Computer-Assisted Instruction in Teaching College Physics

Hsi-chiu Liu
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COMPUTER-ASSISTED INSTRUCTION
IN TEACHING
COLLEGE PHYSICS

by

Hsi-chiu Liu

A Dissertation
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
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This dissertation is dedicated to my wife Grace, for her love, encouragement and patience during the years of my study.

Hsi-chiu Liu

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CHAPTER I

INTRODUCTION

The computer is fast becoming an important tool in teaching at all levels of education and for almost all subjects. Its importance is based on its potential for meeting the requirements of individualized instruction that currently is one of the major emphases in education.

The potential of computers in teaching results from three rather recent developments. The first is time-sharing capabilities that permit a single central computer to serve a large number of relatively inexpensive typewriter terminals connected with ordinary telephone lines. The second is the simplification of programming that permits a teacher or student to make effective use of a computer without devoting time to studying nonessential details. The third is programmed instruction that permits a student to learn at his own pace.

The computer can serve many purposes in education, including the scheduling of classes and classrooms and the performance of other routine administrative record-keeping. But, the development of greatest potential for using the computer in education is probably computer-assisted instruction (CAI), because it is directly involved in the teaching and learning process.

CAI has been claimed, in terms of its potential in education, to have an impact comparable to or even greater than Gutenberg's invention of the printing press in the 1450's. The printing press...
made mass education possible by recording knowledge for economical dissemination. However, the products of the printing process such as books, as well as films, radio, audio systems, and television, have a major common deficiency. None responds to the communication problem on an individualized basis.

Although programmed instruction and language laboratories have taken the first step in the direction of individualized instruction, in general they allow the student only to proceed at a fixed rate of learning. Every student takes the same program and goes through the same steps and repetitive procedures whether he is a fast or slow learner. CAI, on the other hand, is potentially capable of optimally individualizing instruction when an appropriate combination of multimedia is used in the system. Extensive research has been undertaken during the past decade on CAI languages and the development of different types of computer programs to implement these combinations.

Margolin has dealt extensively with the application of computer technology in CAI. He discussed techniques used in programming CAI lessons and described various uses of the computer in classrooms prior to 1970. As a result of his work, Stolow classified computer usage into six modes, namely (1) problem solving, (2) drill and practice, (3) inquiry, (4) simulation and gaming, (5) tutorial instruction, and (6) author mode. Levien and Mosmann classified computer usage into three modes, namely (1) performance uses, (2) management uses, and (3) comprehensive uses. Based on these modes of computer use, Suppes classified CAI development into three levels in terms of the implemen-
tation of individualized instruction. At the first level there are individualized drill-and-practice systems that are designed to supplement the regular curriculum. The role of the computer is to provide regular review and practice on basic concepts and skills. At the second level are tutorial systems that assume the main responsibility for presenting a concept and for developing skills in its use. At the third level are dialogue systems aimed at permitting the student to conduct a genuine dialogue with the computer. The student can input free-form questions and statements that are analyzed by the computer. These questions and statements are understood in the sense that the computer composes and displays appropriate replies. Much effort and talent are being devoted to developing the latter, although implementation is still in the embryonic stage.

The work with CAI was pioneered in the early 1960's at Stanford University by Atkinson and Wilson who first used drill-and-practice and tutorial modes in teaching elementary mathematics and beginning reading. Since then more than two dozen CAI languages have been developed and CAI programs written for many subjects at different levels. Hoye and Wang edited an index of the CAI programs developed through September 1973. These early efforts stimulated this investigator to attack two problems that exist in teaching introductory general physics at Western Michigan University and that may exist at many other universities or colleges as well.

The first problem concerns the student in a large class who needs instructional help beyond that provided in the classroom. A class in
introductory general physics at Western Michigan University usually consists of from sixty (60) to one hundred and ten (110) students requiring a non-calculus physics course. This student-teacher ratio does not enable a student to have much personal contact with his instructor. Hence, students need extra help from other courses.

The second problem concerns the student who needs drill and practice in solving physics problems, particularly those involving mathematics. Although the students' basic skills in mathematics may be adequate, the students still need drill and practice. It is common knowledge that many failures in the course in introductory college physics result not from the inability of the students to understand the concepts, but because of their inability to use mathematics as a tool in solving problems. CAI seems to be a useful technique for effectively supplementing the teaching of introductory college physics in order to solve the problems just mentioned. In this study, a combined mode of CAI was used involving a slide projector and both drill-and-practice and tutorial modes. A series of relevant topics paralleling the regular classroom lectures in introductory college physics were selected and programmed on the computer for the students' individual study and problem-solving drills. The topics selected were those in the areas in which students usually have difficulties either in understanding the concept or in handling the problems.

In summary, the objective of this study in supplementing the teaching of introductory college physics with eight CAI lessons is threefold.
(1) **Individual-paced learning**

Although the coverage of these eight lessons is limited to a few topics, the student is provided with the opportunity to study those topics with which he is most likely to have difficulty. The study is based on his own needs and he works at his own speed.

(2) **Problem-solving ability**

In introductory college physics, there are areas in which students need more practice than in others. Consequently, in addition to the homework assignment, a series of extra problems were programmed into the CAI lessons to provide opportunity for additional practice. These helped develop problem-solving ability by drill and practice, and also served as self tests.

(3) **Interrelationship of topics**

Branching techniques were used in the preparation of the CAI lessons. Related subtopics were referred to and reviewed whenever needed along the main channel of the lesson. Additional elementary material was included in the subtopic areas and more detailed information was therefore made available. The student could then branch back to the main
channel and continue the lesson. At the completion of each lesson, all the related subtopics could be related to provide a more comprehensive understanding of the topics.

The CAI lessons of this project were written using LEARN, the instructional language, developed by VanderLugt in 1972 and described by Meagher. LEARN differs from other CAI languages in that it is programmed in the assembly language of the PDP-10 computer. This allows the CAI lessons to take full advantage of the time-sharing system. Some special features of LEARN were employed in preparing the CAI lessons such as frame-oriented presentation, generation of random numbers, error allowance, phonic permission, branching technique, evaluative technique, slide projector, and hint provision. The eight CAI lessons written for this project are from the areas of electricity, magnetism, optics, and modern physics. They were used by two classes of students in introductory general physics in two semesters during 1974 at Western Michigan University. Each lesson lasted about one hour. Students participated on a voluntary basis. There was about seventy percent participation both semesters.
CHAPTER II

THE DESIGN OF THE EXPERIMENT

The Two Phases of the Project

During the first phase of the research project, in the second half of the 1974 Winter Semester, four CAI lessons were used. During the second phase, in the first half of the 1974 Spring Session, another four CAI lessons were used. Since participation was on a voluntary basis, the entire body of students could be categorized into two groups, CAI and non-CAI. Thus, there was some possibility of evaluating the merits of the CAI lessons.

The procedure was about the same in both phases with one major exception. Students in the second phase had the option to study any additional CAI lessons that had been prepared for, and used in, the first phase.

The sizes of the two CAI groups differed, the Winter group being about three times as large as the Spring, because the enrollment in Physics 111 during the Spring Session was much less than that in the Winter Semester.

Participants in the Project

The participants in this project were students at Western Michigan University who enrolled in Physics 111, the second semester of the first-year course for students requiring non-calculus physics, taught
in both the Winter Semester 1974 and the Spring Session 1974 at Western Michigan University. Thirty-six of fifty-two students in the Winter group agreed to participate, thirty-one of whom completed all four CAI lessons. Fourteen of twenty-four students in the Spring group agreed to participate in the second phase, nine of whom completed all four lessons and two, one additional option lesson. The participation therefore was about seventy percent during both semesters. A five-point credit was awarded to the student for each CAI lesson completed. No credit was given to students who studied the option lessons in the Spring Session.

Equipment

Three computer stations were used for this project. At each station the equipment included either one model 33 teletype or one Tektronix 4010 terminal, one Kodak carrousel projector, one rear-view screen, one slide-projector interface, and one telephone.

CAI lessons were presented on the teletype or the Tektronix terminal that was connected to the PDP-10 computer by telephone. A slide projector was coupled to the teletype or the Tektronix terminal by an interface that was designed and built by VanderLugt and Parrish under the direction of Dr. John Herman. The configuration of the equipment made it possible for three students to study a CAI lesson simultaneously.

Orientation Lesson

Before the project was implemented, a letter from the investigator
was sent to all the students who had enrolled in Physics 111 for the 1974 Winter Semester, briefly explaining the nature of the project. (See Appendix A). Enclosed with this letter was a simplified manual explaining how to use the teletype, although no previous experience with computers was required. (See Appendix B)

An orientation lesson was used with those students who had no previous experience with computers. (See Appendix C) This lesson contained a brief sample of a CAI lesson showing the students the normal procedure for responding to a question or problem, setting up a slide projector, requesting a hint, or using the calculation mode at the terminal.

CAI Lessons

The programming of CAI lessons takes time and patience, each lesson requiring revision many times before it was deemed acceptable. The first step in developing a lesson involved a thorough examination of the textbook used in Physics 111, Principles of Physics by F. 10 Bueche. A more recent publication, Physics by Arthur Beiser 11, was used in the second phase. The chapters containing the concepts or calculations with which students usually have difficulty were selected for the study. These involved four areas for both the Winter and Spring. The titles of the lessons in these eight areas are listed below, the first four being used in the Winter. All eight are included in Appendix C.

Lesson 1: Mirrors and Lenses
Lesson 2: Interference and Diffraction of Light
Lesson 3: Photoelectric Effect and Particle Waves
Lesson 4: Bohr's Atom and Atomic Spectra
Lesson 5: Coulomb's Law and Electric Fields
Lesson 6: Ohm's Law and DC Circuits
Lesson 7: Magnetic Fields and Magnetic Forces
Lesson 8: Electromagnetic Induction

The investigator worked with the instructor in determining the contents of the areas to be covered in the lessons. Prior to writing a lesson, the objectives for that lesson were spelled out explicitly. Based on these objectives, the specific content was arranged in an appropriate order for presentation and compiled into frames. Each lesson consisted of about thirty frames and required about one hour to complete.

A programmed lesson consisted of multiple-choice items, numerical problems, and word-response type items.

Three types of frames were used in writing CAI lessons:

(1) The question frame includes questions or presents information statements. In each question frame, hints and comments for common incorrect responses were entered in the proper positions. Each time a student gave an incorrect response, he was given a hint or comment that usually indicated why the response was incorrect, and the student was asked to try again. Each question frame usually provided
several opportunities to correct the incorrect responses. If the correct answer was not elicited after several trials, the student was supplied with the correct answer and some appropriate explanations.

(2) The review frame permits the student to re-examine some of the important elements of frames that have been presented. In some lessons, the review was a slide on which the critical information or key formulas were summarized. Such slides appeared for all the frames for which the information or formulas were needed.

(3) In the calculation frames, random numbers were generated so that students had different data in the numerical problems. This was a safeguard against students copying correct answers from others who had run the same lesson earlier. A range of error allowance was established for the numerical problems in the calculation frames. Slide rule or pencil-paper calculations could also be used in problem solving in addition to the calculation mode provided by the computer. If the response to a numerical problem was within
three percent of the correct answer, the computer would accept it as correct.

As already mentioned in Chapter L, the branching technique was used commonly in writing the CAI lessons. A superior student usually identified and passed over those remedial frames for which some detailed information or illustration was needed by the average students. With some lessons, students received a set of relevant questions or problems prior to the lesson. If a student achieved a satisfactory score in responding to these questions or problems, he could "skip" frames related to these questions or problems, thus shortening the time involved with the lesson. In general, the more competent the student, the fewer frames covered. On the other hand, the less able students covered more frames and received more detailed information, hopefully building up their basic capabilities. This remedial function is a basic feature of this project. The CAI lessons are also capable of accepting word and phrase answers that have similar grammatical structure to the correct answer but have minor misspellings.

