PUT LIST('SOLUBILITY IN G/100 G H2O')
```

```
 8.   PUT LIST('NO.    0 C    20 C    40 C    NO.    KO    K20    K40')
 9.   R=RANDOM*.05
10.   S=RANDOM
11.   IF S>.5 THEN A=R; ELSE A=-R
12.   SI=.673+.673*A
13.   SII=.99+.99*A
14.   SIII=1.409+1.409*A
15.   KI=4*(SI/27.8)**3
16.   KII=4*(SII/27.8)**3
17.   KIII=4*(SIII/27.8)**3
18.   PUT IMAGE(I,SI,SII,SIII,I,KI,KII,KIII)(IM)
19.   IM:  IMAGE
--  -.---  -.---  -.---     --  .......  .......  .......
20.   END
21.   PUT LIST('  ')
22.   STOP
```

Charles' Law

```
 2.   PUT LIST('SIMULATION OF CHARLES LAW.')
 4.   /*THIS SIMULATES THE DATA FOR THE LAB BENCH EXPERIMENT*/
 6.   /*IN CHEMISTRY VOL. 42 NO. 8*/
 8.   PUT LIST('ENTER NUMBER OF DATA SETS DESIRED.')
10.   GET LIST(N)
12.   PUT LIST('
                ')
14.   DO I=1 TO N
16.   PUT EDIT('DATA SET ',I)(A(9),F(2))
18.   PUT LIST('
                TEMPERATURE     VOLUME
                                      ')
20.   INTVOL=225+RANDOM*50
22.   DO K=1 TO 6
24.   IF RANDOM<.5 THEN SG=-1; ELSE SG=1
26.   TEMP=4+K*5+RANDOM*2
28.   T=TEMP+273
30.   IF K=1 THEN VOL=INTVOL+1; ELSE GO TO DOIT
31.   CONST=T/VOL
31.5  VOL=1
31.6  GO TO OUT
32.   DOIT:  VOL=T/CONST
33.   VOL=VOL-INTVOL
33.5  OUT:
34.   PUT EDIT(TEMP,VOL)(F(5,1),X(14),F(4,1))
36.   END
38.   PUT LIST('
                THE INITIAL VOLUME OF THE SYSTEM IS',TRUNC(INTVOL),'ML
                                                                      ')
40.   END
42.   STOP
```

Equivalent weight of copper

```
 20.   PUT LIST('SIMULATION OF EQUIVALENT WEIGHT OF A METAL')
 30.   PUT LIST('THIS EXPERIMENT WILL SIMULATE WITHIN CERTAIN')
 40.   PUT LIST('EXPERIMENTAL ERRORS THE MASS OF A CERTAIN')
 50.   PUT LIST('METAL OXIDIZED AT THE ANODE BY AN ELECTRON')
 60.   PUT LIST('CURRENT.  IT WILL BE POSSIBLE FOR THE STUDENT')
 70.   PUT LIST('TO CALCULATE THE EQUIVALENT WEIGHT OF THE METAL')
 80.   PUT LIST('IF THE ELECTRON CURRENT IN MILLIAMPERES AND THE')
 90.   PUT LIST('TIME OF ELECTRON FLOW IN SECONDS IS GIVEN.')
100.   PUT LIST('THE STUDENT WILL CALCULATE THE NUMBER OF')
110.   PUT LIST('H ATOMS FORMED AT THE CATHODE DURING ELECTROLYSIS')
120.   PUT LIST('FROM THE NUMBER OF H ATOMS FORMED THE STUDENT WILL')
130.   PUT LIST('DETERMINE THE VOLUME THAT THESE HYDROGEN ATOMS')
140.   PUT LIST('SHOULD OCCUPY AT STP.  FROM THE SIMULATED VOLUME OF')
150.   PUT LIST('HYDROGEN MOLECULES FORMED AT THE CATHODE (AFTER')
160.   PUT LIST('CORRECTION TO STP) THE STUDENT SHOULD BE ABLE TO')
170.   PUT LIST('DETERMINE THE NUMBER OF HYDROGEN ATOMS/MOLECULE')
200.   GET LIST(N)
210.   START:  DO I=1 TO N
220.   PUT EDIT('CURRENT','TIME OF','INITIAL','FINAL','VOL OF','TEMP
       OF')(A(7),X(2),A(7),X(3),A(7),X(4),A(5),X(4),A(6),X(4),A(7))
230.   PUT EDIT('IN MA','CURRENT','MASS CU','MASS CU','H2','H2 & H2O')
       (X(1),A(5),X(3),A(7),X(3),A(7),X(3),A(7),X(5),A(2),X(6),A(8),
       SKIP(1))
240.   A=RANDOM*10
250.   A=300+A
260.   T=1800-RANDOM*100
270.   IF RANDOM>.5 THEN SG=-1; ELSE SG=1
280.   Q=A*.001*T
290.   Q=Q+SG*.05*RANDOM*Q
300.   F=Q/96500
310.   IMCU=12+RANDOM
320.   FMCU=IMCU+31.72*F
330.   VH2=13100*F
340.   PUT IMAGE(A,T,IMCU,FMCU,VH2)(OUTPUT)
350.   PUT LIST('
                  ')
360.   END START
370.   OUTPUT:  IMAGE
--- MA   ----S     --.--- G    --.--- G    --.- ML     25 DEG C
390.   STOP
```

Physics Computer Programs

Boyle's Law simulation

```
10.    PUT LIST('SIMULATION OF BOYLES LAW DATA')
16.    PUT LIST('ENTER THE BAROMETRIC PRESSURE')
18.    GET LIST(PRESS)
19.    PUT LIST('ENTER NUMBER OF SETS OF DATA')
20.    GET LIST(N)
21.    DO I=1 TO N
22.    PUT LIST('  ')
23.    PUT LIST('DATA SET',I)
24.    PUT LIST('  ')
25.    PUT LIST('TRIAL     READING CLOSED TUBE     READING OPEN TUBE')
25.5   RCT=20+RANDOM*10
25.6   CONST=(46.2-RCT)*PRESS/1000
25.7   ROT=RCT
25.8   DO J=1 TO 10
26.    IF J=1 THEN GO TO FIRST
27.    K=CONST
28.    IF RANDOM>.5 THEN SG=-1; ELSE SG=1
28.5   K=K+SG*K*RANDOM*.02
29.    HT=.7+.3*RANDOM
30.    RCT=RCT+HT
31.    P=K*1000/(46.2-RCT)
32.    ROT=RCT+(P-PRESS)/10
36.    FIRST:  PUT IMAGE(J,RCT,ROT)(IM)
38.    IM:  IMAGE
--            --.- CM            --.-- CM
40.    END
41.    PUT LIST('  ')
41.5   END
42.    STOP
```

Magnetic field at the center of a loop simulation

```
 1.    D=0
 1.5   PUT LIST('SIMULATION OF MAGNETIC FIELD AT THE CENTER OF A LOOP')
 2.    PUT LIST('ENTER NUMBER OF DATA SETS FOR N')
 3.    GET LIST(N)
 4.    START:  D=D+1
 5.    PUT LIST('DATA SET',D)
 6.    PUT IMAGE('AMPS','TURNS','ANGLE')(BILL)
 6.5   BILL:  IMAGE
----      -----     -----
 7.    DO I=1,2
 8.    DO L=1 TO 5
 9.    T=RANDOM*.02
10.    S=RANDOM
```

```
11.   IF S>.5 THEN A=T; ELSE A=-T
12.   X=L*I
13.   X=X+A*X
14.   PUT IMAGE(I,L,ATAND(X/10))(MARY)
15.   MARY:  IMAGE
--.--      --     ---.-
16.   END
17.   END
18.   IF D=N THEN STOP
19.   GO TO START
```

Forces on currents simulation

```
 1.   PUT LIST('THIS PROGRAM SIMULATES THE EXPERIMENT')
 1.1  PUT LIST('FORCES ON CURRENTS')
 1.2  START:  GET LIST(D,L,IB,IF)
 1.3  B=6.25*B
 1.4  IF B=25 THEN B=1/60
 2.   F=.06*IB*IF*L/D
 3.   T=RANDOM*.05
 4.   S=RANDOM
 5.   IF S>.5 THEN A=T; ELSE A=-T
 6.   F=F+A*F
 7.   PUT IMAGE(D,L,IB,IF,F)(MARY)
 8.   MARY:  IMAGE
D=-.-     L=--     IB=-.-     IF=-.-     F=--.-
 9.   GO TO START
```

Currents, magnets, and forces simulation

```
 1.   PUT LIST('THIS PROGRAM SIMULATES THE EXPERIMENT')
 1.1  PUT LIST('CURRENTS, MAGNETS, AND FORCES')
 1.2  PUT LIST('SELECT MAGNET A, B, OR C')
 2.   PUT LIST('IF MORE THAN ONE MAGNET IS DESIRED, TYPE IN')
 3.   PUT LIST('THE 2 OR 3 LETTERS IN ALPHABETIC ORDER')
 4.   PUT LIST('FOR A STRONGER MAGNET USE THE LETTER D')
 5.   PUT LIST('FOR THE MAGNETIC FIELD OF THE EARTH USE THE LETTER E')
 6.   DECLARE MAGNET CHAR(3) VAR
 7.   START:  READ INTO(MAGNET)
10.   IF MAGNET='E' THEN B=1/60
11.   IF MAGNET='A' THEN B=6.25
12.   IF MAGNET='D' THEN B=9
13.   IF MAGNET='E' THEN L=30; ELSE L=3
14.   IF MAGNET='AB' THEN B=12.5
15.   IF MAGNET='ABC' THEN B=18.75
16.   GET LIST(I)
17.   F=B*I*L
18.   T=RANDOM*.05
```

```
19.    S=RANDOM
20.    IF S>.5 THEN A=T; ELSE A=-T
21.    F=F+A*F
22.    PUT IMAGE(MAGNET,I,F)(MARY)
23.    MARY:  IMAGE
MAGNET ---      I=-.-      F=----.-
24.    GO TO START
```

Electrical circuit simulation

```
 1.    PUT LIST('THIS PROGRAM SIMULATES AN ELECTRICAL')
 1.01  PUT LIST('CIRCUIT WITH TWO RESISTANCES')
 1.02  BEGIN:  PUT LIST('SELECT CIRCUIT A, CIRCUIT B, OR CIRCUIT C')
 1.04  PUT LIST('FOR NEW CIRCUIT USE A NEGATIVE V')
 1.2   DECLARE CIRCUI CHAR(1)
 1.3   READ INTO(CIRCUI)
 1.31  START:  GET LIST(V,R1,R2)
 1.35  IF CIRCUI='A' THEN R=R1
 1.4   IF CIRCUI='B' THEN R=R1*R2/(R1+R2)
 1.5   IF CIRCUI='C' THEN R=R1+R2
 1.61  IF CIRCUI='A' THEN R2=600
 1.65  IF V<0 THEN GO TO BEGIN
 3.    IF V>12 THEN GO TO FORTY
 4.    IF V>10 THEN GO TO THIRTY
 5.    I=V/R
 6.    T=RANDOM*.05
 6.1   S=RANDOM
 6.2   IF S>.5 THEN D=T; ELSE D=-T
 6.3   I=I+D*I
 9.    IF I>7 THEN GO TO SIXTY
10.    IF I>5 THEN GO TO FIFTY
11.    PUT IMAGE(CIRCUI,R1,R2,V,I)(MARY)
12.    MARY:  IMAGE
CIRCUIT -     R1=--     R2=--     V=--.-     I=--.--
13.    GO TO START
30.    THIRTY:  PUT LIST('WARNING.  YOU ARE EXCEEDING THE RANGE OF YOUR')
30.5   PUT LIST('VOLTMETER.  CHOOSE A SMALLER VALUE OF V')
31.    GO TO START
40.    FORTY:  PUT LIST('YOU JUST BURNED OUT THE VOLTMETER')
41.    STOP
50.    FIFTY:  PUT LIST('WARNING.  YOU ARE EXCEEDING THE RANGE OF')
50.1   PUT LIST('YOUR AMMETER.  CHOOSE A SMALLER VALUE OF V')
50.2   GO TO START
60.    SIXTY:  PUT LIST('YOU JUST BURNED OUT THE AMMETER')
60.1   STOP
```

Coulomb's Law simulation