As a special feature, LEARN has the capability of controlling a slide projector in projecting graphical or photographic information at the proper time. This is accomplished with an interface that couples the projector to the teletype. Ten to fifteen slides were controlled in this way by the computer in each lesson. They were part of each lesson and appear in Appendix C.
Data Collection

Data were collected from four separate sources. The first source was the comments given by students immediately after they finished each CAI lesson. (See Appendix D) These included the reactions of the students to the individual lessons as well as to the project as a whole. The second was responses to the items on the questionnaire that contained specific questions about the project and which was administered to the students immediately after finishing all four lessons in each phase. A copy of the questionnaire appears in Appendix E. Students who completed the questionnaire were awarded five points of extra credit. The third source was the scores on the classroom tests prepared by the course instructor. These were administered every two weeks in the Winter Semester and once every week in the Spring. The CAI lesson covering the material with which the classroom test dealt was scheduled during the week prior to the test. Therefore, these scores revealed some information about the influence of CAI lessons on student achievement. (See Appendix F) The fourth source was the error percentage recorded in studying the CAI lessons. This error percentage was derived from the ratio of the total number of incorrect responses to the total number of correct and incorrect responses the student gave in studying all the CAI lessons in each phase. This error percentage together with the average time of studying a lesson represented, in a general sense, the performance of a student in using the CAI lessons. These two items of information were included in the Student Report. (See Appendix I)
Performance Report

The contents of the three types of LEARN's performance file are as follows:

Lesson Report

The Lesson Report consists of two forms, the Summary Form and the Complete Form. (See Appendix G) The items on the Summary Form are included in the Complete Form that contains the following:

(1) General information:
   Lesson: Title of lesson
   Date: Date of report
   Time: Time of report
   Last update: Last date and time the master record file was updated.
   Date range: A range of dates to be covered by the Report as requested by the investigator.
   Students: A range of students' programmer numbers to be covered by the Report as requested by the investigator.
   Frame range: A range of frame numbers to be covered by the Report as requested by the investigator.

(2) Information by individual student:
   Student: Programmer number of student
   Date: Date the lesson was studied
S. time: Time the lesson was studied
E. time: Total elapsed time for studying the lesson.
A. time: Answering time (E. time less typing time).
Right: Number of correct answers
Wrong: Number of incorrect answers
Neutral: Number of neutral answers
Time up: Number of times student took too long to respond.
Frames: Number of frames student completed (Equal to total number of responses)
CPU time: Central processing unit time.

(3) Summary information for all students who studied the lesson.
Number of times lesson was executed
Average elapsed time
Average total answering time
Average CPU time
Total number of responses
Total number of correct responses
Total number of incorrect responses
Total number of neutral responses
Total number of time ups
Average error rate

(4) Information by individual frame:
Frame number
Frame type
Number of times frame was executed
Number of times calculation mode was used
Average answering time
Total number of correct responses
Total number of incorrect responses
Total number of neutral responses
Total number of time ups
Error rate
Response distributions (subtotal of each type of responses)

From the above list, it can be seen that the Lesson Report summarizes student performance and the general information about each frame in the lesson. The common procedure was to prepare a printout when all students had finished each CAI lesson. The Summary Form of this Report that consists of items (1) through (3) as listed above was always posted in the laboratory for student reference, and the Complete Form of this Report was retained for modifying the lesson.

Answer Report

The Answer Report records all the responses made by all the students for each CAI lesson and was used for modifying lessons. (See Appendix H) The common procedure was to prepare a printout when a lesson had been completed by all students. The Report includes the following:
Students: A range of students' programmer numbers to be covered by the Report as requested by the investigator.

Frames: A range of frame numbers to be covered by the Report as requested by the investigator.

FM: Frame number

Student: Programmer number of individual student.

Tag: Code of response such as the use of letter, number, or question mark to represent a particular answer programmed in the lesson, and the use of positive sign (+), negative (-), or zero (0) to indicate a correct, incorrect or neutral answer respectively.

Answer: Students' responses.

**Student Report**

The Student Report lists the data for each individual student and was used to evaluate the overall performance of each student at the end of each phase. (See Appendix I) It contains the following:

1. **General Information:**
   - Students: The range of students' programmer numbers covered by the Report.
   - Date: Date of report
   - Time: Time of report
   - Last update: Last date and time the master record
file was updated.

Date range: The range of dates covered by the Report.

(2) Information by individual student:

Student: Programmer number of student.
Lesson: Title of lesson.
Date: Date the lesson was executed.
E. time: Total elapsed time for studying the lesson.
A. time: Answering time (E. time less typing time).
Right: Number of correct answers.
Wrong: Number of incorrect answers.
Neutral: Number of neutral answers.
Time up: Number of times student took too long to respond.

Total number of lessons executed
Total elapsed time for all lessons studied
Average error rate

Modification of CAI Lessons

CAI lessons were modified when the two phases of this project were completed. The following information was used for modifying the eight lessons:

(1) Laboratory log book:

The investigator was with the students all the
time they studied the CAI lessons. Any deficiencies found in any lessons were immediately recorded in the laboratory log book.

(2) Student comments:

Most students commented on the lesson they had studied.

(3) Answer Report:

In the Answer Report, the author examined all the responses to all the frames and discovered that some of the same incorrect responses were made by many of the students. These incorrect responses were then included in the lessons as the expected wrong answers. Proper hints or comments were then developed for these expected wrong answers.

(4) Questionnaire:

The completed questionnaire was useful in lesson modification, although most of the comments on the questionnaire were about the project as a whole.
CHAPTER III

DATA ANALYSIS

Introduction

The data analysis for this research project was based on the student comments made immediately after the student studied each lesson, and on the responses to the questionnaires completed at the end of each phase by those students who finished all CAI lessons. An analysis of covariance was computed using the scores of achievement tests administered by the instructor from the Winter phase only because these test scores, obtained in the period when CAI treatment was administered, could be used as variables, and those scores obtained before the CAI treatment was administered could be used as a covariate.

Student Comments

Comments were summarized in five categories in order to answer the following five basic research questions:

1. What purposes could this project serve?
2. How well were the CAI lessons prepared?
3. How did the students view this project?
4. What criticisms did the students make about this project?
5. What suggestions did the students make for improvement?
What purposes could this project serve?

(1) Practice:
Each lesson provided the students with opportunities to solve additional problems. These enabled the students to apply their understanding of concepts of physics to problems in new situations. After the first few lessons, some students indicated that they could solve most of the problems at the end of the chapter. It was evident that the CAI lessons helped the students improve their problem-solving abilities by additional practice.

(2) Review:
Each lesson helped the students review the material covered in the classroom, particularly the main points in the chapters. The lessons also served to clarify topics that were not clear to the students. Students often said in the laboratory that they used the computer listings from each lesson as a guide for preparing for a test. It seemed evident that CAI lessons helped the students discover what they needed to study for a test.

(3) Remedial:
CAI lessons helped students clarify ambigu-
ties that appeared in the textbook. Some lessons helped the students cover topics that they either missed when absent or misunderstood completely during the classroom presentation. A comment made by some students was that they liked the way the material was presented with the computer.

(4) Tutorial:

The tutorial purposes were achieved mainly with slides and the presentation of typical problems. For tutorial purposes, a CAI lesson seemed to be time consuming and difficult for those students who had not read the assigned chapters. However, the lessons enabled students to understand the ideas, concepts, and relationships even with little knowledge when they entered the computer stations in the laboratory. Such comments were made frequently after they finished the CAI lesson.

(5) Self test:

The CAI lessons helped students evaluate their mastery of certain topics. In addition to identifying weak points, the lessons also enabled them to identify the mistakes they commonly made.
(6) Self confidence:

After students developed their problem-solving abilities through practice problems, they were willing to face more challenging problems. They could solve problems they thought they could not do. This increased their favorable attitudes toward physics.

How well were the CAI lessons prepared?

The student comments concerning the programming of the eight lessons are summarized below:

(1) A useful feature of the CAI lessons was the suggestions as to how to proceed after receiving the first "incorrect" notification. Following this notification, the hint gave ideas about where to check for error.

(2) The programmed material was not too difficult to follow even though the material was not read in advance.

(3) The lesson presented the material in a simple way that was understandable and then applied it to more complex problems.

(4) The lesson presented much information in a complete and informative way.

(5) Sometimes the lessons were "tough" but "fun, interesting and helpful."
(6) The lessons were sometimes presented in unique ways that were demanding in terms of the attention they required but they seemed to accomplish their objectives.

(7) The problems were well selected. Usually if they were at the end of a lesson, they helped develop the concepts that were formulated earlier.

(8) The explanations in the lessons were in some cases clearer than those given in class. They frequently clarified much of what was unclear in the textbook.

(9) The formulas on the slides were more effectively presented than in the textbook.

(10) The lessons helped simplify the explanations in the textbook.

(11) The CAI lessons presented various questions that were relevant to what was being studied.

(12) The degree of difficulty within the CAI lessons were appropriate. They contained both easy and difficult questions and were brief and to the point.

(13) The conciseness of the text on the slides was appreciated. It was desirable that copies of these slides could be made.

**How did the students view this project?**
The views of the students concerning the total project are summarized below:

(1) The computer session was more beneficial than the lecture, if the material being studied was read in advance.

(2) It was an effective way to learn material that appeared in the textbook. It seemed easier and more interesting to learn with the computer.

(3) The programmed lessons gave rise to additional incentive to study physics.

(4) Reasoning abilities were developed when the lessons were studied.

(5) This project met the needs in studying Physics 11, and it helped improve achievement grades.

What criticisms did the students make about this project?

The student's criticisms are summarized below:

(1) Some lessons were lengthy. It was indicated that a CAI lesson should not take longer than one hour to complete.

(2) One of the lessons was extremely difficult. Many of the questions could not have been answered correctly without having done the assigned reading thoroughly.

(3) One of the lessons was more like a test than
programmed instruction.

(4) Some formulas were in different forms from those in the textbook and consequently caused confusion.

(5) Some lessons were not easy to understand.

(6) Some of the problems were lengthy.

(7) There was no computer listings for later studies, when a Tektronix terminal was used to study CAI lessons.

What suggestions did the students make for improvement?

A summary of the suggestions made by the students concerning the preparation of the lessons and the entire project appears below:

(1) The CAI lessons should be instituted in other classes, especially in Physics 110, the first-semester of the first-year course in college physics.

(2) CAI lessons should be increased in number to cover more chapters so that students would have choices for study. One lesson should be written for each week of class.

(3) CAI lessons should be self explanatory to eliminate the need to read the material in textbooks or to receive personal assistance.

(4) Formulas should be presented prior to solving problems.
(5) Formulas in CAI lessons should be presented in the same format as in the textbook.

(6) The material covered in a CAI lesson should be read in the textbook before studying it on the computer.

(7) Typed listings of the CAI sessions should always be available for review before the tests.

(8) The amount of deviation from the correct numerical answer equivalent to slide rule accuracy should be accepted by the computer.

Questionnaire

The questionnaire sought four types of information. The first twenty statements dealt with the evaluation of the eight CAI lessons prepared for this project and their implementation. Students were required to rate these statements using "Strongly Agree", "Agree", "Neutral", "Disagree", and "Strongly Disagree". A copy of the questionnaire is shown in Appendix E. The second section sought the opinions of students in modifying CAI lessons. The third section sought the opinions of students about the topics that should be programmed into CAI lessons in supplementing the teaching of Physics 111. The fourth section consisted of general unstructured comments.

Thirty questionnaires were completed in the first phase and nine in the second. The results, based on the responses on all the questionnaires, are summarized on the following pages:
The twenty statements

The scale used to weight the responses to the twenty statements was as follows:

2 points for "Strongly Agree"
1 point for "Agree"
0 point for "Neutral"
-1 point for "Disagree"
-2 points for "Strongly Disagree"

The average of the ratings for each statement was calculated and appear in Table I on page 29.

A comparison of the ratings on both phases of the project appears in Figure 1 on page 30. The solid lines represent the average scores for phase 1 in the Winter and the broken lines for phase 2 in the Spring. An examination of the plot indicates substantial agreement between the ratings. One exception is statement fifteen that says, "I used calculation mode a lot." The higher rating for this statement in phase 2 may be due to the emphasis on the use of calculation mode in the orientation lesson at the beginning of the second phase. The second exception in phase 2— the higher rating for statement ten "The hints provided after a wrong answer helped me figure out the right answer"—may result from the fact that hint was programmed into the lesson for each question or problem in the second phase.

The eight more positive student responses to the project are listed below in decreasing order of rating scores:
**Table I**

Average Scores in Rating the Twenty Statements in the Questionnaire

<table>
<thead>
<tr>
<th>Statement No.</th>
<th>Average score</th>
<th>Winter</th>
<th>Spring</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>1.033</td>
<td>1.333</td>
<td>1.102</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>1.600</td>
<td>1.444</td>
<td>1.564</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>1.467</td>
<td>1.333</td>
<td>1.436</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>1.367</td>
<td>1.333</td>
<td>1.359</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>1.333</td>
<td>1.556</td>
<td>1.384</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>0.867</td>
<td>1.222</td>
<td>0.949</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>1.200</td>
<td>1.444</td>
<td>1.256</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>1.400</td>
<td>1.333</td>
<td>1.385</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>1.233</td>
<td>1.000</td>
<td>1.179</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>0.933</td>
<td>1.333</td>
<td>1.025</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>1.067</td>
<td>1.376</td>
<td>1.138</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>0.867</td>
<td>0.778</td>
<td>0.846</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>1.133</td>
<td>1.000</td>
<td>1.102</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>1.300</td>
<td>1.125</td>
<td>1.260</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>0.167</td>
<td>1.889</td>
<td>0.564</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>1.133</td>
<td>1.000</td>
<td>1.102</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>0.933</td>
<td>0.875</td>
<td>0.920</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>1.333</td>
<td>1.500</td>
<td>1.372</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>0.600</td>
<td>0.500</td>
<td>0.577</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>0.767</td>
<td>0.875</td>
<td>0.792</td>
</tr>
</tbody>
</table>
Figure 1. The average rating of questionnaire statements.
No. 2: The lesson materials are well organized.
No. 3: The lessons achieved the objectives set up at the beginning of each lesson.
No. 8: The lessons helped me review the important concepts in the related chapters.
No. 5: The lessons can be used for drill and practice purposes.
No. 18: A lesson should be studied after the programmed material has been covered in lecture.
No. 4: The lessons are useful for tutorial purposes.
No. 14: The orientation lesson is helpful in instructing how to get on teletype terminals.
No. 7: The lessons can be used for self-test purposes.

The six statements that received the lowest ratings are listed in increasing order of the rating they received:

No. 15: I used calculation mode a lot.
No. 19: "8" is about the right number of lessons in supplementing the teaching of the course Physics 111.
No. 20: I did understand a frame of presentation before I moved on to the next.
No. 12: The lessons correlated subtopics around major topics.
No. 17: The lessons do cover the areas where students
usually have difficulties.

No. 6: The lessons can be used for remedial purposes.

The suggestions in modifying lessons

The suggestions from students for modifying the lessons are summarized below:

Lesson 1:

(1) Make sure that equations have been understood before attempting this lesson.
(2) Go into more depth about the subtopics under major topics dealing with mirrors and lenses.
(3) Exclude the portion on double lens as this will not be covered on the test as stated by the instructor.
(4) Cut it short or divide it into two lessons.

Lesson 2:

(1) Add more problems and include more emphasis on interference.
(2) Include a discussion on why diffraction takes place and derive the equations.
(3) The problems encountered should have been more detailed.
(4) Explain more clearly how to do the problems.

Lesson 3:

(1) Have more material on particle waves.
(2) Be more specific on equations and their derivations.
(3) Have more slides and problems.
(4) Present concepts more clearly.

(5) Put in more theory, definitions and explanations to give a better working knowledge of this material.

Lesson 4: (Last lesson studied in phase 1)

(1) Do more on ionization, proton collision, energy level, Balmer formula and the units of energy and electric charge.

(2) Use the same symbols as in the textbook.

(3) The last lesson should be short, to the point, with no extra frills.

Lesson 5: (First lesson studied in phase 2)

(1) Have more problems but omit some definitions.

(2) Clarify the procedure since it is the first lesson.

Lesson 6: Extremely difficult problem should have a hint at the end of the problem.

Lesson 7:

(1) Have more emphasis on finding the directions of magnetic fields.

(2) Make it clear that there are unwritten formulas for doing the problems in this lesson.

Lesson 8:

(1) Add more definitions and practice problems.

(2) Have a couple more explanatory slides.

There were fewer suggestions for modifying the second group of CAI
lessons (Lessons 5-8), probably because the suggestions made on the first group (Lessons 1-4) were used in writing or modifying those for the second phase.

The above suggestions may be summarized as follows:

1. The first lesson should be kept easy and short, since students are not familiar with procedures for studying programmed lessons on a computer.

2. A lesson should cover a limited topical area in which all the important concepts should be introduced in detail with several practice problems.

3. Greater numbers of explanatory slides need to be used with the first lesson than with those that follow.

4. A hint should be included in every comment on incorrect responses.

5. The symbols used in the lesson should be the same as in the textbook within the limitation of letters and symbols on the teletype keyboard.

6. All lessons should indicate concisely how to proceed from one frame to the next.

Topics that should be covered with CAI lessons

The responses to the questionnaire indicated that students thought that the following topics should be programmed into CAI lessons for Physics 111.

Electricity:
Electric fields and Coulomb's law

Electric potentials

DC circuits and Ohm's law

Power and work

Capacitance, capacitive reactance, and impedance

LC and LCR circuits

AC generator and AC circuits

Transformers and measuring instrument (voltmeter, ammeter and galvanometer)

Wheatstone bridge

Inductors and transistors

Magnetism:

Geographic magnetic fields

Ampere's law

Mass of electron, proton and other charged particles

Solenoid and toroid

Electromagnetic induction and electromagnetic waves

Motors and DC generators

Optics:

Mirrors, lenses, combination of mirror and lens, and lenses in contact

Human eye and cameras

Reflection and refraction of light

Prism and prism spectrometer

Compound-lens systems (telescope, microscope and binoculars)
Diffraction and interference of light
Grating spectrometer and thin film interference
Polarized light

Modern physics:
Photoelectric effect
Compton effect
Atomic models and Bohr's atom
Energy level and ionization
Nuclear reaction
Wave mechanics
Laser
X-rays and x-ray diffraction
Solar energy

Other comments

The following general comments appeared on the questionnaire. Those that overlapped with comments previously mentioned are not included.

(1) This project was a very good supplement to the lecture, but it never would be a complete substitute for a teacher.

(2) One student said, "It would be good to have these lessons as study guides throughout the semester. It helped me out tremendously. For those topics studied using CAI my test average was 95.5."

(3) In general, a CAI lesson should be a supplemental half-hour project. Perhaps it should be shortened to cover
the more difficult portions only, not the whole chapter.

(4) The computer is not very helpful for tutorial purposes. The student cannot ask the computer any questions.

(5) The consultant should not help the students so much but let students "blunder" on their own initiative.

(6) It would be more helpful, if possible, to have the material on the slides also reproduced on paper so students can refer to them in their assigned work.

(7) More multiple choice items should be added in all lessons but only allow three choices.

(8) Some students said, "These programs helped me a lot especially with problems in the chapters."

(9) Some others said, "These lessons were extremely helpful and improved my overall understanding."

(10) The lessons brought out all the main points of each chapter along with good example problems that encouraged the student to do more related problems.

Achievement Test Scores

Since participation was voluntary, it was agreed at the beginning of this study that an extensive statistical analysis of the quantitative data collected would probably not provide completely dependable results. However, an examination of the scores on the achievement tests administered in the first phase was thought to be useful.
First, the sample sizes of the two groups, CAI and non-CAI, of the Winter class as shown in Table II on page 39 are large enough for a statistical analysis of the test scores.

Second, the scores on the achievement test 1, 2 and 3 of the Winter class could be used to evaluate the degree of randomness of the voluntary assignment of students to the two groups since the CAI lessons were not used until after these tests were taken. (See Table III on page 39) In order to evaluate the degree of randomness, the averages of these three test scores were used to run a $t$-test in order to test the following null hypothesis:

Even though the two groups, CAI and non-CAI, are formed voluntarily, the average abilities of the two groups studying Physics 111 do not differ significantly before CAI treatment.

The statistical computation produced a $t$-score of 1.753 that was significant at the 0.086 level. Consequently the investigator could not accept or reject the above hypothesis because the usual criterion of significance at the 0.05 level was not met.

A second analysis was made with the achievement scores obtained in the Winter phase using an analysis of covariance. According to Winer\textsuperscript{12}, the analysis of covariance has two basic functions. It helps to (1) increase the validity of the results when a random sampling is used, and (2) remove potential sources of bias when an experimenter can not assign individuals at random. The latter function fits the present project. Therefore, the average scores of the first
### Table II

The Two Groups in Physics 111

<table>
<thead>
<tr>
<th>Research phase</th>
<th>Winter class</th>
<th></th>
<th></th>
<th>Spring class</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CAI</td>
<td>Non-CAI</td>
<td></td>
<td>CAI</td>
<td>Non-CAI</td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>No. of lessons studied</td>
<td>Size</td>
<td>No. of lessons studied</td>
<td>Size</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
<td></td>
<td>1 2 3 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of students</td>
<td>36 32 0 31</td>
<td>17 14  2 9</td>
<td></td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Remarks: One student from another class of the same course participated in this project. Her name and the scores of achievement tests were not shown in Appendix F.

### Table III

Time Schedule of CAI Instruction and Achievement Tests

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CAI period</td>
<td></td>
<td>CAI</td>
<td></td>
<td></td>
<td></td>
<td>C</td>
<td>A</td>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td>Test No.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring</td>
<td>CAI period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CAI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test No.</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
three achievement tests were used as covariates in the analyses of covariance in order to test the following null hypothesis:

The average achievement of the two groups, CAI and non-CAI, in studying Physics 111 do not differ significantly after the CAI group has used CAI lessons in this project.

The results of computing the F-tests appear in Table IV on page 41. In the computation of the F-tests, the scores achieved by those students who studied CAI lessons but never completed all given lessons, and those who were assigned letter grade X as shown in Appendix F were excluded. For the rest of the students, the semester average was calculated by subtracting the laboratory score (and subtracting the twenty-five extra points, if it is a CAI student) from the semester total. In the analysis involving letter grades, the regular weighting was used, namely 4 for A, 3 for B, 2 for C, 1 for D, and 0 for E. The results of these analyses appear also in Table IV.

An examination of the results of the analysis indicates that the hypothesis is rejected for two of the variables, namely the semester average and semester letter grade. In other words, students who used the CAI lessons achieved better results in studying Physics 111 than those who did not.
Table IV

Results of the Analysis of Covariance with the Scores of Achievement Tests in the 1974 Winter Semester

<table>
<thead>
<tr>
<th>Analyzed Variable</th>
<th>F-Test Value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test No. 4</td>
<td>5.08</td>
<td>0.029</td>
</tr>
<tr>
<td>Test No. 5</td>
<td>3.13</td>
<td>0.084</td>
</tr>
<tr>
<td>Test No. 6</td>
<td>2.13</td>
<td>0.152</td>
</tr>
<tr>
<td>Test No. 7</td>
<td>3.12</td>
<td>0.084</td>
</tr>
<tr>
<td>Semester Average</td>
<td>7.96</td>
<td>0.007</td>
</tr>
<tr>
<td>Letter grade</td>
<td>10.10</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Error Rate and Studying Time

The error rate is the ratio of the number of incorrect responses to the number of total responses. The average error rate and the average period of time spent in studying one CAI lesson are shown in Table V on page 42. The fairly high error rate might indicate that students learn by trial-and-error. The average study time seemed to be too long. Perhaps CAI lessons should be shorter or made easier so that an average student could complete a lesson within one hour.
Table V

Average Error Rate and Time Consumed in Studying One CAI Lesson

<table>
<thead>
<tr>
<th>Item</th>
<th>Winter Semester</th>
<th>Spring Term</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error (%)</td>
<td>29</td>
<td>46</td>
<td>34</td>
</tr>
<tr>
<td>Time (min.)</td>
<td>65</td>
<td>70</td>
<td>67</td>
</tr>
</tbody>
</table>
CHAPTER IV
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

In this study, computer-assisted instruction (CAI) was used to supplement the teaching of introductory physics (Physics 111) in 1974 at Western Michigan University. Eight lessons were programmed for the PDP-10 time-sharing computer with a frame-oriented language (LEARN), each consisting of about thirty frames. Approximately one hour was required for an average student to complete a lesson. Four lessons were used in the 1974 Winter Semester and another four in the 1974 Spring Session. Thirty-six students participated on a voluntary basis in the Winter and fourteen in the Spring. This represented about seventy percent participation of all enrollees in the semester and session. As an incentive, five-points extra credit was awarded to the student for studying each lesson.

The objective of this project was to provide the student with an opportunity to improve his ability to solve physics problems through practice, and to understand better the principles and concepts of physics by tutorial and remedial processes. Another feature was that each student learned at his own rate. The content of the lessons was material from those chapters with which students usually have difficulties either in understanding the concepts or handling the problems of physics. Short comments and hints were programmed for every ques-
tion or problem. Branching techniques were used in adjusting procedures to account for individual differences in gaining understanding. Another feature was a slide projector that was controlled by the computer for presenting graphical illustrations and summary of formulas.

Three computer terminals were used. Every lesson was scheduled by the student a few days before the relevant test was administered so that test scores could be used as a basis for evaluating the effectiveness of the CAI lessons. Students were encouraged to make comments on the lessons they had just studied. A questionnaire was completed by students who completed all lessons for each semester or session. Student comments, the responses to the questionnaires, and the test scores provided by the instructor constituted the main source of the information for evaluating the success of the effort. In addition, the computer kept a record of the students' performance as they studied the lessons. This record helped the investigator revise the lessons.