```
 1.   PUT LIST('THIS PROGRAM SIMULATES COULOMBS LAW DATA')
 1.1  START:  GET LIST(Q1,Q2,F)
 2.   D=SQRT(Q1*Q2/F)
 3.   T=RANDOM*.05
 4.   S=RANDOM
 5.   IF S>.5 THEN A=T; ELSE A=-T
 6.   D=D+A*D
 7.   PUT IMAGE(Q1,Q2,F,D)(MARY)
 8.   MARY:  IMAGE
Q1=--.--     Q2=--.--     F=--     D=--.--
 9.   GO TO START
```

Electric calorimeter simulation

```
 1.   PUT LIST('SIMULATION OF ELECTRIC CALORIMETER')
 2.   PUT LIST('ENTER MASS IN GRAMS OF EMPTY CALORIMETER CUP FOR MC')
 3.   PUT LIST('ENTER MASS IN GRAMS OF CUP WITH WATER FOR MCW')
 4.   PUT LIST('ENTER CURRENT IN AMPERES FOR I')
 5.   PUT LIST('ENTER TIME OF RUN IN SECONDS FOR TIME')
 6.   PUT LIST('ENTER INITIAL TEMPERATURE OF WATER FOR T1')
 7.   START:  GET LIST(MC,MCW,I,TIME,T1)
 7.1  IF I>5 THEN GO TO METER
 8.   M=MCW-MC
 8.1  IF M>300 THEN GO TO WATER
 8.2  IF M<0 THEN GO TO GOOFY
 8.4  M=M+3
 9.   TI=TIME
10.   T=RANDOM*.5
11.   S=RANDOM
12.   IF S>.5 THEN A=T; ELSE A=-T
13.   V=10+10*A
14.   DT=V*I*TI/M/4.186
15.   T2=T1+DT
15.1  IF T2>99 THEN GO TO BOIL
15.5  Z=.1*A
16.   PUT LIST('MASS OF CALORIMETER CUP IS',MC,'GRAMS')
16.1  PUT LIST('MASS OF CALORIMETER CUP AND WATER IS',MCW,'GRAMS')
16.2  PUT LIST('INITIAL TEMPERATURE IS',T1,'DEGREES C')
16.3  PUT LIST('WATER EQUIVALENT OF CALORIMETER IS 3 GRAMS')
17.   PUT LIST('CURRENT IS',I,'AMPERES')
18.   PUT LIST('TIME IS',TI,'SECONDS')
19.   PUT IMAGE(T2)(MARY)
19.1  MARY:  IMAGE
FINAL TEMPERATURE IS --.- DEGREES C.
20.5  PUT IMAGE(Z)(BILL)
20.6  BILL:  IMAGE
RUN NUMBER -.----
```

```
21.   GO TO START
30.   BOIL:  PUT LIST('YOU HAVE BOILED THE WATER.  RESULTS NOT VALID.')
31.   GO TO START
40.   METER:  PUT LIST('YOU ARE OVERLOADING THE AMMETER.  5 AMPERES
      MAXIMUM')
41.   GO TO START
50.   WATER:  PUT LIST('CALORIMETER CUP RAN OVER.  300 GRAMS MAXIMUM')
51.   GO TO START
60.   GOOFY:  PUT LIST('YOUR VALUE OF MCW IS GOOFY')
61.   GO TO START
```

Radiation from a point source simulation

```
 1.   PUT LIST('THIS PROGRAM SIMULATES THE INTENSITY OF RADIATION')
 2.   PUT LIST('AT VARIOUS DISTANCES FROM A POINT SOURCE.')
 3.   PUT LIST('ENTER NUMBER OF DATA SETS NEEDED FOR N.')
 4.   GET LIST(N)
 5.   C=0
 5.2  START:  C=C+1
 5.4  PUT LIST('DATA SET',C)
 5.5  PUT LIST('DISTANCE','METER READING')
 6.   DO D=1 TO 10
 7.   K=100
 8.   I=K/D/D
 9.   T=RANDOM*.05
10.   S=RANDOM
11.   IF S>.5 THEN A=T; ELSE A=-T
12.   I=I+A*I
13.   PUT IMAGE(D,I)(MARY)
14.   MARY:  IMAGE
---.-     ---.-
15.   END
16.   IF C=N THEN STOP
16.1  PUT LIST('
                 ')
16.2  PUT LIST('
                 ')
17.   GO TO START
```

Magnetic field of long, straight wire simulation

```
1.    D=0
1.5   PUT LIST('SIMULATION OF MAGNETIC FIELD OF A LONG STRAIGHT WIRE')
2.    PUT LIST('ENTER NUMBER OF DATA SETS FOR N')
3.    GET LIST(N)
4.    START:  D=D+1
5.    PUT LIST('DATA SET',D)
6.    PUT IMAGE('DISTANCE','ANGLE')(BILL)
```

```
 6.5  BILL:  IMAGE
--------     -----
 7.   DO DIST=3 TO 21 BY 3
 9.   T=RANDOM*.05
10.   S=RANDOM
11.   IF S>.5 THEN A=T; ELSE A=-T
12.   X=6/DIST
13.   X=X+A*X
14.   PUT IMAGE(DIST,ATAND(X))(MARY)
15.   MARY:  IMAGE
--.--      --     ---.-
16.   END
18.   IF D=N THEN STOP
18.5  PUT LIST('
                 ')
19.   GO TO START
```

Convex lens simulation