Conclusions

The functions of this project

Four major functions of this project in supplementing the teaching of introductory general physics using computer-assisted instruction are listed below:

(1) The activity helped students improve their abilities in solving physics problems by means of practice.
(2) The activity helped students review important concepts and principles of physics.

(3) The activity helped students identify and remedy their weaknesses in certain areas of physics.

(4) The activity helped increase students' interest in studying physics.

The features of this project

This project had a number of features that seemed to facilitate learning. The frame-oriented presentation of materials enabled the student to learn at his own rate. The branching and evaluative techniques provided additional opportunities for dealing with individual differences in learning abilities. The programmed hints and comments led students to sequence their responses correctly with respect to questions and problems. The slides used to present graphical illustrations helped the students acquire insight of abstract concepts. The extensive feedback provided by the programming, whether positive or negative, reinforced learning. When the student failed to respond correctly after a number of trials, the provision of correct answers together with appropriate explanations further enhanced learning.

The accomplishments of this project

An analysis of student comments and the responses to the questionnaires indicated that students, in general, reacted positively to the project. The use of the computer proved to be an attraction. The more able students apparently studied the CAI lessons more care-
fully than the less able and therefore benefited more. According to
the responses, the objectives listed at the beginning of the lessons
were met. The result of the analysis of covariance with the scores
of achievement tests indicated that students who used the CAI lessons
achieved more than students who did not. In summary, the use of CAI
appeared to have value as a supplement to teaching Physics 111.

The limitations of this project

The computer language used in this project did not have the
capabilities for dealing with the dialogue mode of instruction.
Consequently, students could not address the computer with questions
in free forms. This limited the extent to which the tutorial purpose
could be accomplished with selected materials. It was impossible to
include all anticipated questions from every student in a single pro-
grammed lesson.

Another limitation was the breadth and depth of the lessons.
Out of the class period of fifty minutes, the typing time for the
teletype was about fifteen minutes. A Tektronix terminal could print
on the screen twice as fast as the teletype, but students did not
like the Tektronix terminal because it did not provide hard copy for
review purposes. With these limitations, only typical problems and
main concepts in the area could be programmed in a lesson.

Since only three projector interfaces were built for this project,
only three computer terminals were used. With this limitation, study
time had to be scheduled by appointment. This together with un-
scheduled downtime of the computer system caused some students who would otherwise have completed all the given CAI lessons to drop out of the project.

Since there were only seven and one-half weeks in the Spring Session, only eight CAI lessons were prepared. Students studied one lesson per week in the Spring. Eight lessons could not cover all the areas with which students usually have difficulties.

In general, lessons were not designed to replace the classroom instructor. They were limited to supplementing the teaching and relieving the instructor from some routine personal assistance to the students. Instead of this assistance, students were expected to solve their problems or clarify their concepts by means of the programmed lessons in the computer.

Recommendations

The design of a CAI project

Although at this stage of computer development CAI cannot replace the instructor, it may be expected to be useful to supplement the teaching of many subjects at college level. For this purpose, practice-and-drill, review, and remedial modes are recommended.

A CAI lesson should cover about one week of work but should not require more than fifty minutes for the average student to complete. The area covered by a single lesson should be sufficiently restricted to include fairly detailed information. For a CAI course, there
should be as many narrow-range lessons prepared as possible so that students can choose from among them according to their needs.

Apparently, the best time to study a CAI lesson is after the relevant topics have been discussed in the classroom and before a test on those topics is administered. Prereading of the material covered by the lesson is highly recommended.

An orientation lesson should be made available to the students prior to the start of a CAI project. This lesson should describe procedures for using a computer terminal, how to respond to questions, how to request hints, how to use the calculation mode, and how to log off the terminal.

**The equipment for a CAI project**

A time-sharing computer is obviously essential for a CAI project since many students can study the same lesson simultaneously.

The slide projector controlled by the computer worked fairly well in this project. However, a pamphlet in which the slide materials were reproduced as illustrations might serve equally well or even better for a CAI project. Students could refer at any time to any page when needed. Pamphlets cost less than slides, are easy to reproduce, and can be used readily without an interface.

It is fatiguing to read a computer printout continuously, especially when the typing ribbon has been used extensively and the print is light. If an audio tape and a TV screen are used and controlled by the computer, the student could then use both his eyes and ears in studying the lesson. These pieces of equipment are expensive, but
they would have advantages for a CAI project.

A Tektronix terminal has a much higher printing rate than the teletype. However, a shortcoming of a Tektronix terminal is that a printout is not available for review. If a program could be written to request such a printout from a line printer at the end of a lesson, the usefulness of a Tektronix terminal would be increased.

The programming of a CAI lesson

The first step in preparing CAI lessons is to determine the topics to be covered and the objectives of the lesson. Obviously this will involve the course instructor. Once the objectives have been established for a lesson, materials should be selected and programmed so as to achieve those objectives.

Before the student is asked to answer questions or to solve problems, adequate orientation including typical examples of problems should be presented. For a difficult problem, hints should be included in the problem text. A CAI lesson, so programmed, will serve as more than a programmed "test".

As many expected incorrect responses should be programmed in a lesson as possible because comments provided to accompany these incorrect responses can point out the student's mistakes. Through such corrective comments, CAI lessons can achieve tutorial purposes better, even though the student can not address the computer with questions.

Since the student is dealing with a machine in studying a CAI lesson, communication is a common problem. To reduce or eliminate
this problem, common words and short sentences should be used wherever possible. The first lesson should be easy and short, because the student is not yet accustomed to the procedures involved in studying a lesson on the computer. Extensive text material should be presented on paper or slides in order to reduce typing time, especially if a teletype is used.
APPENDIX A

THE INVESTIGATOR'S LETTER
TO STUDENTS OF PHYSICS 111

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Dear Student:

My name is Joe Liu, and I am a graduate student working on my doctorate degree in science education. As part of my research, 4 lessons have been prepared for computer-assisted instruction in the area of Physics 111. These lessons are designed to help you acquire a better understanding of physical concepts, develop a greater problem-solving ability, and correlate subtopics toward a more comprehensive knowledge of the course. Hopefully, therefore, these lessons will assist you to earn a better grade on each test.

Dr. Herman, your instructor, has agreed to allow me to use his class of Physics 111 to try out these 4 lessons in the 1974 Winter semester. In this semester, part of your assignment is to study these lessons. No previous experience with the computer is necessary. However, an orientation session will be made available in Room 2208, Rood Hall for those students who have never been exposed to the computer. The time for orientation will be announced in your classroom.

As an added incentive, Dr. Herman has also agreed to give you 5 points for each lesson you complete and 5 points for filling out the questionnaire that will be given to you as soon as you have just completed the 4 lessons. In order to get the 5 points for filling out the questionnaire, you must complete the 4 given lessons.

Each lesson will be studied prior to the test on its related unit. A schedule will be prepared for you to sign up for a convenient hour to study each lesson. A lesson takes about 1 hour to complete.

Finally, I would like to stress the fact that it is important that all of you participate in working on the lessons. At the end of each lesson, I would appreciate hearing any criticisms, suggestions, or any comments that you might have regarding any aspect of the lesson you have just studied. Thank you.

Very sincerely

Joe Liu

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APPENDIX B

A SIMPLIFIED MANUAL
OF HOW TO USE TELETYPING IN STUDYING CAI LESSONS
A SIMPLIFIED MANUAL
OF HOW TO USE TELETYPE IN STUDYING CAI LESSONS

NOTE: A more complete manual is programmed in a lesson named ORIENT that will be studied during orientation session.

I. How to get on the teletype?

1. Turn on the power to the teletype by turning the knob at the lower right of the panel to "LINE" position.

2. Pick up the telephone receiver and dial "36250 11". When a high pitch signal is heard, place the receiver on the coupler with the cord pointing away from you.

3. When the teletype terminates a message saying "PLEASE LOGIN", type "LOGIN".

4. After the teletype terminates another message by "#", type your project-programmer numbers separated by a comma.

5. Following "PASSWORD:" typed out by the teletype, type your password. This word will not appear on the paper.

6. If you have your numbers and password typed in correctly, you will be identified as a legitimate user of the computer. The teletype will then type out the message of the day and terminate it with a dot (.). You are now on the computer.

II. How to study a CAI lesson?

1. Once you are on the computer, type "R LEARN".

2. Following the message "ENTER COMMAND", type "GET X" where X represents the name of the lesson that you want to study.

3. From here on, respond to all kinds of questions asked by the computer. Do not walk away in the middle of a lesson. You have to finish the lesson once you have started it.

III. How to turn off the teletype?

When you see the message "THIS IS THE END OF THE LESSON. SEE YOU LATER.", you know that you have completed the lesson. Wait a couple of minutes until the teletype has logged off itself automatically. Then, put back the telephone receiver and turn off the teletype. Tear off your printout from the teletype. You are done.
APPENDIX C

CAI LESSONS

ORIENT
LESN1: Mirrors and Lenses
LESN2: Interference and Diffraction of Light
LESN3: Photoelectric Effect and Particle Waves
LESN4: Bohr's Atom and Atomic Spectra
LESN5: Coulomb's Law and Electric Fields
LESN6: Ohm's Law and DC Circuits
LESN7: Magnetic Fields and Magnetic Forces
LESN8: Electromagnetic Induction

55
"LEARN LESSON LISTING"

LESSON: ORIENT
DATE: 2/17/79
TIME: 14:14
PPN: 24000, 24005

5 TYPE=Q
PAGE
TEXT
IS YOUR TERMINAL
1 TTY
2 TEK 4010
3 TEK 4002

\ ANSWER
1 0 1
2 0 2
3 0 3
? 0
ACTION
1 2 3
CISO=SA=1
@ PLEASE TYPE 1, 2 OR 3 ACCORDING TO THE CLASSIFICATION
OF YOUR TERMINAL:

10 TYPE=Q
PAGE
STORE ON>
REVIEW ON>
HINT ON>
TEXT
THIS IS THE ORIENTATIONAL LESSON FOR STUDYING PHYSICS
USING TELETYPE AND SLIDE PROJECTOR, \=2
1. SETTING UP THE SLIDE PROJECTOR, \=2
EACH LESSON REQUIRES THE USE OF A SET OF SLIDES WHICH
MUST BE MOUNTED ON A PROJECTOR CONNECTED TO A TELETYPE;
THE SLIDE TRAY MUST BE POSITIONED TO SLIDE ZERO AT THE
BEGINNING OF THE LESSON. TURN ON THE PROJECTOR BY MOVING
THE SWITCH ON THE BACK TO THE "FAN" POSITION, THE
COMPUTER WILL TURN ON THE BULB AT THE PROPER TIME, \=2
QUESTION: TO WHAT POSITION OF THE PROJECTOR YOU SHOULD
TURN THE SWITCH?

\56
PAGE 5

20 TYPE=Q
PAGE
TEXT
TURN ON YOUR PROJECTOR TO THE "FAN" POSITION AND SET THE SLIDE TRAY TO ZERO, WHEN YOU ARE DONE, TYPE "READY":

ANSWER
A 0 READY
ACTION
A

IF YOU ARE HAVING A PROBLEM WITH THE PROJECTOR, SEE YOUR CONSULTANT, OTHERWISE, TYPE "READY":

50 TYPE=Q
PAGE
SLIDE 1
SLIDE ON
TEXT

II: STUDYING LESSONS 1-2
AFTER YOU TURN ON THE TELETYPE AND LOGIN (BY DIALING 36250 IF YOUR TERMINAL IS A TELETYPE OR 38100 FOR TEK TERMINALS, AND TYPING IN "LOGIN", YOUR NUMBER, AND PASSWORD), THE COMPUTER WILL TYPE OUT THE MESSAGE OF THE DAY AND END UP WITH A PERIOD (.) INDICATING THAT THE COMPUTER IS READY FOR YOUR USE, TYPE "R LEARN" AS YOUR FIRST COMMAND TO RUN A LESSON.  WHAT SHOULD YOU TYPE IN ORDER TO RUN A LESSON?

ANSWER
A + R LEARN
ACTION
A

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60 TYPE-Q
PAGE TEXT
THE TELETYPExE SHOULD STOP WITH AN ASTERISK (*) AFTER
YOU TYPED IN "R LEARN", FOLLOWING THE ASTERISK,
TYPE "GET" AND THE NAME OF THE LESSON THAT YOU WANT TO
STUDY SUCH AS "GET ORIENT".\*2

QUESTION: WHAT SHOULD YOU TYPE IF YOU WANT TO STUDY A
LESSON NAMED "LESN"?

\ ANSWER
A* GET LESN
ACTION
A
F1
F1
A1

70 TYPE-Q
PAGE TEXT
THE RUBOUT KEY IS USED TO CORRECT TYPING ERRORS, WHEN
YOU TYPE THE RUBOUT KEY THE LAST CHARACTER WHICH YOU TYPED
IS ERASED. IF YOU TYPE THIS KEY N TIMES, THE LAST N CHARA-
CTERS THAT YOU TYPED ARE ERASED. THE ERASED CHARACTERS ARE
PRINTED ON THE TELETYPExE PAPER BETWEEN SLASHES. IF YOU
WISH TO ERASE AN ENTIRE LINE, DEPRESS THE CONTROL KEY AND
HOLD IT DOWN WHILE TYPING U, REMEMBER THAT NO CHANGES CAN
BE MADE ON A LINE AFTER A CARRIAGE RETURN HAS BEEN TYPED;\*2

QUESTION: WHAT IS THE NAME OF THE KEY YOU SHOULD TYPE :
WHEN YOU WANT TO ERASE A TYPING ERROR?

\ ANSWER
A* RUBOUT
ACTION
A
F1
F1
F1
A1
P1

72 TYPE=R
CALCULATION MODE
TEXT

THE CALCULATION MODE MEANS THAT STUDENT CAN USE THE TELETYPING TO DO THE MATHEMATICAL CALCULATIONS JUST AS A DESK CALCULATOR. IT IS STRONGLY RECOMMENDED THAT YOU SHOULD USE THIS CALCULATION MODE IN FIGURING OUT THE ANSWERS TO THE PROBLEMS IN THE LESSONS TO BE STUDIED.

IN ORDER TO ENTER THE CALCULATION MODE TYPE THE "ESC" (ON SOME TELETYPING KEYBOARD IT IS NAMED AS "ALT" INSTEAD) AND AGAIN TO GET OUT OF THE CALCULATION MODE, REMEMBER THAT YOU SHOULD FIRST TYPE "TYPE" IN ASKING FOR AN ANSWER TO AN ARITHMETIC EXPRESSION, ONE EXAMPLE IS SHOWN BELOW:

WHAT IS THE SUM OF 1 AND 2?

*5

TELETYPING PRINTS $ WHEN YOU TYPE "ESC" KEY TO GET INTO THE CALCULATION MODE:

#CALC MODE TELETYPING OUTPUT,

*TYPE 1+2 YOU TYPE IN "TYPE 1+2",

$ 3 TELETYPING OUTPUT (THE ANSWER),

*5

TELETYPING PRINTS $ WHEN YOU TYPE "ESC" KEY TO GET OUT OF CALCULATION MODE,

ANSWER TELETYPING OUTPUT REQUESTING YOU TO TYPE IN THE ANSWER TO THE PROBLEM.

*3 YOU TYPE IN THE ANSWER "3",

WHEN YOU FINISH WITH THE INFORMATION ABOUT THE CALCULATION MODE, TYPE "GO":

\ANSWER

A 0 GO

ACTION

A

P

IF SEEN(1075) 0, B130

RITYPE "#C" TO GET BACK WHERE YOU LEFT OFF:

RITYPE "GO" TO CONTINUE:

80 TYPE=R

ARITHMETIC OPERATORS

90 TYPE=R

TEXT

THE ARITHMETIC OPERATORS YOU MAY USE ARE:

+ ADDITION
- SUBTRACTION
* MULTIPLICATION
/ DIVISION
^ EXPONENTIATION
SQRT SQUARE ROOT

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CUBE ROOT

ABSOLUTE VALUE

INTEGER

EXPONENTIAL

NATURAL LOGARITHM

BASE 10 LOGARITHM

TANGENT (RADIANS)

TANGENT (DEGREES)

SINE (RADIANS)

SINE (DEGREES)

COSINE (RADIANS)

COSINE (DEGREES)

INVERSE TANGENT (RADIANS)

INVERSE TANGENT (DEGREES)

INVERSE SINE (RADIANS)

INVERSE SINE (DEGREES)

INVERSE COSINE (RADIANS)

INVERSE COSINE (DEGREES)

WHEN YOU ARE READY TO CONTINUE THE LESSON, TYPE "GO"!

ANSWER

A 0 GO

ACTION

A

CLIIF SEEN(1080)=0,81100

R I T Y P E "#C" TO GET BACK WHERE YOU LEFT OFF.

R I T Y P E "GO" WHEN YOU FINISH WITH THIS LIST AND WANT TO
CONTINUE THE LESSON.

100 TYPE-Q

PAGE

TEXT

IN CASE YOU WANT TO REVIEW A CERTAIN TOPIC WHICH HAS BEEN ASSIGNED A REVIEW-TOPI
C NUMBER SUCH AS THE ABOVE ARITHMETIC OPERATOR LIST, YOU TYPE A NUMBER SIGN FOLLOWED
BY THE NUMBER THAT HAS BEEN ASSIGNED TO THAT TOPIC AND HAS BEEN PRINTED OUT ON THE TELETYPE PAPER, SUCH AS 

110 TYPE-Q

PAGE

TEXT

IN ORDER TO REPRESENT VERY LARGE OR VERY SMALL NUMBERS, YOU MAY USE A MODIFIED FORM OF EXPONENTIAL NOTATION. FOR EXAMPLE, 1.5E12 REPRESENTS 1.5 TIMES TEN TO THE TWELVE
TH POWER. ALSO, 1.5E-15 REPRESENTS 1.5 TIMES TEN TO THE NEGATIVE FIFTEENTH POWER. REMEMBER THAT YOU CAN NOT LEAVE

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120 TYPE-Q
PAGE

Some of the questions in the Lessons must be answered with a number followed by units, although most of the questions require only the magnitude in a unit explicitly spelled out by the lesson author. The following abbreviations may be used when a unit is required:

- Meter (M)
- Centimeter (CM)
- Second (SEC)
- Kilogram (KG)
- Gram (G)
- Joule (J)
- Electron Volt (EV)
- Cycle/Second (CPS)
- Angstrom (Å)

Compound units should be entirely abbreviated or entirely unabbreviated, such as

- kg/m/sec (correct)
- kilogram-meter/second (correct)
- kg=m/sec (incorrect)

Question: What is the abbreviated unit for Angstrom?

Answer: Å

Action: A

150 TYPE-Q
PAGE

Slide 2
SLIDE ON TEXT
SLIDE 2 SHOWS FOUR SIMPLE PROBLEMS FOR YOU TO PRACTICE THE CALCULATION MODE: WHAT IS THE ANSWER TO THE FIRST PROBLEM?
\ANSWER
1 + 10
ACTION
FL
\1

160 TYPE=Q PAGE TEXT
WHAT IS THE ANSWER TO THE SECOND PROBLEM?
\ANSWER
1 + 10
ACTION
FL
\1

170 TYPE=Q PAGE TEXT
WHAT IS THE VALUE OF K IN THE third PROBLEM?
\ANSWER
1 + 100
ACTION
FL
\1

180 TYPE=Q PAGE TEXT
WHAT IS THE VALUE OF F IN THE FOURTH PROBLEM?
WHEN YOU HAVE DIFFICULTY IN ANSWERING A QUESTION WHEN DOING A PROBLEM, YOU MAY ALWAYS ASK FOR A HINT BY TYPING A "?" FOLLOWED BY A CARRIAGE RETURN. PRACTICE THE HINT REQUISITION IN SOLVING THE FOLLOWING TWO PROBLEMS. 

WHAT IS THE SQUARE ROOT OF THE QUANTITY 200 TIMES THE SINE OF 30 DEGREES?

\$\sqrt{200 \sin 30} \$


WHAT IS THE ANGLE X, IF \( \tan x = \frac{3}{4} \)? GIVE YOUR ANSWER IN DEGREE.

\$\tan^{-1}\left(\frac{3}{4}\right) \$

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USE THE FOLLOWING CALCULATION MODE COMMAND:
TYPE ATAND(3/4)

TYPE Q
PAGE ACTION

THIS IS THE END OF THE ORIENTATION LESSON. BE SURE YOU
DO NOT FORGET TO TURN OFF THE TELETYPE AND HANG UP THE
TELEPHONE RECEIVER.

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SLIDE 1

THE ORIENTATIONAL LESSON
FOR
STUDYING PHYSICS
USING
TELETYPEx AND SLIDE PROJECTOR
SLIDE 2. PROBLEMS FOR PRACTICING CALCULATION MODE.

1. $5 + 5 = ?$
2. $2.0 \times 10^3 \times 5.0 \times 10^{-3} = ?$
4. $1/P + 1/Q = 1/F$ where $P = 10$ and $Q = 10$. 
WHAT TYPE OF TERMINAL ARE YOU USING?

1  TTY
2  TEK 4010
3  TEK 4002

PLEASE TYPE 1, 2 OR 3 ACCORDING TO THE CLASSIFICATION OF YOUR TERMINAL.

THIS LESSON MAKES USE OF A SET OF SLIDES ENTITLED "MIRROR AND LENS". THESE SLIDES SHOULD BE MOUNTED ON THE PROJECTOR, AND THE SLIDE TRAY SHOULD BE POSITIONED TO SLIDE ZERO. BE SURE THAT THE PROJECTOR IS TURNED ON TO THE FAN POSITION, THEN, TYPE "READY".
If you are having a problem with the projector, see the consultant. Otherwise, type "Ready" (no quotation mark).

20 TYPE-Q
PAGE
SLIDE 1
SLIDE ON TEXT
READ THE OBJECTIVES OF THIS LESSON ON SLIDE 1.
WHEN YOU FINISH YOUR READING, TYPE "GO".
ANSWER
A 0 GO
? 0
ACTION
A
RITYPE "GO" TO CONTINUE (NO QUOTATION MARK).

30 TYPE-Q
PAGE
SLIDE 2
TEXT
SLIDE 2 INDICATES THE NOTATIONS TO BE USED IN THIS LESSON. WHEN YOU FINISH WITH THIS SLIDE, TYPE "GO".
ANSWER
A 0 GO
? 0
ACTION
A
P1
RITYPE "GO" TO CONTINUE.

35 TYPE=R
SIGN CONVENTIONS

40 TYPE-Q
SLIDE 3
TEXT
PLEASE READ SLIDE 3 CAREFULLY AND TRY TO MEMORIZE (A) THROUGH (E). YOU ARE GOING TO USE THEM REPEATEDLY IN ANSWERING THE FOLLOWING QUESTIONS.
IF YOU ARE INTERESTED IN THE DERIVATION OF EQUATION (A)
AND (B), TYPE "DERIVE"; OTHERWISE, TYPE "GO" TO CONTINUE THE LESSON.

\ANSWER
A 0 DERIVE
B 0 GO
?
ACTION
A
B

IF SEEN(1040)=0,55
RITYPE "G" TO GET BACK WHERE YOU LEFT OFF.

RITYPE "GO" TO CONTINUE THE LESSON OR TYPE "DERIVE" TO REVIEW THE DERIVATION OF EQUATIONS (A) AND (B).

50 TYPE=Q
PAGE
SLIDE 4
TEXT
THE DERIVATION IS SHOWN WITH THE FOLLOWING FOUR SLIDES;
WHEN YOU FINISH WITH SLIDE 4, TYPE "GO".

\ANSWER
A 0 GO
?
ACTION
A
RITYPE "GO" TO CONTINUE.

51 TYPE=Q
SLIDE 5
TEXT
WHEN YOU FINISH WITH SLIDE 5, TYPE "GO".

\ANSWER
A 0 GO
?
ACTION
A
RITYPE "GO" TO CONTINUE.

52 TYPE=Q
SLIDE 6
TEXT
WHEN YOU FINISH WITH SLIDE 6, TYPE "GO",

\ANSWER
A 0 GO
? 0
\ACTION
A
RITYPE "GO" TO CONTINUE;

53 TYPE=Q
SLIDE 7
TEXT
WHEN YOU FINISH WITH SLIDE 7, TYPE "GO",

\ANSWER
A 0 GO
? 0
\ACTION
A
P
C1 IF SEEN(1053)=0, B155
RITYPE "#C" TO GET BACK WHERE YOU LEFT OFF;
@
RITYPE "GO" TO CONTINUE;

55 TYPE=R
GRAPHICAL METHOD (RAY TRACING)

60 TYPE=Q
SLIDE 8
TEXT
SLIDE 8 SHOWS THE THREE MAJOR RAYS OFTEN USED IN DETERMINING THE POSITION AND THE NATURE OF AN IMAGE. YOU SHOULD KNOW THEM BY HEART. WHEN YOU FINISH WITH THIS SLIDE, TYPE "GO";

\ANSWER
A 0 GO
? 0
\ACTION
A
C1 IF SEEN(1060)=0, B170
RITYPE "#C" TO GET BACK WHERE YOU LEFT OFF;
@
RITYPE "GO".