```
 1.   PUT LIST('THIS PROGRAM SIMULATES THE FORMATION OF')
 1.1  PUT LIST('IMAGES BY A CONVEX LENS')
 1.4  F=15
 1.5  HO=1
 2.   START:  GET LIST(SO)
 2.1  IF SO<-F THEN GO TO TEN5
 2.5  DECLARE X CHAR(20) VAR
 3.   T=RANDOM*.05
 4.   S=RANDOM
 5.   IF S>.5 THEN A=T; ELSE A=-T
 6.   SI=F*F/SO
 7.   SI=SI+A*SI
 7.5  HI=HO*F/SO
 8.   IF SI<0 THEN X='ERECT & VIRTUAL'; ELSE X='INVERTED AND REAL'
 9.   PUT IMAGE(SO,SI,HO,HI,X)(MARY)
10.   MARY:  IMAGE
SO=-----.-     SI=-----.--     HO=---.--     HI=-----.--
      --------------------
11.   GO TO START
12.   TEN5:  PUT LIST('USE A LARGER VALUE OF SO')
13.   GO TO START
600.
```

APPENDIX B. LABORATORY QUIZZES

Chemistry Laboratory Quizzes

Equivalent weight of an acid

1. True - False

   The amount of water added to the solid acid in the experiment will not affect the amount of dilute NaOH solution needed to neutralize the acid.

2. A student suddenly discovers that he or she forgot to add the phenolphthalein indicator. To avoid starting over, the best procedure would be (a) evaporate some of the solution and then add indicator and continue titration; (b) back titrate with standard acid; (c) add indicator; if solution is pink, back titrate with standard acid; (d) add indicator and then add enough solid acid to turn solution to light pink.

Use the following to answer questions 3 through 7.

When 0.255 g of solid acid titrated with phenolphthalein, 28.25 ml of 0.2136 NaOH is required to neutralize the solution.

3. How many moles of base are used? (a) 5.43×10^{1} (b) 5.43×10^{-1} (c) 7.62×10^{-3} (d) 5.43×10^{-3}

4. How many moles of H^+ are donated by the above acid during titration? (a) 5.43×10^{-1} (b) 5.43×10^{-3} (c) 7.62×10^{-2} (d) 1.85×10^{-12}

5. The grams of solid acid per mole H^+ donated by the acid is (a) 34 (b) 47 (c) 470 (d) answer not given

6. If a student in the process of titration allows air bubbles to form in the buret tip between the initial reading and the final reading, the volume of the base delivered would be (a) less than the difference between the final and initial readings, (b) greater than the difference between the initial and final volume, (c) the same because the tip is not part of the calibration, (d) need more information.

7. If the molarity of the base used (NaOH) in the above titration was 0.2206 M instead of the given 0.2156 M, the mass of solid acid per mole of H^+ ion would be (a) larger, (b) smaller, (c) same, (d) need more information.

8. If the ratio of the moles of H^+ ion per mole of solid acid with a molecular formula of $C_5H_7O_8$ is 3, the following is a correct representation of the acid.

   (a) $WC_5H_7O_8$ (b) $H_3C_5H_7O_8$ (c) $H_3C_5H_4O_8$ (d) $N_7C_5O_8$

9. If the formula wt. of acid in 8 is 195, the grams of acid per mole of H^+ is (a) 195 (b) 585 (c) 65 (d) 58.5

10. If a solid acid contains 2 ionizable H^+ per mole and has a formula weight of 78, the moles of H^+ ion in 10 grams of acid is

    (a) $\underline{78} \times \frac{1}{10} \times \frac{1}{2}$ (b) $\frac{10}{78} \times \frac{2}{1}$ (c) $2 \times \frac{78}{10}$ (d) $\underline{78} \times \frac{1}{10} \times \frac{2}{10}$

Analysis of potassium chlorate - potassium chloride mixture

In an experiment similar to Part II of the Analysis of Potassium Chlorate mixtures, you are given the following data:

Mass of test tube, MnO_2 and mixture	11.923 g
Mass of test tube, MnO_2 and mixture	11.612 g
Mass of test tube and MnO_2	10.807 g

In Part I the equation for the reaction was established:

$$2KClO_{3(s)} \xrightarrow[\text{cat.}]{\text{heat}} 2KCl_{(s)} + 3O_{2(g)}$$

1. The mass of oxygen lost is (a) 1.116 g (b) 0.311 g (c) 0.805 g (d) 1.427 g

2. The moles of oxygen atoms lost is (a) 2.52×10^{-2} (b) 1.93×10^{-2} (c) 9.7×10^{-3} (d) 7.2×10^{-2}

3. The moles of oxygen molecules formed is (a) 1.93×10^{-2} (b) 1.22×10^{-2} (c) 3.6×10^{-2} (d) 9.7×10^{-3}

4. The moles of potassium chlorate in the sample is (a) 1.66×10^{-3} (b) 1.28×10^{-2} (c) 6.47×10^{-3} (d) 2.4×10^{-2}

5. The mass of potassium chlorate in the sample is (F.W. - 122) (a) 0.805 g (b) 0.290 g (c) 0.787 g (d) 0.521 g

6. The mass of potassium chloride in the sample is (a) 0.805 g (b) 1.116 g (c) 0.321 g (d) 1.427 g

7. The % by mass of potassium chlorate in the sample is (a) 36% (b) 70.5% (c) 40% (d) 73%

A common error in this experiment is the failure to completely decompose the potassium chlorate. Assume this error (in complete decomposition) takes place in Part I of the experiment where the simplest formula equation for the reaction was established, but not in Part II where % purity of potassium chlorate was determined. Answer questions 8-10 using this assumption.

8. The number of oxygen atoms in the potassium chlorate would be (a) too high, (b) too low, (c) not affected, (d) need more information to determine this effect.

9. If the student heated the MnO_2 strongly enough to decompose the MnO_2 to MnO, the number of oxygen atoms in potassium chlorate would be (a) the same since we are dealing only with potassium chlorate, (b) too high, (c) too low, (d) I'm not programmed for this information.

10. The answer for Part II percent of potassium chlorate in the mixture would be (a) not affected, (b) too low, (c) too high, (d) the percent would be affected somewhat, but careful technique would minimize this error.

Reduction of MnO_4^-

GIVEN: XO_4^{-2} reacts with I^- in an acid medium to form I_2 and X^{+n}.
25.40 ml of 0.1200 M XO_4^{-2} is titrated to the end point (starch) with
16.50 ml of 5.500×10^{-1} M I^-. Answer Questions 1-7 with this data.

1. The half-equation for the oxidation of I^- to I_2 is:

2. The moles of I^- used in the reaction above is (a) 9.1×10^{-3} (b) 9.1×10^{2} (c) 3.0×10^{-3} (d) 5.5×10^{-1}

3. The moles of e^- lost by the I^- in the reaction is (a) 9.1×10^{-2} (b) 4.5×10^{-3} (c) 9.1×10^{-3} (d) 18×10^{-3}

4. The moles of e^- gained by XO_4^{-2} is (a) 9.1×10^{-2} (b) 9.1×10^{-3} (c) 18×10^{-3} (d) 4.5×10^{-3}

5. The moles of e^- gained per mole of XO_4^{-2} is (a) 1 (b) 2 (c) 3 (d) 4

6. The oxidation state of X^{+n} (value of n) is (a) 6 (b) 3 (c) 4 (d) 2

7. The equation for reduction of XO_4^{-2} to X^{+n} (in acid) is:

8. In the acid titration of MnO_4^- with $H_2SO_3(HSO_3^-)$, the color of the solution at the endpoint is (a) colorless, (b) green, (c) pink, (d) blue.

9. If during the titration an air bubble appears in the buret containing the I^- solution, the oxidation state of X^{+n} will be (a) too high, (b) too low, (c) not affected since the volume was measured by the calibrated part of the buret, (d) an error in the oxidation state will be introduced, but slide rule accuracy of the calculations will cancel the error.

10. Suppose the buret containing the I^- is calibrated so that it delivers 17.00 ml instead of the measured 16.50 ml. The oxidation state of X^{+n} will be (a) too low, (b) too high, (c) not affected since the volume of XO_4^{-2} will be equally affected, (d) I'm not programmed for this information.

Heat of solution

An acid similar to H_2SO_4 reacts exothermically with H_2O.

Calorimeter constant	12.5 cal/g °C
Specific heat of H_2O	1.0 cal/g-°C
Volume of acid	5.75 ml
% of acid	75.0 %
Specific gravity	1.65
Mass of H_2O	200 g
Initial temperature	25.0 °C
Final temperature	28.0 °C
Molecular weight of acid	78.0 g/mole

1. The specific gravity of an acid solution is 0.50. The % acid by composition is 70%. The mass of acid in 10 ml of the solution is (a) 0.35 (b) 3.5 (c) 0.70 (d) 5.0

2. The moles of acid used in the titration is (a) 9.1×10^{-2} (b) 6.2×10^{-1} (c) 9.1×10^{-1} (d) 1.23

3. The heat gained by the water is (a) 200 (b) 300 (c) 600 (d) 37.5

4. The heat gained by the calorimeter is (a) 200 (b) 37.5 (c) 15.0 (d) 300

5. The heat liberated by the water is (a) 637 (b) 215 (c) 337 (d) 37.5

6. The assumption you are making in question 5 to obtain an answer is (a) the heat lost by the water and calorimeter equals the heat gained by the acid, (b) the heat lost by the calorimeter is equal to the heat gained by the water, (c) the heat lost by the water equals the heat released by the H_2O, (d) the heat gained by the water and the calorimeter is equal to the heat released by the acid.

7. The heat of solution of the acid (cal/mole) is (a) 3.700×10^3 (b) 7.000×10^3 (c) 10.7×10^3 (d) 6.5×10^3

8. The principal source of error in this experiment is (a) the heat gained by the calorimeter, (b) the uncertainty of the volume of water used, (c) using 1 g/ml as the density of the water rather than determining the actual density of the final solution, (d) uncertainty of reading the temperature.

9. If the student in reading the thermometer records the final temperature at 28.0° rather than the actual reading of 28.4°, the calculated heat gain by the water will be (a) too low, (b) too high, (c) not affected since 0.4° change is not enough to be noticed, (d) not enough information given.

10. If the thermometer reading (final reading) was 29.0°C rather than the actual reading of 28.0°C, the heat of solution would be (a) too low, (b) too high, (c) not affected, (d) I didn't do the experiment so this is not a fair question.

<u>Molecular weight by the Dumas Method</u>

GIVEN:	Mass of flask + condensed vapor	123.914 g
	Mass of flask	122.192 g
	Barometer reading	755 mm
	Temperature of hot oil	200°C
	Volume of flask	634 ml

1. The volume of the vapor in the flask at STP is (a) $634 \times \frac{237}{473} \times \frac{760}{755}$ (b) $634 \times \frac{200^\circ C}{100^\circ C} \times \frac{760}{755}$ (c) $634 \times \frac{273}{473} \times \frac{755}{760}$ (d) $634 \times \frac{273}{473}$

2. The molecular weight of the compound is (a) 93 (b) 176 (c) 106 (d) not given.

In this experiment the liquid has an appreciable vapor pressure at room conditions. During the final weighing at room temperature the flask is filled with air and molecules of the liquid. During the initial weighing the flask was filled with air only. Assume the mass of the vapor molecules is greater than the mass of air molecules. The volume of the flask is 300 ml and the atm pressure is 740 mm. Use this information to answer Questions 3 through 7.