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In answering the following questions, you may need to review the sign conventions. Every time you want to do so, type "#1"; also, every time you want to review the graphical method, type "#2".

If the "x" in Slide 9 is a concave mirror, in which region as indicated on the top of this slide would the image of the arrow be formed?

Answer:
Extra off
A + B
Match 1
B = A C D E F
? 0
Action
A
F
I
B
F

Reuse graphical method and remember that you should draw the object distance and focal length to the scale.

Answer:
A + diminished
Phonic on
A + diminished
B = magnified
? 0
Action
A
F
I
B
F
RE EXAMINE THE LENGTHS OF THE OBJECT ARROW AND IMAGE ARROW IN THE GRAPH YOU JUST DREW.

CHOOSE AND TYPE EITHER "MAGNIFIED OR "DIMINISHED".

90 TYPE=Q
SLIDE 9
TEXT
IS THE IMAGE [REAL/VIRTUAL]?

ANSWER
A + REAL
PHONIC ON
A + REAL
B = VIRTUAL
? 0
ACTION
A
F: B
F: 
R A REAL IMAGE IS FORMED BY THE ACTUAL REFLECTED OR REFRACTED RAYS, WHILE A VIRTUAL IMAGE IS NOT FORMED BY ACTUAL RAYS BUT AN IMAGE FROM WHICH THE REFLECTED OR REFRACTED RAYS ARE SEEMINGLY EMITTED.

B
F: 
CHOOSE AND TYPE EITHER "REAL" OR "VIRTUAL".

100 TYPE=Q
SLIDE 9
TEXT
IS THE IMAGE ARROW POINTING [UP/DOWN]?

ANSWER
A + DOWN
B = UP
? 0
ACTION
A
F: B
F: 

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RIEXAMINE THE ORIENTATION OF THE IMAGE ARROW YOU JUST FOUND IN THE GRAPH YOU JUST DREW.

1) CHOOSE AND Type EITHER "UP" OR "DOWN".

110 TYPE Q
PAGE
SLIDE 9
TEXT
IF THE "X" IN SLIDE 9 IS A CONVEX MIRROR, IN WHICH REGION WOULD THE IMAGE OF THE ARROW BE FORMED?

ANSWER
EXTRA OFF
A + D
MATCH 1
B = A B C E F
? 0
ACTION
A
1 B
I
1
USE GRAPHICAL METHOD AND REMEMBER THAT YOU SHOULD DRAW THE OBJECT DISTANCE AND FOCAL LENGTH TO THE SCALE.

120 TYPE Q
SLIDE 9
TEXT
IS THE IMAGE [MAGNIFIED/DIMINISHED]?

ANSWER
A + DIMINISHED
PHONIC ON
A = DIMINISHED
B = MAGNIFIED
130  TYPE=Q
SLIDE 9
TEXT
IS THE IMAGE [REAL/VIRTUAL]?
\ANSWER
A + VIRTUAL
PHONIC ON
A + VIRTUAL
B = REAL
ACTION
A
B
F
A
R

140  TYPE=Q
SLIDE 9
TEXT
IS THE IMAGE ARROW POINTING [UP/DOWN]?
\ANSWER
A = UP
B = DOWN
ACTION
A
B
F
A
R

150  TYPE=Q
PAGE
SLIDE 9

TEXT

IF THE "X" IN SLIDE 9 IS A CONVERGING LENS, IN WHICH REGION WOULD THE IMAGE OF THE ARROW BE FORMED?

\ ANSWER
\ EXTRA OFF
\ A + E
\ MATCH 1
\ B = A B C D F
\ ? Ø
\ ACTION
\ A
\ F1
\ B
\ F1
\ R1


160 TYPE-Q
SLIDE 9
TEXT

IS THE IMAGE [MAGNIFIED/DIMINISHED]?

\ ANSWER
\ A + DIMINISHED
\ PHONIC ON
\ A + DIMINISHED
\ B = MAGNIFIED
\ ACTION
\ A
\ F1
\ B
\ F1
\ A1
\ Ø
\ R1

170 TYPE-Q
SLIDE 9
TEXT
IS THE IMAGE [REAL/VIRTUAL]?

\ ANSWER
A \ REAL
PHONIC ON
A \ REAL
B = VIRTUAL
ACTION
A
F
B
F
A
R
180 TYPE=Q
SLIDE 9
TEXT
IS THE IMAGE ARROW POINTING [UP/DOWN]?
\ ANSWER
A \ DOWN
B = UP
ACTION
A
F
B
F
A
R
190 TYPE=Q
PAGE
SLIDE 9
TEXT
IF THE "X" IN SLIDE 9 IS A DIVERGING LENS, IN WHICH REGION WOULD THE IMAGE OF THE ARROW BE FORMED?
\ ANSWER
EXTRA OFF
A + C
MATCH 1
B = A B D E F
? ø
ACTION
A
Use graphical method to answer this and the following three questions.

200 Type-Q
Slide 9
Text
Is the image [magnified/diminished]?

Answer
A = diminished
Phonic on
A = diminished
B = magnified
Action
A
F1
B
F1
A1
G
R1

210 Type-Q
Slide 9
Text
Is the image [real/virtual]?

Answer
A = virtual
Phonic on
A = virtual
B = real
Action
A
F1
B
F1
A1
220 TYPE=Q
SLIDE 9
TEXT
IS THE IMAGE ARROW POINTING [UP/DOWN]?
\ ANSWER
A = UP
B = DOWN
ACTION
A
F1
C1 IF RIGHT(70&220)>12, B1390
B
F1
A1
@ R1

230 TYPE=Q
PAGE
SLIDE 10
TEXT
AGAIN CONSIDER THE ARROW WHICH IS NOW PLACED IN REGION C. IF THE "X" IS A CONCAVE MIRROR, ON WHICH SIDE [LEFT/RIGHT] OF THE MIRROR WOULD THE IMAGE OF THE ARROW BE FORMED?
\ ANSWER
A = RIGHT
B = LEFT
ACTION
A
@ B
F1
RI USE GRAPHICAL METHOD TO ANSWER THIS AND THE FOLLOWING THREE QUESTIONS.
\ F1
A1
@ R I CHOOSE AND TYPE EITHER "LEFT" OR "RIGHT":

240 TYPE=Q
SLIDE 10
TEXT
IS THE IMAGE [MAGNIFIED/DIMINISHED]?
\ANSWER
A + MAGNIFIED
PHONIC ON
A + MAGNIFIED
B - DIMINISHED
ACTION
A
B
F1
A1
@
RI

250 TYPE-Q
SLIDE 10
TEXT
IS THE IMAGE [REAL/VIRTUAL]?
\ANSWER
A + VIRTUAL
PHONIC ON
A + VIRTUAL
B - REAL
ACTION
A
B
F1
A1
@
RI

260 TYPE-Q
SLIDE 10
TEXT
IS THE IMAGE ARROW POINTING [UP/DOWN]?
\ANSWER
A + UP
B - DOWN
ACTION
A
F1
B
IF THE "X" IN SLIDE 10 IS A CONVEX MIRROR, IN WHICH REGION WOULD THE IMAGE OF THE ARROW BE FORMED?

ANSWER

EXTRA OFF
A + D
MATCH 1
B = A B C E F

ACTION
A
R I

270 TYPE-Q

USE GRAPHICAL METHOD TO ANSWER THIS AND THE FOLLOWING THREE QUESTIONS.


280 TYPE-Q

IS THE IMAGE [MAGNIFIED/DIMINISHED]?

ANSWER
A + DIMINISHED
PHONIC ON
A + DIMINISHED
B = MAGNIFIED
ACTION
A
R I
290 TYPE-Q
SLIDE 10
TEXT
IS THE IMAGE [REAL/VIRTUAL]? \
ANSWER
A + VIRTUAL
PHONIC ON
A + VIRTUAL
B - REAL
ACTION
A
F1
B
F1
A1
Q1

300 TYPE-Q
SLIDE 10
TEXT
IS THE IMAGE ARROW POINT [UP/DOWN]? \
ANSWER
A + UP
B - DOWN
ACTION
A
F1
B
F1
A1
Q1

310 TYPE-Q
PAGE
SLIDE 10
TEXT
IF THE "X" IS A CONVERGING LENS, ON WHICH SIDE [LEFT/RIGHT] OF THE LENS IS THE IMAGE OF THE ARROW FORMED? \

ANSWER
A + LEFT
B = RIGHT
?
ACTION
A
F
B
F
RI
USE GRAPHICAL METHOD TO ANSWER THIS AND THE FOLLOWING THREE QUESTIONS,
B
F
A
R
CHOOSE AND TYPE EITHER "LEFT" OR "RIGHT":

320 TYPE-Q
SLIDE 10
TEXT
IS THE IMAGE [MAGNIFIED/DIMINISHED]?
\nANSWER
A + MAGNIFIED
PHONIC ON
A + MAGNIFIED
B = DIMINISHED
ACTION
A
F
B
F
A
R

330 TYPE-Q
SLIDE 10
TEXT
IS THE IMAGE [REAL/VIRTUAL]?
\nANSWER
A + VIRTUAL
PHONIC ON
A + VIRTUAL
B = REAL
ACTION
A
340 TYPE-Q
SLIDE 10
TEXT
IS THE IMAGE ARROW POINTING [UP/DOWN]?
\ ANSWER
A = UP
B = DOWN
ACTION
A
B
F1
A
F1
R1

350 TYPE-Q
PAGE
SLIDE 10
TEXT
IF THE "X" IN SLIDE 10 IS A DIVERGING LENS, IN WHICH REGION WOULD THE IMAGE OF THE ARROW BE FORMED?
\ ANSWER
EXTRA OFF
A + C
MATCH 1
B = A B D E F
? Ø
ACTION
A
F1
F1
B
R1
R1
B
F1

R1: USE GRAPHICAL METHOD TO ANSWER THIS AND THE FOLLOWING THREE QUESTIONS.
360 TYPE-Q
SLIDE 10
TEXT
IS THE IMAGE [MAGNIFIED/DIMINISHED]?
\ANSWER
A = DIMINISHED
PHONIC ON
A = DIMINISHED
B = MAGNIFIED
ACTION
A F1
B F1
A1 F
R1

370 TYPE-Q
SLIDE 10
TEXT
IS THE IMAGE [REAL/VIRTUAL]?
\ANSWER
A = VIRTUAL
PHONIC ON
A = VIRTUAL
B = REAL
ACTION
A F1
B F1
A1 F
R1

380 TYPE-Q
SLIDE 10
TEXT
IS THE IMAGE ARROW POINTING [UP/DOWN]?
\
ANSWER
A * UP
B - DOWN
ACTION
A
B
C
D
E
F

390 TYPE-Q
PAGE
SLIDE 11
TEXT
SLIDE 11 SHOWS HOW TO SOLVE PROBLEMS WHEN A COMBINATION OF LENSES OR MIRRORS IS INVOLVED. GENERALLY, TWO SIMULTANEOUS EQUATIONS ARE USED AS SHOWN IN (A). EQUATION (B) IS THE TOTAL MAGNIFICATION OF TWO LENSES OR ONE LENS AND ONE MIRROR. EQUATION (C) IS DERIVED FROM EQUATION (A) WHEN TWO LENSES ARE IN CONTACT WITH EACH OTHER (D=0).
WHEN YOU FINISH READING SLIDE 11, TYPE "GO",
\ ANSWER
A 0 GO
? 0
ACTION
A
RITYPE "GO" TO CONTINUE.\n
400 TYPE-Q
PAGE
SLIDE 12
TEXT
THE FOLLOWING QUESTION IS OF THE "COMBINED" TYPE. YOU MAY USE THE CALCULATION MODE ON THE TELETYPETO SOLVE THIS QUESTION, READ THE PROBLEM IN SLIDE 12 AND CHOOSE YOUR ANSWER FROM BELOW:
A 12 CM TO THE RIGHT OF L2, DOWNWARD, REAL
B 12 CM TO THE RIGHT OF L2, DOWNWARD, VIRTUAL
C 12 CM TO THE LEFT OF L2, UPWARD, REAL
D 10 CM TO THE RIGHT OF L2, UPWARD, REAL
E 10 CM TO THE RIGHT OF L2, DOWNWARD, REAL
F 10 CM TO THE LEFT OF L2, DOWNWARD, VIRTUAL
\
ANSWER
EXTRA OFF
A + E
MATCH 1
B = A B C
C = D
D = F
? Ø
ACTION
A
FI
B C D
R1
FIND Q1 FROM THE FIRST EQUATION OF THE TWO SIMULTANEOUS
EQUATIONS (A) IN SLIDE 12, AND FIND Q2 FROM THE SECOND
EQUATION. THEN FIGURE OUT YOUR RIGHT ANSWER FROM Q2:
REMEMBER THAT CONCAVE MIRROR AND CONVERGING LENS HAVE
POSITIVE FOCAL LENGTHS, WHILE CONVEX MIRROR AND DIVERGING
LENS HAVE NEGATIVE FOCAL LENGTHS.
B
F1
R1 THE FOCAL LENGTH OF L1 IS NEGATIVE, TRY AGAIN.
D
F1
R1 THE IMAGE ORIENTATION IS WRONG, TRY AGAIN.
F
F1
R1 THE IMAGE NATURE IS WRONG, TRY AGAIN.
B
R1
F
FI
A1
R1
416 TYPE =Q
SLIDE 13
TEXT
SLIDE 13 SHOWS THE GRAPHICAL METHOD OF SOLVING THIS
PROBLEM, WHEN YOU FINISH THIS SLIDE, TYPE "GO".
\ ANSWER
A 0 GO
? Ø
ACTION
A
@ R1 TYPE "GO" TO CONTINUE.
420 TYPE=Q
PAGE
TEXT
THIS IS THE END OF THIS LESSON. SEE YOU LATER;
\ACTION
S1OFF
S10
LI
Slide 1. Objectives.