3. If the atm pressure is 740 mm and the vapor pressure of the liquid is 160 mm at room conditions, the pressure of air inside the flask is (a) 740 (b) 900 (c) 580 (d) 160

4. If the liquid in the flask has a vapor pressure of 160 mm at room conditions, and the outside air pressure is 740 mm, the fraction of air displaced is (a) $\frac{740}{760}$ (b) $\frac{160}{580}$ (c) $\frac{160}{740}$ (d) $\frac{740}{900}$

5. The final mass of the liquid collected is (a) too large, (b) too small, (c) not affected since the air molecules are lighter than the vapor molecules, (d) not affected since corrections to STP will be made.

6. The volume of vapor molecules at room conditions (740 mm) is (a) $\frac{160}{740} \times 300$ (b) $\frac{740}{760} \times 300$ (c) $\frac{160}{580} \times 300$ (d) $\frac{580}{740} \times 300$

7. If not all the unknown liquid was evaporated from the flask during the boiling procedure, the calculated molecular weight would be (a) low, (b) high, (c) not affected as the final weighing procedure will determine this mass, (d) I'm not programmed for this question.

8. If some moisture is trapped in the inner aluminum foil and becomes part of the final mass of the liquid in the flask, the apparent molecular weight of the compound will be (a) too large, (b) too small, (c) not affected because H_2O molecules are lighter than the vapor molecules, (d) need more information.

9. The temperature of boiling water at room conditions (745 mm) is (a) greater than 100°C, (b) equal to 100°C, (c) less than 100°C, (d) equal to the vapor pressure of the liquid.

10. Ideally the moles of vapor molecules collected (room conditions) in the flask is (a) greater than the initial moles of air molecules, (b) less than the initial moles of air molecules, (c) same as the initial moles of air, (d) the moles of vapor molecules are different from the moles of air molecules but the masses are the same.

Combining weight of a metal

In an experiment similar to the one you did in the laboratory, Joe Cool collected the following data:

DATA

Mass of crucible + lid + metal oxide	25.761
Mass of crucible + lid + metal	24.321
Mass of crucible + lid	21.200

RESULTS

Mass of oxide	4.561 g
Mass of metal	3.121 g

1. Mass of metal combined with 1.0 g of oxygen is (a) 1.000 g (b) 2.180 g (c) 1.440 g (d) 7.682

2. Mass of metal combined with 16 g of oxygen is (a) 35.000 g (b) 16.00 g (c) 23.20 g (d) 123.0 g

The atomic mass of the metal is, if: (Questions 3-14)

3&4 1 mole of metal atoms combined with 1 mole of oxygen atoms (16 g of oxygen) ____________________

5&6 1 mole of metal atoms combined with 2 moles of oxygen atoms (32 g of oxygen) ____________________

7&8 2 moles of metal atoms combined with 1 mole of oxygen atom (16 g of oxygen) ____________________

9&10 2 moles of metal atoms combined with 3 moles of oxygen atoms (48 g of oxygen) ____________________

11&12 3 moles of metal atoms combined with 2 moles of oxygen atoms (32 g of oxygen) ____________________

13&14 If the specific heat of the metal is 0.118 cal/g^{o}C, the approximate atomic mass (weight) of the metal is ____________________.

15. Using the data from 3-12 and 13-14, the atomic mass (weight of the metal) is ____________________.

16. If some of the metal fails to react with nitric acid, the experimental value of the atomic mass of the metal will be (a) the same as if all the metal reacted, (b) too low, (c) too high, (d) will have no effect as difference in mass will be negligible.

17. If some of the metal nitrate is not decomposed to the metal oxide, the experimental value of the atomic mass of the metal will be (a) too high, (b) too low, (c) not affected since careful weighing will correct this error, (d) more information is needed before a decision is made.

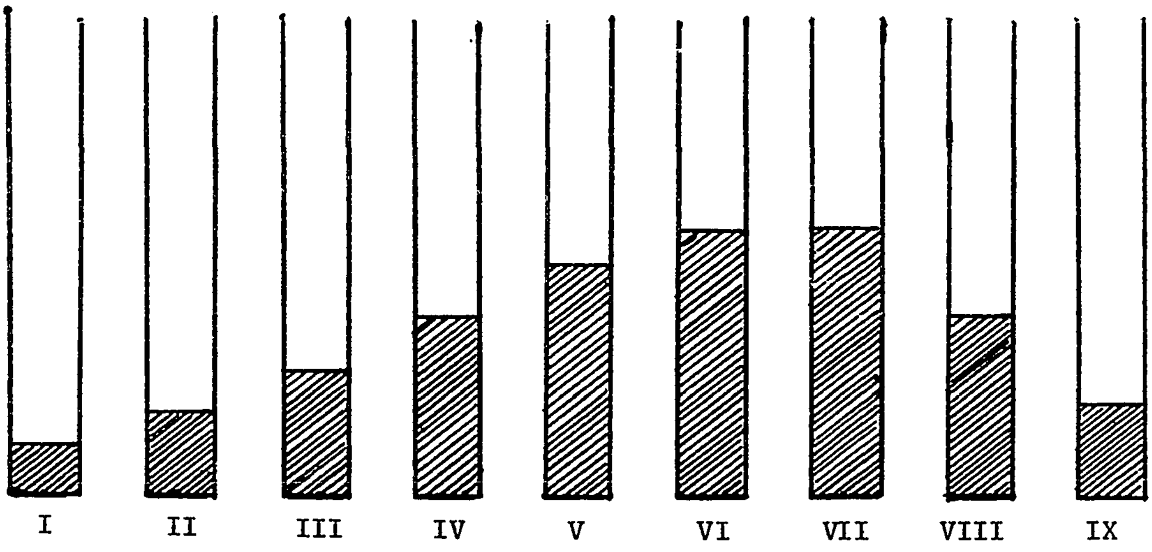
18. The best method of insuring complete decomposition of the metal nitrate is to (a) adjust the burner for maximum heating, (b) heat initially for 15 minutes, cool, weigh and reheat until a constant mass is obtained, (c) heat for 1 hour instead of the 15 minutes, (d) use a larger burner.

19. If some of the metal compound splatters from the crucible during decomposition, the experimental atomic mass of the element will be (a) too low, (b) too high, (c) not affected since a certain mass of the material is to be removed by heating anyway, (d) not detectable since the balance is accurate to milligrams.

20. Suppose the analytical balance consistently weighs 15% too low (compared to a standard mass); the experimental value of the atomic mass will be (a) 15% too low, (b) 15% too high, (c) same as if the weighing was performed on a balance that consistently agreed with standard values, (d) 30% too low.

Formula of a precipitate

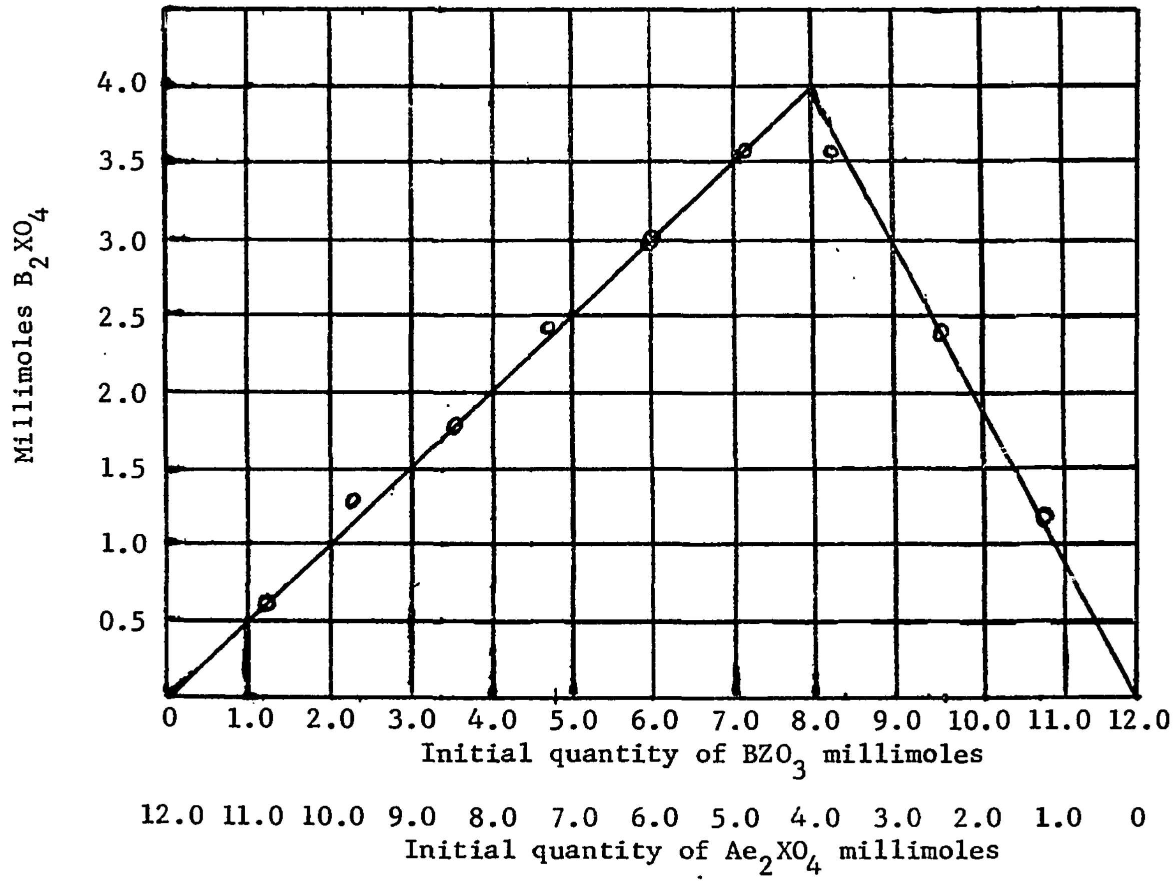
Using the method of continuous variation similar to Experiment 16, formula of a ppt, Joe Cool mixed solutions of 0.24 M Ae_2XO_4 and 0.24 M BZO_3 in 9 different test tubes. Below is a sketch of the orange (naturally) ppt in the test tubes. His results and graph are also reproduced. Joe Cool is a very dedicated and sincere student the last 3 weeks of each grading period.



JOE COOL'S DATA

Test tube number	I	II	III	IV	V	VI	VII	VIII	IX
Volume of 0.24 M BZO_3 solution in ml	5	10	15	20	25	30	35	40	45
Millimoles of BZO_3	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6	10.8
Volume of 0.24 M Ae_2XO_4 solution in ml	45	40	35	30	25	20	15	10	5
Millimoles of Ae_2XO_4	10.8	9.6	8.4	7.2	6.0	4.8	3.6	2.4	1.21
Average mass of B_2XO_4	0.20	0.39	0.58	0.78	0.98	1.18	1.20	0.80	0.39
Average millimoles of B_2XO_4	0.6	1.2	1.7	2.4	3.0	3.6	3.6	2.4	1.2

JOE'S GRAPH



1. The formula weight of Ae_2XO_4 is 194. What mass of Ae_2XO_4 is needed to prepare 50 ml of a 0.24 M solution? (a) 46.6 g (b) 24.6 g (c) 2.32 g (d) 1.94 g

2. What controlled the height of the ppt in test tubes 1 through 4? (a) height of test tube, (b) moles of BZO_3, (c) moles of Ae_2XO_4, (d) volume of the final solution.

3. Though you measured the height of the ppt in this experiment, what property of the precipitates were you measuring indirectly? (a) mass of ppt, (b) volume of solid formed, (c) temperature of ppt, (d) size of the test tube.

4. The height of the ppt is not related to the moles of ppt formed because (a) atoms and molecules in a solid have restricted motion, (b) the volume of the ppt is determined by crystal size, type of shaking and entrapment of water and air, (c) moles of ppt formed is inversely proportional to diameter of test tube, (d) answer not given.

5. From Joe Cool's graph, what is the combining millimole ratio between Ae_2XO_4 and BZO_3? (a) 1:1 (b) 2:1 (c) 1:2 (d) 2:3

6. The equation for the ppt reaction using Joe Cool's data and graph is ____________________.

7. What was the limiting reagent (determines amount of ppt formed) in test tubes 6 through 9? (a) Ae_2XO_4 (b) H_2O (c) BZO_3 (d) B_2XO_4

8. Predict the number of millimoles of ppt formed in test tube number 4: (a) 4.8 (b) 2.0 (c) 2.4 (d) 3.6

9. How would you verify the prediction in Question 8? (a) weigh the test tubes and contents, (b) filter dry and weight the ppt formed in #4 and calculate the number of moles formed, (c) plot a graph of the height of ppt vs. test tube number; (d) ask Joe Cool.

10. What mass of B_2XO_4 would be obtained by adding 10.0 ml of BZO_3 to 40.0 ml of Ae_2XO_4? (a) 1.00 g (b) 1.20 g (c) 0.39 g (d) 0.80 g

<u>Specific heat of a metal</u>

1. If 100 g of H_2O at 40°C were contained in an aluminum cup weighing 100 g, the cup also being at 40°C, cooling the cup or its contents to 0°C would release (a) 4000 cal (b) 4880 cal (c) 4022 cal (d) 8080 cal

For questions 26 through 32 consider the following experiment: A calorimeter of weight 100 g and specific heat 0.1 cal/g$^\circ$C contains 100 g of water at 15°C. After a block of metal weighing 50 g and at a temperature of 1020°C is dropped in, the temperature rises to 20°C.

2. The temperature change (Δt) is (a) 20° (b) 35° (c) 5°C (d) 985°C

3. The number of calories gained by the water is (a) 500 (b) 1000 (c) 2000 (d) 2500

4. The number of calories gained by the calorimeter is (a) 500 (b) 100 (c) 200 (d) 50

5. The calorimeter constant is (a) 10 cal/$^\circ$C (b) 100 cal/$^\circ$C (c) 0.1 cal/$^\circ$C (d) 5 cal/$^\circ$C

6. The number of calories lost by the block is (a) 400 (b) 2200 (c) 9500 (d) 2550

7. The number of calories lost by each gram of the block is (a) 8 (b) 44 (c) 51 (d) 190

8. The specific heat capacity of the metal block is (a) 2.1×10^{-1} cal/g$^\circ$C (b) 8×10^{-3} cal/g$^\circ$C (c) 5.1×10^{-2} cal/g$^\circ$C (d) 1.9×10^{-2} cal/g$^\circ$C

9. A laboratory experiment to determine the specific heat of a metal yielded the following data:

Weight of metal	240.9 g
Weight of calorimeter & stirrer	380.9 g
Weight of H_2O	400.0 g
Temperature change of metal	10.0°C
Temperature change of water	2.4°C

The experimenter cannot proceed with calculations until he determines (a) the initial temperature of H_2O, (b) the final temperature of H_2O, (c) some additional data needed, (d) no additional data; he can proceed with the calculations.

10. Which of the following is a correct comparison of the heat lost by the washers and the heat gained by the water? (a) The washers lose more calories than the water gains because the washers are a greater number of degrees above room temperature than the water is below room temperature. (b) The washers lose less calories than the water gains because the washers are a greater number of degrees above room temperature. (c) The washers lose more heat than the water gains because the calorimeter also requires some heat to change its temperature. (d) The washers lose less heat than the water gives because the calorimeter requires some heat to change its temperature.

Heat of reaction

EQUATIONS

1. $Ca_{(s)} + 2H_2O = Ca^{++}_{(aq)} + 2OH_{(aq)} + H_{2(g)}$

2. $CaO_{(s)} + H_2O = Ca^{++}_{(aq)} + 2OH^{-(aq)}$

3. $H_{2(g)} + \frac{1}{2}O_2 = H_2O_{(e)}$

4. $Ca + \frac{1}{2}O_{(s)} = CaO_{(s)}$

PART I

Given: 0.40 g of $Ca_{(s)}$, (40 amn) reacts with 200 g of water in a calorimeter. See Equation 1. The temperature rises 5^oC; the cal. constant is 6 cal/^oC.

a. How many moles of Ca reacts with the H_2O?

b. What is the heat released by 0.40 g of Ca reacting with the water?

c. What is the heat released per mole Ca? Call this ΔH_1.

PART II

When 4.6 g of $CaO_{(s)}$ (FW 46) reacts with 200 g of H_2O in the calorimeter as Part I, the temperature of the H_2O in the calorimeter rises 9.5^oC. See Equation 2. Cal. constant = 6 cal/^oC.

a. How many moles of CaO reacted?

b. What is the heat released by the 4.6 g of CaO reacting with water?

c. What is the heat released per mole of CaO? Call this ΔH_2.

PART III

The reaction of $\frac{1}{2}O_2 + H_2 \;\; H_2O_{(1)}$ releases 68.3 kcal.

Combine Equations 1, 2, and 3 in such a way as to determine Hr of $Ca_{(s)} + \frac{1}{2}O_2 = CaO$.

QUESTIONS:

If 0.2 grams of calcium were reacted with the 200 g of H_2O in the calorimeter, how many calories of heat would be released?

Would the H_1 value in Part I be affected? Explain.

Water of hydration

1. A hydrate with $2H_2O$ molecules compared to one with $7H_2O$ molecules (a) has a greater % of water, (b) lower % of water, (c) can't tell from the data given.
2. If you put the hydrate in a crucible that wasn't completely dry, the percent of water calculated for the hydrate would be (a) the same since all the water is driven off, (b) too low, (c) too high, (d) depends on the mass of the crucible.
3. The reason for heating and weighing the anhydrous salt more than once is (a) to check the accuracy of the weighing procedure, (b) the water is more effectively removed by several heatings rather than one long one, (c) to insure that all the water is removed.
4. If the mass of the hydrate is 4.70 g and the mass of the anhydrous salt is 3.76 g, the percent of water is (a) 20% (b) 10% (c) 43% (d) insufficient data
5. If the formula for the anhydrous compound in Question 4 is $CaSO_4$, then the number of water molecules in the hydrate is (a) 8 (b) 6 (c) 4 (d) 2.

Solubility product of $PbCl_2$

1. The saturated solution you are given is already at equilibrium at room temperature. Failure to add solid $PbCl_2$ to establish the new equilibrium at 40^o would (a) have no effect, (b) cause precipitation, (c) cause an unsaturated solution to be formed, (d) achieve the new saturated state sooner.
2. It is very important that exactly 20.0 ml of solution be used in each evaporation process. TRUE or FALSE?
3. If 20.0 ml of solution are evaporated giving a mass of 0.20 g of $PbCl_2$ residue, the solubility product of the lead chloride is (a) 4.62×10^{-5} (b) 5.2×10^{-7} (c) 1.29×10^{-3} (d) 1.8×10^{-4}

4. The proper K_{sp} expression for $PbCl_2$ is (a) $K_{sp} = [Pb^{+2}][Cl^-]^2$ (b) $K_{sp} = [Pb^{+2}][2Cl^-]^2$ (c) $K_{sp} = [P_b^{+2}][Cl_2^-]$ (d) $K_{sp} = [Pb][Cl]^2$

5. If the solubility of $PbCl_2$ = 0.032 mole/liter, the K_{sp} is (a) 1.03×10^{-3} (b) 2.05×10^{-3} (c) 1.31×10^{-4} (d) 4.8×10^{-5}

Gas laws

1. Using the kinetic molecular theory, describe the effect of increasing the temperature on a confined volume of gas. Be sure to describe in terms of the energy and motion of the individual atoms and/or molecules.

2. In terms of the kinetic molecular theory, what effect does the number of particles have on the pressure? Why?

3. Find the volume at STP given 500 liters of gas collected at 25°C and 800 mm of Hg pressure.

4. If a fixed mass of gas at a fixed temperature and a pressure of 200 mm of Hg occupies a volume of 2 liters,

   (a) what volume would it occupy at a pressure of 175 mm of Hg?

   (b) What pressure would it exert in a volume of 3 liters?

5. A volume of gas was measured at pressure P_1 and found to be 200 ml. At a pressure P_2 the volume was 250 ml. If the temperature remains constant, what is the ration P_1/P_2?

Equivalent weight of copper

I. An electrolytic cell is set up. A current of 12 amperes is passed through a $SnCl_2$ solution for 20 minutes. Assume $[H^+] = 10^{-7}$, $[OH^-] = 20^{-7}$, and $SnCl_2 = 1$ molar. Assume inert electrodes are used.

A. How many coulombs of charge pass through the cell?

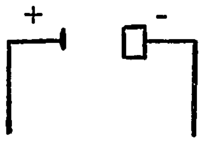
B. Moles of electrons?

C. Assume that Cl^- is oxidized. How many liters of Cl_2 are formed? Assume S.T.P.

D. Write the half reaction to indicate the most probable reduction reaction. (Ignore overvoltage affects.)

E. Design a cell for the above electrolytic process.

Given:



Label anode and cathode.

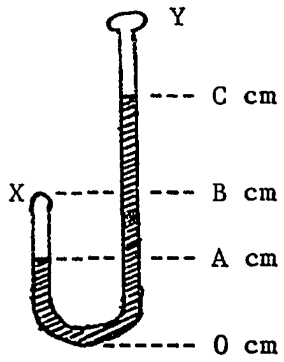
Write net equations at each electrode.

II. Given: $A^{+n} \longrightarrow ne^- + A.$

If a current of 250 ma flowed for 30 minutes and deposits 0.218 of the metal, what is the equivalent weight of the metal? The metal has an atomic weight of 280. What was the oxidation state of the metal ion A^{+n}?

Physics Laboratory Quizzes

Boyle's Law



Initially the mercury in both arms of the tube is at the same level and the tube is open to the atmosphere at both X and Y. End X is then closed and mercury is added to the tube resulting in the situation shown in the sketch. A vertical metric rule is placed by the tube with the scale zero at the lower extreme of the "J tube".

1. What length of the tube is directly proportional to the volume of the confined air? (a) C - B (b) C - A (c) B - A (d) A - 0 (e) B - 0

2. What was the approximate pressure of the air in the short arm of the "J tube" <u>before</u> end X was closed? All answers are in cm of mercury. (a) 0 (b) B - A (c) C - A (d) B - 0 (e) 74

3. What is the total pressure acting on the confined gas as shown in the diagram? (In cm Hg) (a) C - 0 (b) C - A (c) B - A (d) B - 0 (e) correct answer not given

4. Which is the correct relationship between the pressure of a gas and its volume at constant temperature? (a) $P \alpha V$ (b) $P \alpha V^2$ (c) $P \alpha 1/V$ (d) $P \alpha 1/V^2$ (e) $P^2 \alpha V$

5. Suppose mercury is added to the "J tube" until the difference between the levels in the open and closed arms is exactly twice what it is in the sketch. What would this do to the volume of the confined air? (a) It would decrease it to 1/2 its present value. (b) It would decrease it to less than 1/2 its present value. (c) It would decrease the volume, but the new volume would be more than 1/2 the present volume. (d) It would have no effect on the volume. (e) The volume would become zero.

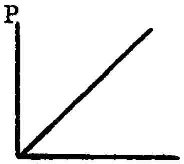
6. What information is needed to determine the relationship between P and V beyond that obtained from the "J tube" scale readings? (a) The density of mercury. (b) The diameter of the tube. (c) The kind of gas that is in the tube. (d) The atmospheric pressure. (e) The room temperature.

7. What assumption(s) are made in this experiment? (a) The temperature of the confined gas is constant. (b) The mass of the confined gas is constant. (c) The pressure of the confined gas is constant. (d) Both "a" and "b". (e) "a", "b" and "c".

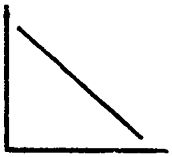
8. What affect does the amount of mercury below level "A" have on the pressure of the confined air? (a) The pressure is directly proportional to the amount of mercury. (b) The pressure is inversely proportional to the amount of mercury. (c) The pressure is always independent of the amount of mercury. (d) The pressure is independent of this mercury only if the levels in each arm were equal when both ends of the tube were open. (e) The pressure is directly proportional to the amount of mercury only when the mercury levels in the two arms are not the same.

9. Which of the sketches below most nearly resembles a graph of P vs. V?

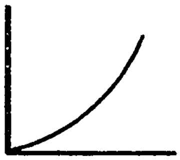
10. Which of the sketches below most nearly resembles a graph of P vs. 1/V?



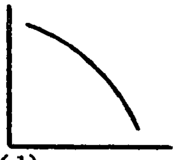
(a)



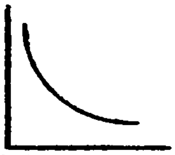
(b)



(c)



(d)



(e)

The magnetic field at the center of a loop

1. A coil of wire produces a magnetic field of strength B when the current in the coil is 2 amperes. If the current is changed to 1 ampere, what will be the value of the new magnetic field? (a) 1/4 B (b) 1/2 B (c) 2 B (d) 4 B (e) none of these

2. If the current in the coil in Question 1 is left at 2 amperes, but the number of turns of wire in the coil is doubled, what will be the new value of the magnetic field? (a) 1/4 B (b) 1/2 B (c) 2 B (d) 4 B (e) none of these

3. How must the plane of a coil be aligned with respect to the direction of the earth's magnetic field if the deflection of a compass from the north-south line is to be used as a means of determining the strength of the coil's magnetic field? (a) The plane of the coil must be oriented in the N-S direction. (b) The plane of the coil must be in the E-W direction. (c) The plane of the coil may be either in N-S or E-W, but not at an in-between position. (d) It will work in any position other than E-W, but the more nearly it is N-S, the easier it is to get good results. (e) The position of the coil makes no difference in the experiment.

4. Why is it necessary to keep the wires leading from the coil to the power source parallel to each other and in the plane of the loop and also keep excess wire from around the loop? (a) It avoids unwanted electric fields. (b) It makes the equipment look neater. (c) It avoids tangles of wire. (d) It avoids short circuits. (e) It avoids unwanted magnetic fields.

5. What effect does the strength of the magnetic compass needle have on the experiment? (a) The stronger the compass needle, the greater the deflection. (b) The stronger the compass needle, the less the deflection. (c) The compass's strength has no effect on the results.