Having completed this lesson, the student should be able (by calculation or by graphing method) to determine:

1. the position,
2. the magnification,
3. the orientation, and
4. the nature (real or virtual)

of the image formed by a single mirror or lens as well as formed by the combination of mirror and lens.
Slide 2. Notations used in connection with mirror and lens.
Slide 3. Sign conventions and the formulas for mirror and lens.

Formulas:

\[ \frac{1}{p} + \frac{1}{q} = \frac{1}{f} \]  \hspace{1cm} \[ \frac{I}{O} = \frac{Q}{P} = M \text{ (magnification)} \]

Sign conventions:

Light \rightarrow Mirror

\begin{align*}
\text{P ( + )} & \rightarrow \text{P ( - )} \\
\text{Q ( + )} & \rightarrow \text{Q ( - )}
\end{align*}

\begin{align*}
\text{F = ( + ) for concave mirror and converging lens.} \\
\text{F = ( - ) for convex mirror and diverging lens.}
\end{align*}

Light \rightarrow Lens

\begin{align*}
\text{P ( + )} & \rightarrow \text{P ( - )} \\
\text{O ( - )} & \rightarrow \text{Q ( + )}
\end{align*}

Q = ( + ) for inverted real image.

Q = ( - ) for erect virtual image.

Object at 2F forms image at 2F for concave mirror and converging lens.
Slide 4. Derivation of equations for concave mirror.

\[ \triangle ABH \cong \triangle EBD \]

\[ M = \frac{I}{O} = \frac{Q}{P} \]  \hspace{1cm} (1)

\[ \triangle AF'H \cong \triangle JF'G \]

\[ \frac{I}{O} = \frac{F}{P-F} \]  \hspace{1cm} (2)

\[ (1) = (2) \hspace{0.5cm} \frac{Q}{P} = \frac{F}{P-F} \]

\[ QP - QF = PF \]  \hspace{1cm} (3)

Divide (3) by FPQ and rearranged,

\[ \frac{1}{P} + \frac{1}{Q} = \frac{1}{F} \]
Slide 5. Derivation of equations for convex mirror.

\[ \frac{1}{O} = \frac{-Q}{F} \]  \hspace{1cm} (1)

(Object distance is negative for convex mirror.)

\[ \frac{Q}{P} = M \] (Magnification takes absolute value.)

\[ \frac{L}{O} = \frac{-F - (-Q)}{-F} = \frac{F - Q}{F} \]  \hspace{1cm} (2)

(Focal length is negative for convex mirror.)

\[ (1) = (2) \hspace{1cm} \frac{-Q}{P} = \frac{F - Q}{F} \]

\[ PF - PQ = -FQ \]  \hspace{1cm} (3)

Divide (3) by FPQ and rearranged,

\[
\frac{1}{P} + \frac{1}{Q} = \frac{1}{F}
\]

\[ \triangle ABH \sim \triangle EBD \]

\[ M = \frac{I}{O} = \frac{Q}{P} \]  \hspace{1cm} (1)

\[ \triangle JF'B \sim \triangle EF'D \]

\[ \frac{I}{O} = \frac{Q - F}{F} \]  \hspace{1cm} (2)

\[ (1) = (2) \quad \frac{Q}{P} = \frac{Q - F}{F} \]

\[ PQ - PF = FQ \]  \hspace{1cm} (3)

Divide (3) by FPQ and rearranged,

\[ \frac{1}{P} + \frac{1}{Q} = \frac{1}{F} \]

\[ \triangle ABH \sim \triangle EBD \]
\[ \frac{I}{O} = \frac{-Q}{P} \]  \hspace{1cm} (1)
(Image distance is negative for virtual image.)

\[ \frac{Q}{P} = M \] (Magnification takes absolute value.)

\[ \triangle JF'B \sim \triangle EF'D \]
\[ \frac{I}{O} = \frac{-F - (-Q)}{-F} = \frac{F - Q}{F} \] \hspace{1cm} (2)
(Focal length is negative for diverging lens.)

\[ (1) = (2) \hspace{1cm} \frac{-Q}{P} = \frac{F - Q}{F} \]
or
\[ PF - PQ = -FQ \] \hspace{1cm} (3)

Divide (3) by FPQ and rearranged,
\[ \frac{1}{P} + \frac{1}{Q} = \frac{1}{F} \]
Slide 8. The three major rays in the graphical determination of image position.
Slide 9. A sketch to help determine: (a) the position, 
(b) the magnification, 
(c) the nature, and 
(d) the orientation of the image of the arrow.
Slide 10. A sketch to help determine: (a) the position,
(b) the magnification,
(c) the nature, and
(d) the orientation of the image of the arrow.
Slide 11. Formulas for solving a problem involving the combination of either lenses or mirrors or both.

\[
\begin{align*}
\text{(A)} & \quad \frac{1}{P_1} + \frac{1}{Q_1} = \frac{1}{F_1} \\
& \quad \frac{1}{D - Q_1} + \frac{1}{Q_2} = \frac{1}{F_2} \\
& \quad M_1 = \frac{Q_1}{P_1} \\
& \quad M_2 = \frac{Q_2}{P_2} \\
& \quad M = M_1 M_2 \\
& \quad = \frac{Q_1}{P_1} \frac{Q_2}{P_2} \\
\text{(C)} & \quad \frac{1}{F_1} + \frac{1}{F_2} = \frac{1}{F}
\end{align*}
\]
Slide 12. A 2-lens problem:

A 6 cm focal length diverging lens stands 36 cm in front of a 8 cm focal length converging lens as shown below. Find: (a) the position, (b) the orientation, and (c) the nature of the image of the arrow which stands 12 cm in front of the diverging lens.
Slide 13. An illustration of ray tracing in finding the arrow image for the problem given in slide 12.
"LEARN LESSON LISTING"

LESSON: LESN2
DATE: 2/17/75
TIME: 14:13
PPN: 24000:24005

5 TYPE=Q
TEXT
IS YOUR TERMINAL
1 TTY
2 TEK 4010
3 TEK 4002

\ ANSWER
1 0 1
2 0 2
3 0 3
? 0
ACTION
1 2 3
CSSD=SA-1

PLEASE TYPE 1, 2 OR 3 ACCORDING TO THE CLASSIFICATION OF YOUR TERMINAL;

10 TYPE=Q
PAGE
STORE ON>
HINT ON>
TEXT
LESSON 2: INTERFERENCE AND DIFFRACTION OF LIGHT
   This lesson makes use of a set of slides entitled
   "INTERFERENCE AND DIFFRACTION", these slides
   should be mounted on the projector, and the slide tray
   should be positioned to slide zero, be sure that the
   projector is turned on to the fan position, then, type
   "READY".

\ ANSWER
EXTRA OFF
PHONIC ON>
A 0 READY
? 0
ACTION

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A

IF YOU ARE HAVING PROBLEMS WITH THE PROJECTOR, SEE THE CONSULTANT. OTHERWISE, TYPE "READY" (NO QUOTATION MARK).

20 TYPE "Q"
PAGE
SLIDE 1
SLIDE ON
TEXT
READ THE OBJECTIVES OF THIS LESSON ON SLIDE 1. WHEN YOU FINISH READING THIS SLIDE, TYPE "GO".
\ANSWER
A 0 GO
? 0
ACTION
A
R TYPE "GO" TO CONTINUE (NO QUOTATION MARK).

30 TYPE "Q"
PAGE
SLIDE 2
TEXT
ALL PHENOMENA IN THIS LESSON ARE TO BE INTERPRETED BY THE WAVE NATURE OF LIGHT; FIRSTLY, INTERFERENCE REFERS TO THE INTERACTION OF TWO (OR MORE) WAVES GENERATED BY TWO (OR MORE) WAVE SOURCES, WHEN THE TWO WAVES ARE IN PHASE; (THAT IS THEY MEET CREST WITH CREST AND TROUGH WITH TROUGH) IT IS CALLED [CONSTRUCTIVE/DESTRUCTIVE] INTERFERENCE. CHOOSE ONE AS YOUR ANSWER.
\ANSWER
A + CONSTRUCTIVE
A + CONSTRUCTIVE INTERFERENCE
B = DESTRUCTIVE
B = DESTRUCTIVE INTERFERENCE
? 0
ACTION
A
F 1
B
F 1
FITWO WAVES REINFORCE EACH OTHER HERE.
\RPLEASE ANSWER EITHER "CONSTRUCTIVE" OR "DESTRUCTIVE".

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Figure (b) in Slide 2 shows the interaction of two waves one of which is half wavelength ahead of the other; this causes a complete cancellation for two identical waves. Such interference is named interference."

\[ \text{ANSWER} \]
\[ A = \text{DESTRUCTIVE} \]
\[ B = \text{CONSTRUCTIVE} \]

\[ ? = 0 \]

\[ \text{ACTION} \]
\[ A \]
\[ F \]
\[ B \]
\[ F \]

\[ \text{The two waves cancel each other here.} \]

\[ \text{PLEASE FILL THE BLANK WITH EITHER "CONSTRUCTIVE" OR "DESTRUCTIVE".} \]

---

50 TYPE = 0

PAGE

SLIDE 3

TEXT

Consider Young's double-slit experiment. In Slide 3, the single slit is used to generate two coherent sources at slits $S_1$ and $S_2$. Coherent means that two sources generate their crests or troughs at the same time. This is the first requirement of Young's double-slit experiment when you finish with this slide, type "GO".

\[ \text{ANSWER} \]
\[ A = 0 \]
\[ ? = 0 \]

\[ \text{ACTION} \]
\[ A \]

\[ \text{R ITYPE "GO" TO CONTINUE.} \]

---

60 TYPE = 0

PAGE

SLIDE 4

TEXT

The other two requirements for Young's experiment are:

1) The space between the two sources must be small, and
2) The distance between the sources and screen must be large, as can be seen in Slide 4, L is much greater than d. Consider the first order bright band at B1. What would be the expression for the wavelength? Choose your answer from the following multiple choice answers:

A) \( \text{Wavelength} = \frac{(x_1) d}{L} \)
B) \( \text{Wavelength} = \frac{(x_1) L}{d} \)
C) \( \text{Wavelength} = \frac{d L}{(x_1)} \)
D) \( \text{Wavelength} = \frac{2d L}{(x_1)} \)

Answer.

Phonic off

Extra off

A + A

Match 1

B = B C D

? 0

Action

A

F

I B

F

R I use the two similar triangles: S1 - S2 = A and O - B0 = B1.

B

F

R I take sines of the two angles (Theta 1 and Theta 2) and set them equal to each other after replacing O - L1 side by L. Try again.