6. A compass needle points in the direction of a magnetic field, B. A second magnetic field, at right angles to B, causes the compass to deflect 45 degrees from its original position. What is the strength of the second magnetic field? (a) 1/4 B (b) 1/2 B (c) B (d) 2 B (e) 4 B

7. A coil of wire with 10 turns produces a magnetic field, B, when the current is 1 ampere. If the number of turns and current are both doubled, what field would result? (a) 1/4 B (b) 1/2 B (c) B (d) 2 B (e) 4 B

8. The magnetic field of a coil causes a compass needle to deflect 30 degrees from the north when the current in the coil is 1 ampere. If the current in the coil is increased to 2 amperes, how many degrees will the compass be deflected from north? (a) Less than 30 (b) 30 (c) More than 30, but less than 60 (d) 60 (e) 90

9. How does reversing the current in a coil affect the direction of the magnetic field produced by the coil? (a) It changes the direction less than 90 degrees. (b) It changes the direction 90 degrees. (c) It changes the direction 180 degrees. (d) It changes the direction by more than 180 degrees. (e) It does not change the direction of the field.

10. What is indicated by the direction a compass needle points? (a) The direction of the earth's magnetic field. (b) The strength of the earth's magnetic field. (c) The direction of the vector sum of all magnetic fields at the point. (d) A combination of the strengths and directions of all magnetic fields at the point. (e) The direction of the vector sum of the horizontal components of all magnetic fields at the point.

Forces on currents

1. Why were you directed to adjust the balance to the "zero position" with the current in the balance loop on and adjusted to the value to be used in that particular part of the experiment? (a) To compensate for the mass of the additional electrons in the loop. (b) To lessen the chance of bumping against the balance when connecting it in the circuit. (c) To lessen the chance of electrical shock. (d) To balance out the effect of the earth's magnetic field. (e) To balance out the effect of the earth's gravitational field.

2. What happens when a small cylindrical magnet is brought near a balance loop that is carrying a current? (a) The balance loop is attracted to the magnet. (b) The balance loop is repelled from the magnet. (c) The balance loop experiences a force at right angles to the axis of the magnet. (d) The loop may be either attracted to or repelled from the magnet depending on the direction of current and polarity of the magnet. (e) There is no effect.

3. If the force exerted on the balance loop by the fixed loop is F, what is the force on the fixed loop? (a) $1/F$ (b) $1/F^2$ (c) F^2 (d) $2F$ (e) none of these

4. Which is the correct relationship between the force on the balance loop and the current in the fixed coil? (a) $F \alpha I_f$ (b) $F \alpha 1/I_f$ (c) $F \alpha I_f^2$ (d) $F^2 \alpha I_f$ (e) none of these

5. Two parallel wires 2 cm apart each carry a current of 5 amperes. The force they exert on each other is 20 units. What force will they exert if the distance is changed to 4 cm? (a) 5 units (b) 10 units (c) 40 units (d) 80 units (e) none of these

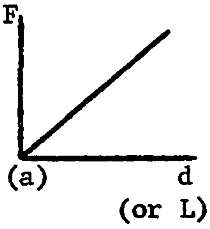
6. Suppose the wires in Question 5 are left 2 cm apart, but the currents are 5 amperes and 10 amperes. What force will they now exert? (a) 5 units (b) 10 units (c) 40 units (d) 80 units (e) none of these

7. A wire carrying a current of 5 amperes exerts a force of 28 units on a current balance loop 30 cm long. What will be the force exerted on a 7.5 cm loop? (a) 2 units (b) 7 units (c) 14 units (d) 28 units (e) none of these

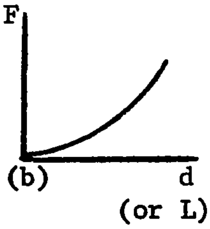
8. Which of the following equations is correct? (a) $F = kI_1I_2/d^2$ (b) $F = KI_1I_2d/L$ (c) $F = kI_1I_2d/L^2$ (d) $F = kI_1I_2L/d$ (e) none of these

9. Which sketch below most nearly represents the graph of force versus length of balance loop?

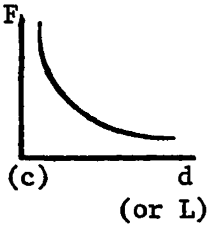
10. Which sketch below most nearly represents the graph of force versus the distance between the balance loop and the fixed coil?



(a)



(b)



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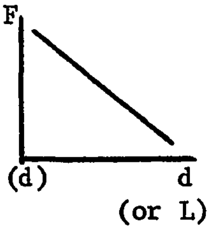

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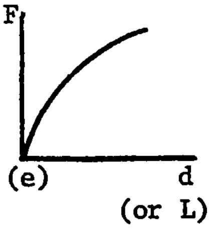


(e)

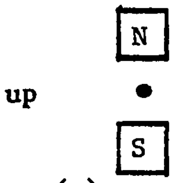
Currents, magnets, and forces

1. If the length of the region of interaction between a magnetic field and a current carrying conductor is doubled, what is the factor by which the force is changed? (a) 1/4 (b) 1/2 (c) 1 (d) 2 (e) 4

2. Which of the following is correct? (a) $F \alpha BIL$ (b) $F \alpha BI/L$ (c) $F \alpha BL/I$ (d) $F \alpha L/BI$ (e) $F \alpha I/BL$

3. If the current in a conductor in a magnetic field is doubled, by what factor is the force of interaction changed? (a) 1/4 (b) 1/2 (c) 1 (d) 2 (e) 4

4. A wire is arranged to move horizontally only. If the dot is the end view of the wire, which is the best orientation of the magnets to move the wire to the left or right?

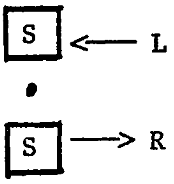


(a)

(b)

(c)

(d)



(e)

5. The force of interaction between a horizontal wire, constrained so as to move only horizontally, and the earth's magnetic field is (a) zero, (b) independent of position, (c) strongest when the wire runs in an east-west direction, (d) strongest when the wire runs in a north-south direction.

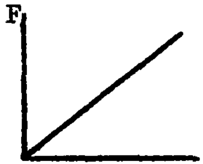
6. Which of the following is true of the plots of force versus current for two magnets, if one is stronger than the other? (a) The stronger the magnet is the less the slope will be. (b) The stronger the magnet is the greater the slope will be. (c) The graph for the stronger magnet will go above the origin. (d) Statements "a" and "c" are both true. (e) Statements "b" and "c" are both true.

7. What factors determine the magnitude of the force on a current carrying conductor in a magnetic field? (a) current, (b) strength of magnetic field, (c) length of region of interaction, (d) "a" and "b", (e) "a", "b" and "c"

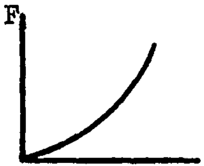
8. How do you convert force in "cm of wire" to force in Newtons? (a) Multiply "cm of wire" by 9.8 and divide by 100. (b) Multiply "cm of wire" by kg/cm and divide by 9.8. (c) Change "cm of wire" to "meters of wire" and multiply by 9.8. (d) Change "cm of wire" to "meters of wire" and divide by 9.8. (e) None of these are correct.

9. Which of the sketches below most nearly approximates the graph of the force on a current carrying conductor in a magnetic field versus the current in the conductor?

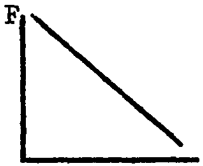
10. Which of the sketches below most nearly approximates the graph of the force on a current carrying conductor in a magnetic field versus the length of the region of interaction?



(a)



(b)



(c)

(d)

(e)

Electrical circuits

1. What is the equation of the graph of V vs. I for a circuit with a resistance of 3 ohms? (a) $I = 3V$ (b) $V = 3I$ (c) $V = 3I^2$ (d) $I = 3V^2$ (e) none of these

2. What change occurs as the voltage across a resistance is increased? (a) The current increases. (b) The current decreases. (c) The current stays the same. (d) The resistance increases. (e) The current increases and the resistance decreases.

3. Two 4-ohm resistances are connected in series. What is their combined resistance in ohms? (a) 2 (b) 4 (c) 8 (d) 16 (e) none of these

4. Two 4-ohm resistances are connected in parallel. What is their combined resistance in ohms? (a) 2 (b) 4 (c) 8 (d) 16 (e) none of these

5. Which is the correct equation relating voltage, resistance, and current? (a) $V = IR$ (b) $R = IV$ (c) $I = VR$ (d) $V = I^2R$ (e) $V = I^2/R$

6. If 6 volts is applied to a resistance of 2 ohms, what is the current in amperes? (a) 1/3 (b) 3 (c) 4 (d) 12 (e) none of these

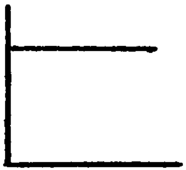
7. A 6-ohm resistance and a 3-ohm resistance are connected in parallel. What is their combined resistance in ohms? (a) 2 (b) 3 (c) 4.5 (d) 9 (e) 18

8. How is a graph of V vs. I changed by increasing the resistance? (a) It intercepts the V-axis farther above the origin. (b) It intercepts the V-axis farther below the origin. (c) It has a steeper slope. (d) It intercepts the I-axis farther to the right of the origin. (e) It intercepts the I-axis farther to the left of the origin.

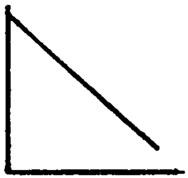
9. Which of the sketches below most closely resembles the graph of V vs. I for constant R?

(a)

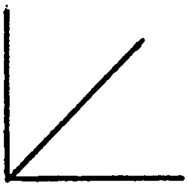
(b)



(c)

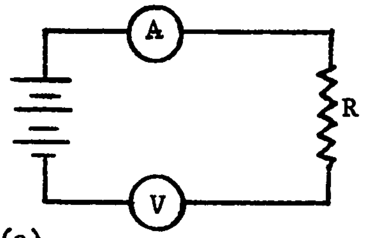


(d)

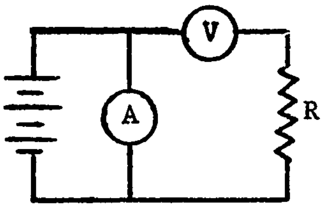


(e)

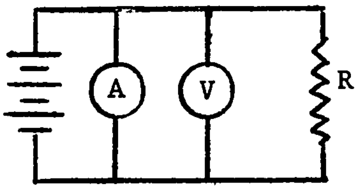
10. Which of the sketches below represents a correct way to connect an ammeter and a voltmeter in a circuit?



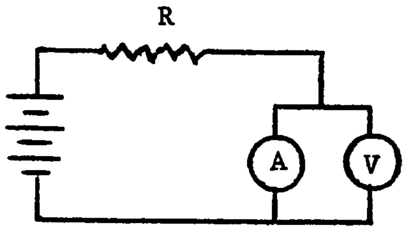
(a)



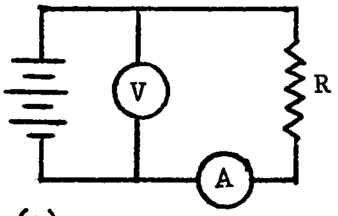
(b)



(c)



(d)



(e)

Coulomb's Law

1. What happens if two balls with the same static electrical charge are brought near each other? (a) There is no effect if they have the same charge. (b) They attract each other. (c) They repel each other. (d) They attract at first and later repel. (e) They repel at first and later attract.

2. How does the electrical force between two small, charged spheres compare with the gravitational force between them? (a) The forces are equal. (b) Gravity is much stronger. (c) Electrical forces are much stronger. (d) There is no gravitational force between the spheres, so the question is meaningless.

3. Which graph is most nearly a straight line? (a) F vs. d^2 (b) F vs. d (c) F vs. 1/d (d) F vs. $1/d^2$ (e) F vs. $1/d^3$

4. Which is correct? (a) $F = kd/Q_1Q_2$ (b) $F = kQ_1Q_2/d$ (c) $F = kd/(Q_1 + Q_2)$ (d) $F = kdQ_1Q_2$ (e) $F = kQ_1Q_2/d^2$

5. If the distance between the two charged spheres is made twice as large, what happens to the force? (a) It becomes four times as large. (b) It becomes twice as large. (c) It stays the same. (d) It becomes one-half as large. (e) It becomes one-fourth as large.

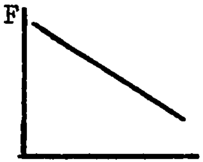
6. If the charge on one sphere is halved and the charge on the other sphere is left the same, what happens to the force? (a) It is 4 times as large. (b) It is 2 times as large. (c) It stays the same. (d) It is one-half as large. (e) It is one-fourth as large.

7. What is the main reason that you must not recharge the spheres between readings? (a) The position of the spheres might be changed. (b) The balance might be disturbed. (c) It takes too much time. (d) You would not know how to get the position the same as it was. (e) You would not know how to get the charge the same as it was.

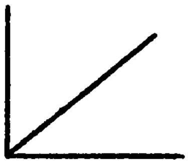
8. Two charged spheres exert a force of 12 units on each other when they are 4 cm apart. What force will they exert on each other when they are 2 cm apart? (a) 3 (b) 6 (c) 12 (d) 24 (e) 48

9. A sphere of charge Q is touched to an identical uncharged sphere. What charge does the sphere that was originally uncharged now have? (a) zero (b) 1/4 Q (c) 1/2 Q (d) Q (e) 2 Q

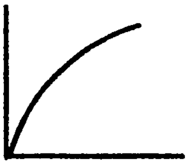
10. Which of the following sketches most nearly represents the graph of F vs. d?



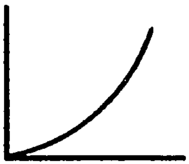
(a)



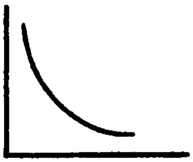
(b)



(c)



(d)



(e)

Electric calorimeter

1. If a current of 5 amperes is used to heat a quantity of water for a period of 600 seconds, how many coulombs of charge pass through the circuit? (a) 24 (b) 50 (c) 120 (d) 3000 (e) none of these

2. How many calories are needed to warm 200 grams of water 10 C^o? (a) 10 (b) 20 (c) 200 (d) 210 (e) 2000

3. About how many joules are needed to equal 1 calorie? (a) 1/1000 (b) 1/4.2 (c) 4.2 (d) 1000 (e) 4200

4. If 8000 joules of energy are delivered to the water by the passage of 2000 coulombs through the heating element, what is the potential difference in volts? (a) 0.25 (b) 4 (c) 6,000 (d) 10^4 (e) 16×10^6

5. If a potential difference of 12 volts results in a current of 5 amperes in the heating coil, what is the resistance in ohms of the coil? (a) 5/12 (b) 2.4 (c) 60 (d) 300 (e) none of these

6. Why should you try to heat the water as many degrees above room temperature as it was originally below room temperature? (a) To prevent overloading the heating element. (b) To insure that equal numbers of coulombs will be lost and gained from the calorimeter. (c) To accurately determine the water equivalent of the calorimeter. (d) To balance the heat gained from the surroundings. (e) The correct answer is not given.

7. What is the name of the instrument used to directly measure energy per unit charge? (a) ammeter (b) ohmmeter (c) calorimeter (d) coulombmeter (e) none of these

8. Which of the following is correct? (a) $4.2\ mc\ \Delta t = IVT$ (b) $mc\ \Delta t = 4.2\ IVT$ (c) $mc\ \Delta t = 4.2\ IV$ (d) $mc\ \Delta t = IVT$ (e) $4.2\ mc\ \Delta t = IV$

9. What is meant by water equivalent? (a) The amount of water that has a mass equivalent to an object. (b) The temperature of an object that is equivalent to the water. (c) A material that may be used instead of water. (d) The amount of water that would act the same as an object with respect to heating. (e) none of these

10. What is volt? (a) A measure of energy per unit charge. (b) A joule per coulomb. (c) A measure of potential difference. (d) "a" and "b" are correct. (e) "a", "b" and "c" are all correct.

Radiation from a point source

1. What is the main reason that the light bulb should be placed no closer than about 5 cm from the photocell? (a) The photocell would be overloaded. (b) The micro-ammeter would be overloaded. (c) The distance would be difficult to measure. (d) The light bulb could not be considered a point source. (e) Correct answer not given.

2. Suppose the experiment is performed in a room that is only partially darkened and the meter reads 10 microamperes before the small lamp is turned on. What effect would this have on the experiment? (a) It would make the data useless. (b) The data could be used without regard to the effect of ambient light. (c) The data could be used if 10 microamperes were subtracted from each meter reading. (d) The data would be valid as taken if none of the meter readings were much larger than 50 microamperes. (e) The data could be used if 10 microamperes were added to all meter readings.

3. The star alpha centauri is very similar to the sun in color and light output. The intensity of illumination here at earth is 10^{11} times greater from the sun than from alpha centauri. How many times farther away from us than the sun is alpha centauri? (a) 10^{11} (b) 10^{-11} (c) 10^{22} (d) 10^{-22} (e) 3×10^5

4. The intensity of illumination on the earth's surface from two identical stars is found to be in the ratio 1 to 9. What is the ratio of their distances from the earth? (a) 3 to 1 (b) 4.5 to 1 (c) 9 to 1 (d) 81 to 1 (e) none of these

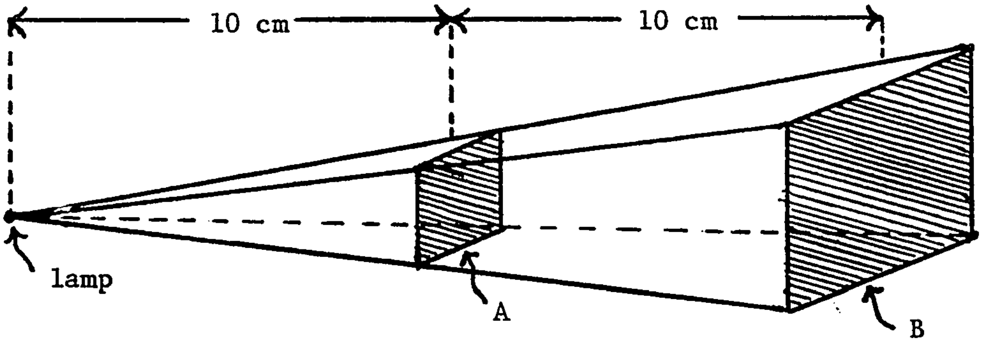
5. Which is the correct relationship between the intensity of illumination, I, and the distance, d? (a) $I = kd$ (b) $I = kd^2$ (c) $I = k/d$ (d) $I = k/d^2$ (e) none of these

6. If the meter reads 60 at a distance of 5 inches, what will it read when the distance is 10 inches? (a) 2 (b) 6 (c) 12 (d) 15 (e) 120

7. Which of the following graphs is most nearly a straight line? (a) I vs. d (b) I vs. d^2 (c) I vs. $1/d$ (d) I vs. $1/d^2$ (e) I vs. $1/d^3$

Questions 8, 9, and 10 refer to the diagram at the top of the next page.

8. If area A is 25 square centimeters, what is area B? (a) 50 cm^2 (b) 100 cm^2 (c) 125 cm^2 (d) 500 cm^2 (e) 2500 cm^2

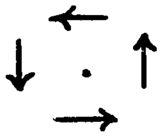


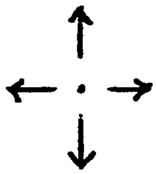
9. If the TOTAL energy incident on surface A in a given interval of time is 16 joules, what is the TOTAL energy in joules incident on B in the same amount of time?

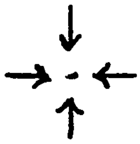
10. How would the energy per square centimeter (intensity) at position A compare with the intensity at position B? Assume the intensity at A is 100 units and state the intensity at B. (a) 25 (b) 50 (c) 100 (d) 200 (e) 400

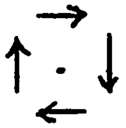
Magnetic field near a long, straight wire

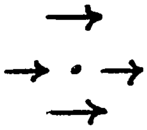
1. Which of the following represents the magnetic field about a long, straight wire? Assume that the dot represents the end of the wire and that positive charges flow into the page.


(a)


(b)


(c)


(d)


(e)

2. Where should a compass be placed, relative to a vertical wire, to measure the magnetic field produced by the wire? (a) East of the wire, (b) north of the wire, (c) west of the wire, (d) either east or west of the wire, (e) It may be placed any direction from the wire.

3. Which of the following conditions would NOT decrease the accuracy of the results in this experiment? (a) Using a current 100 times smaller than 5 amperes. (b) Using a current 100 times larger than 5 amperes. (c) Measuring the field at distances less than 5 centimeters. (d) Measuring the field at distances more than 100 centimeters. (e) Using a stronger compass needle.

4. Which of the following would tend to introduce errors in the results of the experiment? (a) The presence of nearby iron objects. (b) The presence of nearby wires carrying alternating current. (c) Changing

to a compass that is more strongly magnetic. (d) An ammeter that consistently reads 20% high. (e) All of these.

5. If the magnetic field at 10 cm from a long, straight wire is B, what is the field at 20 cm from the same wire if the current is unchanged? (a) 1/8 B (b) 1/4 B (c) 1/2 B (d) 2 B (e) 4 B

6. What is the correct relationship between the magnetic field, B, and the distance, d? (a) $B = kd$ (b) $B = kd^2$ (c) $B = k/d$ (d) $B = k/d^2$ (e) none of these

7. How would the compass behave if it is placed directly east of a wire at a distance such that the field produced by the wire is exactly equal in magnitude to the earth's field? Assume a vertical wire with the lower end connected to the positive source. (a) It would point N. (b) It would point NE. (c) It would point NW. (d) It would point SE. (e) It would point SW.

8. Assume the same conditions as in #7, but that the compass is placed directly north of the wire. Which direction would the compass now point? (a) N (b) NE (c) NW (d) SE (e) SW

9. A typical set of data is shown at the left below. What conclusion may be drawn from this data? (a) Doubling the distance halves the angle. (b) Tripling the distance halves the angle. (c) Doubling the distance reduces the angle by 1/3. (d) Increasing the distance by 3 cm reduces the angle by 1/3. (e) None of these.

10. Which of the following graphs could be represented by the sketch at the right below? (a) B vs. d (b) B vs. $1/d$ (c) B vs. $1/d^2$ (d) B vs. $1/d^3$ (e) None of these.

Distance	Angle
3 cm	64°
6	46
9	34
12	26
15	22
18	19
21	16

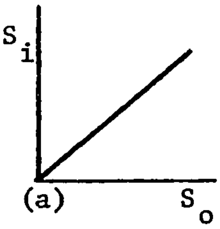
Convex lens

1. How does the size of an image formed by a convex lens compare with the size of the object? (a) The image is always larger. (b) The image is always the same size. (c) The image is always smaller. (d) The image may be either larger or smaller, but never the same size. (e) The image may be larger, smaller, or the same size.

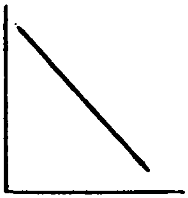
2. Is the image formed by a convex lens right side up (erect) or upside down (inverted)? (a) It is always erect. (b) It is always inverted. (c) It may be either erect or inverted.

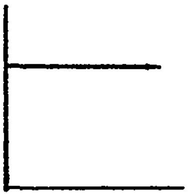
3. What happens to the size and position of the image formed by a convex lens when you move the lens with respect to the object? (a) The position of the image changes and the size stays the same. (b) The position of the image stays the same, but the size changes. (c) Both the size and position of the image change. (d) Neither the size nor position of the image changes.

4. Which sketch most nearly represents the graph of S_i as a function of S_o?



(a)


(b)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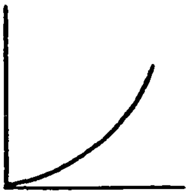
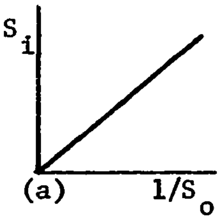
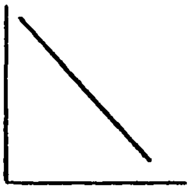

(d)

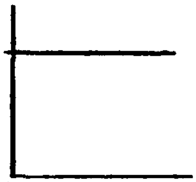

(e)

5. Which sketch most nearly represents the graph of S_i as a function of $1/S_o$?



(a)


(b)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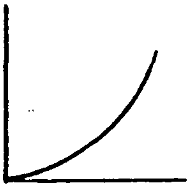
(d)


(e)

6. If the object is between the lens and the principal focus, which of the following is true? (a) The image is inverted and real. (b) The image is smaller and virtual. (c) The image is erect and real. (d) The image is larger and virtual. (e) The object and image are on opposite sides of the lens from each other.

7. Which is the correct formula? (a) $S_i S_o = f^2$ (b) $S_i^2 S_o = f$ (c) $S_i = S_o f^2$ (d) $S_i S_o = f$ (e) $S_i S_o^2 = f$

8. If an object 12 cm from the focal point of a lens forms an image on the opposite side of the lens 3 cm from the focal point, what is the focal length of the lens? (a) 2 cm (b) 4 cm (c) 6 cm (d) 36 cm (e) 108 cm

9. A real image formed by a convex lens is (a) always smaller than the object, (b) always larger than the object, (c) always on the side of the lens opposite the object, (d) always erect, (e) sometimes erect and sometimes inverted.

10. When an object is very far away from a convex lens, where is the image? (a) on the same side of the lens as the object, (b) an equal distance from the lens on the opposite side from the object, (c) on the surface of the lens, (d) at the focal point, (e) at the same place as the object.

APPENDIX C. ATTITUDINAL QUESTIONNAIRES

Directions. In this survey, we want to find out how you describe different things. There are no "right" or "wrong" answers. On each page in this booklet you will find a heading printed like this:

CHEMISTRY

The rest of the page contains pairs of words that you will use to describe your image of the heading at the top of the page. Each pair of words will be on a scale which looks like this:

QUICK 0 0 0 0 0 0 0 SLOW

You are to fill in the oval which best represents how you feel that word pair describes the heading at the top of the page. For example, you might mark the "QUICK-SLOW" scale this way for "CHEMISTRY".

If you feel that "CHEMISTRY" is very closely connected with "QUICK", mark the scale like this:

QUICK ● 0 0 0 0 0 0 SLOW

If you feel that "CHEMISTRY" is only somewhat connected with "QUICK", mark the scale like this:

QUICK 0 ● 0 0 0 0 0 SLOW

If you feel that "CHEMISTRY" is equally connected with "QUICK" and "SLOW", or not connected with either, mark the scale like this:

QUICK 0 0 0 ● 0 0 0 SLOW

If you feel that "CHEMISTRY" is somewhat connected with "SLOW" or very closely connected with "SLOW", you would mark one of the ovals next to "SLOW" just as above.

Look at the heading at the top of the page; get an impression of it in your mind, and then work down the page marking the scales as quickly as you can. We are interested in your first impressions, so work rapidly and do not go back and change any marks.

Be sure to check every scale and only make one mark on each scale.

PHYSICS

	7	6	5	4	3	2	1	
Important	0	0	0	0	0	0	0	Unimportant
Unproductive	0	0	0	0	0	0	0	Productive
Useful	0	0	0	0	0	0	0	Useless
Successful	0	0	0	0	0	0	0	Unsuccessful
Bad	0	0	0	0	0	0	0	Good
Comforting	0	0	0	0	0	0	0	Threatening

	7	6	5	4	3	2	1	
Helpful	0	0	0	0	0	0	0	Obstructive
Clear	0	0	0	0	0	0	0	Hazy
Pleasurable	0	0	0	0	0	0	0	Painful
Cluttered	0	0	0	0	0	0	0	Orderly
Predictable	0	0	0	0	0	0	0	Unpredictable
Complex	0	0	0	0	0	0	0	Simple

	7	6	5	4	3	2	1	
Reliable	0	0	0	0	0	0	0	Unreliable
Difficult	0	0	0	0	0	0	0	Easy
Wasteful	0	0	0	0	0	0	0	Saving
Educational	0	0	0	0	0	0	0	Mystifying
Dependable	0	0	0	0	0	0	0	Undependable
Dull	0	0	0	0	0	0	0	Interesting

CHEMISTRY

	7	6	5	4	3	2	1	
Important	0	0	0	0	0	0	0	Unimportant
Unproductive	0	0	0	0	0	0	0	Productive
Useful	0	0	0	0	0	0	0	Useless
Successful	0	0	0	0	0	0	0	Unsuccessful
Bad	0	0	0	0	0	0	0	Good
Comforting	0	0	0	0	0	0	0	Threatening

	7	6	5	4	3	2	1	
Helpful	0	0	0	0	0	0	0	Obstructive
Clear	0	0	0	0	0	0	0	Hazy
Pleasurable	0	0	0	0	0	0	0	Painful
Cluttered	0	0	0	0	0	0	0	Orderly
Predictable	0	0	0	0	0	0	0	Unpredictable
Complex	0	0	0	0	0	0	0	Simple

	7	6	5	4	3	2	1	
Reliable	0	0	0	0	0	0	0	Unreliable
Difficult	0	0	0	0	0	0	0	Easy
Wasteful	0	0	0	0	0	0	0	Saving
Educational	0	0	0	0	0	0	0	Mystifying
Dependable	0	0	0	0	0	0	0	Undependable
Dull	0	0	0	0	0	0	0	Interesting

LABORATORY WORK

	7	6	5	4	3	2	1	
Important	0	0	0	0	0	0	0	Unimportant
Unproductive	0	0	0	0	0	0	0	Productive
Useful	0	0	0	0	0	0	0	Useless
Successful	0	0	0	0	0	0	0	Unsuccessful
Bad	0	0	0	0	0	0	0	Good
Comforting	0	0	0	0	0	0	0	Threatening

	7	6	5	4	3	2	1	
Helpful	0	0	0	0	0	0	0	Obstructive
Clear	0	0	0	0	0	0	0	Hazy
Pleasurable	0	0	0	0	0	0	0	Painful
Cluttered	0	0	0	0	0	0	0	Orderly
Predictable	0	0	0	0	0	0	0	Unpredictable
Complex	0	0	0	0	0	0	0	Simple

	7	6	5	4	3	2	1	
Reliable	0	0	0	0	0	0	0	Unreliable
Difficult	0	0	0	0	0	0	0	Easy
Wasteful	0	0	0	0	0	0	0	Saving
Educational	0	0	0	0	0	0	0	Mystifying
Dependable	0	0	0	0	0	0	0	Undependable
Dull	0	0	0	0	0	0	0	Interesting

THE COMPUTER AS A LABORATORY AID

	7	6	5	4	3	2	1	
Important	0	0	0	0	0	0	0	Unimportant
Unproductive	0	0	0	0	0	0	0	Productive
Useful	0	0	0	0	0	0	0	Useless
Successful	0	0	0	0	0	0	0	Unsuccessful
Bad	0	0	0	0	0	0	0	Good
Comforting	0	0	0	0	0	0	0	Threatening

	7	6	5	4	3	2	1	
Helpful	0	0	0	0	0	0	0	Obstructive
Clear	0	0	0	0	0	0	0	Hazy
Pleasurable	0	0	0	0	0	0	0	Painful
Cluttered	0	0	0	0	0	0	0	Orderly
Predictable	0	0	0	0	0	0	0	Unpredictable
Complex	0	0	0	0	0	0	0	Simple

	7	6	5	4	3	2	1	
Reliable	0	0	0	0	0	0	0	Unreliable
Difficult	0	0	0	0	0	0	0	Easy
Wasteful	0	0	0	0	0	0	0	Saving
Educational	0	0	0	0	0	0	0	Mystifying
Dependable	0	0	0	0	0	0	0	Undependable
Dull	0	0	0	0	0	0	0	Interesting

Directions. This is *not* an examination; it is part of a project to study the attitudes of students toward using a computer terminal. *No* results will be used in *any way* that will affect your grade in this or in any other course. We are interested in your feelings or opinion about each statement.

After you have read each statement, please circle the "A" (agree) if you agree with the statement or the "D" (disagree) if you disagree with the statement. Once you have made this decision, please indicate how strongly you agree or disagree with the statements by circling one of the numbers which appears to the right of each statement.

For example, consider the statement

		slight	strong
	A		
All men are created equal.		1 2 3 4 5	
	D		

Do you agree or disagree with this statement? Circle "A" ("D"). How strongly do you agree (disagree) with this statement? Circle the appropriate number.

Please be sure to circle both a number and a letter after each statement, *unless* you are *completely undecided* whether you agree or disagree with the statement. In that case, circle *both "A" and "D"*, but do not circle any of the numbers. This response indicates that you neither agree nor disagree with the statement.

There are *no right or wrong answers* to the statements. The answers which will be most helpful to this project are the ones which best *reflect your own feelings* about each of the statements. Thank you for your cooperation.

			slight			strong	
1.	It scares me to have to use a computer terminal.	A D	1	2	3	4	5
2.	The feeling I have toward using a computer terminal is a good feeling.	A D	1	2	3	4	5
3.	Using a computer terminal can be made understandable to almost every high school student.	A D	1	2	3	4	5
4.	I can't see where computer terminals will ever help me.	A D	1	2	3	4	5
5.	I don't think I can ever do well using a computer terminal.	A D	1	2	3	4	5
6.	Only people with very special talent can learn to use a computer terminal.	A D	1	2	3	4	5
7.	Using a computer terminal is fascinating and fun.	A D	1	2	3	4	5
8.	I feel a sense of insecurity when attempting to use a computer terminal.	A D	1	2	3	4	5
9.	I feel at ease using a computer terminal.	A D	1	2	3	4	5
10.	Using a computer terminal is something which I enjoy a great deal.	A D	1	2	3	4	5
11.	I do not like using a computer terminal.	A D	1	2	3	4	5
12.	When I hear the words "computer terminal", I have a feeling of dislike.	A D	1	2	3	4	5

		slight strong
13.	Using a computer terminal makes me feel secure.	A 1 2 3 4 5 D
14.	Using a computer terminal is stimulating.	A 1 2 3 4 5 D
15.	Very vew people can learn to use a computer terminal.	A 1 2 3 4 5 D
16.	It makes me nervous to even think about having to use a computer terminal.	A 1 2 3 4 5 D
17.	Using a computer terminal is enjoyable.	A 1 2 3 4 5 D
18.	I approach using a computer terminal with a feeling of hesitation - hesitation from a fear of not knowing what I should do to operate it.	A 1 2 3 4 5 D
19.	I really like using a computer terminal.	A 1 2 3 4 5 D
20.	I hope I am not required to use a computer terminal in the future.	A 1 2 3 4 5 D
21.	Using a computer terminal makes me feel uncomfortable, restless, irritable, and impatient.	A 1 2 3 4 5 D
22.	Any person of average intelligence can learn to understand a good deal about how to use a computer terminal.	A 1 2 3 4 5 D
23.	I would like to use a computer terminal whether or not it is required.	A 1 2 3 4 5 D
24.	Using a computer terminal makes me feel as though I'm lost in a jungle of numbers and can't find my way out.	A 1 2 3 4 5 D

	slight strong
25. Almost anyone can learn to use a computer terminal if he is willing to try.	A 1 2 3 4 5 D
26. Using a computer terminal is very interesting to me.	A 1 2 3 4 5 D
27. The laboratory quizzes helped me to understand the experiment.	A 1 2 3 4 5 D
28. I wish I had been in the other group during the study of computer simulated experiments.	A 1 2 3 4 5 D