B

F

R I from the two similar triangles A = S1 - S2 and O - B0 = B1; it is approximated that \( \frac{d}{L} = \frac{\text{wavelength}}{x_1} \) after setting \( L = 0 - B1. \)

A

R

65 type = C

L = INT(10*SR+1)*1E2
D = INT(10*SR+1)*15+1
X = INT(10*SR+1)*1E2
W = X*D/L*1E8

70 type = 0

Page

Text

Here is a problem of determining the wavelength of a single-colored light using double-slit interference.
THE MEASURED DATA ARE: THE SLIT-TO-SCREEN DISTANCE IS \[ 111.0 \text{ cm} \], THE SPACE BETWEEN THE TWO SLITS IS \[ 111.2 \text{ cm} \], AND THE FIRST ORDER BRIGHT BAND IS \[ 111.3 \text{ cm} \]. TO FIND THE WAVELENGTH OF THE INCIDENT LIGHT AND GIVE YOUR ANSWER IN ANGSTROMS.

\[
\text{WAVELENGTH} = \frac{X_1 D}{L}.
\]

\[ X_1 = 0.03 \text{ cm} \]

\[ \text{ANGLER} = \text{WAVELENGTH} \times \text{ANGSTROMS} \]

\[ \text{ACTION} = \]

\[ \text{AT} \]

\[ \text{BP} \]

\[ \text{REUSE THE FORMULA}: \ WAVELENGTH = \frac{X_1 D}{L}. \]

\[ \text{ACTION} = \]

\[ \text{LOOK AT SLIDE 4 AGAIN. CAN YOU DERIVE A GENERAL FORMULA FOR THE EXPRESSION OF WAVELENGTH FOR THE N TH ORDER BRIGHT FRINGE? CHOOSE THE RIGHT ANSWER FROM:}\]

\[ A \ WAVELENGTH = \frac{X_N D}{N L} \]

\[ B \ WAVELENGTH = \frac{X_N D}{L} \]

\[ C \ WAVELENGTH = \frac{X_N L}{D} \]

\[ D \ WAVELENGTH = \frac{X_N L}{N D} \]

\[ \text{WHERE} \ (X_N) \ \text{IS THE DISPLACEMENT OF THE N TH ORDER BRIGHT FRINGE FROM THE CENTRAL MAXIMUM.}\]

\[ \text{ACTION} = \]

\[ \text{LOOK AT SLIDE 4 AGAIN. CAN YOU DERIVE A GENERAL FORMULA FOR THE EXPRESSION OF WAVELENGTH FOR THE N TH ORDER BRIGHT FRINGE? CHOOSE THE RIGHT ANSWER FROM:}\]

\[ A \ WAVELENGTH = \frac{X_N D}{N L} \]

\[ B \ WAVELENGTH = \frac{X_N D}{L} \]

\[ C \ WAVELENGTH = \frac{X_N L}{D} \]

\[ D \ WAVELENGTH = \frac{X_N L}{N D} \]

\[ \text{WHERE} \ (X_N) \ \text{IS THE DISPLACEMENT OF THE N TH ORDER BRIGHT FRINGE FROM THE CENTRAL MAXIMUM.}\]

\[ \text{ACTION} = \]

\[ \text{LOOK AT SLIDE 4 AGAIN. CAN YOU DERIVE A GENERAL FORMULA FOR THE EXPRESSION OF WAVELENGTH FOR THE N TH ORDER BRIGHT FRINGE? CHOOSE THE RIGHT ANSWER FROM:}\]

\[ A \ WAVELENGTH = \frac{X_N D}{N L} \]

\[ B \ WAVELENGTH = \frac{X_N D}{L} \]

\[ C \ WAVELENGTH = \frac{X_N L}{D} \]

\[ D \ WAVELENGTH = \frac{X_N L}{N D} \]

\[ \text{WHERE} \ (X_N) \ \text{IS THE DISPLACEMENT OF THE N TH ORDER BRIGHT FRINGE FROM THE CENTRAL MAXIMUM.}\]

\[ \text{ACTION} = \]

\[ \text{LOOK AT SLIDE 4 AGAIN. CAN YOU DERIVE A GENERAL FORMULA FOR THE EXPRESSION OF WAVELENGTH FOR THE N TH ORDER BRIGHT FRINGE? CHOOSE THE RIGHT ANSWER FROM:}\]

\[ A \ WAVELENGTH = \frac{X_N D}{N L} \]

\[ B \ WAVELENGTH = \frac{X_N D}{L} \]

\[ C \ WAVELENGTH = \frac{X_N L}{D} \]

\[ D \ WAVELENGTH = \frac{X_N L}{N D} \]

\[ \text{WHERE} \ (X_N) \ \text{IS THE DISPLACEMENT OF THE N TH ORDER BRIGHT FRINGE FROM THE CENTRAL MAXIMUM.}\]

\[ \text{ACTION} = \]

\[ \text{LOOK AT SLIDE 4 AGAIN. CAN YOU DERIVE A GENERAL FORMULA FOR THE EXPRESSION OF WAVELENGTH FOR THE N TH ORDER BRIGHT FRINGE? CHOOSE THE RIGHT ANSWER FROM:}\]

\[ A \ WAVELENGTH = \frac{X_N D}{N L} \]

\[ B \ WAVELENGTH = \frac{X_N D}{L} \]

\[ C \ WAVELENGTH = \frac{X_N L}{D} \]

\[ D \ WAVELENGTH = \frac{X_N L}{N D} \]

\[ \text{WHERE} \ (X_N) \ \text{IS THE DISPLACEMENT OF THE N TH ORDER BRIGHT FRINGE FROM THE CENTRAL MAXIMUM.}\]

\[ \text{ACTION} = \]

\[ \text{LOOK AT SLIDE 4 AGAIN. CAN YOU DERIVE A GENERAL FORMULA FOR THE EXPRESSION OF WAVELENGTH FOR THE N TH ORDER BRIGHT FRINGE? CHOOSE THE RIGHT ANSWER FROM:}\]

\[ A \ WAVELENGTH = \frac{X_N D}{N L} \]

\[ B \ WAVELENGTH = \frac{X_N D}{L} \]

\[ C \ WAVELENGTH = \frac{X_N L}{D} \]

\[ D \ WAVELENGTH = \frac{X_N L}{N D} \]

\[ \text{WHERE} \ (X_N) \ \text{IS THE DISPLACEMENT OF THE N TH ORDER BRIGHT FRINGE FROM THE CENTRAL MAXIMUM.}\]

\[ \text{ACTION} = \]

\[ \text{LOOK AT SLIDE 4 AGAIN. CAN YOU DERIVE A GENERAL FORMULA FOR THE EXPRESSION OF WAVELENGTH FOR THE N TH ORDER BRIGHT FRINGE? CHOOSE THE RIGHT ANSWER FROM:}\]

\[ A \ WAVELENGTH = \frac{X_N D}{N L} \]

\[ B \ WAVELENGTH = \frac{X_N D}{L} \]

\[ C \ WAVELENGTH = \frac{X_N L}{D} \]

\[ D \ WAVELENGTH = \frac{X_N L}{N D} \]

\[ \text{WHERE} \ (X_N) \ \text{IS THE DISPLACEMENT OF THE N TH ORDER BRIGHT FRINGE FROM THE CENTRAL MAXIMUM.}\]

\[ \text{ACTION} = \]

\[ \text{LOOK AT SLIDE 4 AGAIN. CAN YOU DERIVE A GENERAL FORMULA FOR THE EXPRESSION OF WAVELENGTH FOR THE N TH ORDER BRIGHT FRINGE? CHOOSE THE RIGHT ANSWER FROM:}\]

\[ A \ WAVELENGTH = \frac{X_N D}{N L} \]

\[ B \ WAVELENGTH = \frac{X_N D}{L} \]

\[ C \ WAVELENGTH = \frac{X_N L}{D} \]

\[ D \ WAVELENGTH = \frac{X_N L}{N D} \]

\[ \text{WHERE} \ (X_N) \ \text{IS THE DISPLACEMENT OF THE N TH ORDER BRIGHT FRINGE FROM THE CENTRAL MAXIMUM.}\]

\[ \text{ACTION} = \]

\[ \text{LOOK AT SLIDE 4 AGAIN. CAN YOU DERIVE A GENERAL FORMULA FOR THE EXPRESSION OF WAVELENGTH FOR THE N TH ORDER BRIGHT FRINGE? CHOOSE THE RIGHT ANSWER FROM:}\]

\[ A \ WAVELENGTH = \frac{X_N D}{N L} \]

\[ B \ WAVELENGTH = \frac{X_N D}{L} \]

\[ C \ WAVELENGTH = \frac{X_N L}{D} \]

\[ D \ WAVELENGTH = \frac{X_N L}{N D} \]

\[ \text{WHERE} \ (X_N) \ \text{IS THE DISPLACEMENT OF THE N TH ORDER BRIGHT FRINGE FROM THE CENTRAL MAXIMUM.}\]

\[ \text{ACTION} = \]

\[ \text{LOOK AT SLIDE 4 AGAIN. CAN YOU DERIVE A GENERAL FORMULA FOR THE EXPRESSION OF WAVELENGTH FOR THE N TH ORDER BRIGHT FRINGE? CHOOSE THE RIGHT ANSWER FROM:}\]

\[ A \ WAVELENGTH = \frac{X_N D}{N L} \]

\[ B \ WAVELENGTH = \frac{X_N D}{L} \]

\[ C \ WAVELENGTH = \frac{X_N L}{D} \]

\[ D \ WAVELENGTH = \frac{X_N L}{N D} \]

\[ \text{WHERE} \ (X_N) \ \text{IS THE DISPLACEMENT OF THE N TH ORDER BRIGHT FRINGE FROM THE CENTRAL MAXIMUM.}\]

\[ \text{ACTION} = \]

\[ \text{LOOK AT SLIDE 4 AGAIN. CAN YOU DERIVE A GENERAL FORMULA FOR THE EXPRESSION OF WAVELENGTH FOR THE N TH ORDER BRIGHT FRINGE? CHOOSE THE RIGHT ANSWER FROM:}\]

\[ A \ WAVELENGTH = \frac{X_N D}{N L} \]

\[ B \ WAVELENGTH = \frac{X_N D}{L} \]

\[ C \ WAVELENGTH = \frac{X_N L}{D} \]

\[ D \ WAVELENGTH = \frac{X_N L}{N D} \]

\[ \text{WHERE} \ (X_N) \ \text{IS THE DISPLACEMENT OF THE N TH ORDER BRIGHT FRINGE FROM THE CENTRAL MAXIMUM.}\]

\[ \text{ACTION} = \]

\[ \text{LOOK AT SLIDE 4 AGAIN. CAN YOU DERIVE A GENERAL FORMULA FOR THE EXPRESSION OF WAVELENGTH FOR THE N TH ORDER BRIGHT FRINGE? CHOOSE THE RIGHT ANSWER FROM:}\]

\[ A \ WAVELENGTH = \frac{X_N D}{N L} \]

\[ B \ WAVELENGTH = \frac{X_N D}{L} \]

\[ C \ WAVELENGTH = \frac{X_N L}{D} \]

\[ D \ WAVELENGTH = \frac{X_N L}{N D} \]

\[ \text{WHERE} \ (X_N) \ \text{IS THE DISPLACEMENT OF THE N TH ORDER BRIGHT FRINGE FROM THE CENTRAL MAXIMUM.}\]

\[ \text{ACTION} = \]

\[ \text{LOOK AT SLIDE 4 AGAIN. CAN YOU DERIVE A GENERAL FORMULA FOR THE EXPRESSION OF WAVELENGTH FOR THE N TH ORDER BRIGHT FRINGE? CHOOSE THE RIGHT ANSWER FROM:}\]

\[ A \ WAVELENGTH = \frac{X_N D}{N L} \]

\[ B \ WAVELENGTH = \frac{X_N D}{L} \]

\[ C \ WAVELENGTH = \frac{X_N L}{D} \]

\[ D \ WAVELENGTH = \frac{X_N L}{N D} \]

\[ \text{WHERE} \ (X_N) \ \text{IS THE DISPLACEMENT OF THE N TH ORDER BRIGHT FRINGE FROM THE CENTRAL MAXIMUM.}\]

\[ \text{ACTION} = \]
L , T R Y A G A I N , " 
B
A I
O
R I

9 0 T Y P E - G
P A G E
S L I D E 5
T E X T
A M U L T I P L E - S L I T P L A T E I N A S E N S E , N O R M A L L Y I T H A
S H O W N I N S L I D E 5 , I T I S C A L L E D G R A T I N G S P E C T R O M E T E R ,
\A N S W E R
A @ G O
? @
A C T I O N
A
R I T Y P E " G O " T O C O N T I N U E , " 

1 0 0 T Y P E - G
P A G E
S L I D E 6
T E X T
L O O K A T T H E L E N S W H I C H I S T H E S E C O N D L E N S O F T H E S P E C-
D I S T A N C E F R O M G R A T I N G T O S C R E E N ,
\A N S W E R
A @ G O
? @
A C T I O N
A
@
This slide shows the first two orders of bright spectral lines by the grating. These lines are much sharper than the fringes formed through a double-slit. Thus, it is much more accurate to determine the wavelength of light using a grating spectrometer. Can you give the general formula for measuring wavelength by a grating?

Choose the right formula from:

A \sin(\text{theta of N th order}) = \text{ND/lambda}
B \sin(\text{theta of N th order}) = N \text{ lambda/d}
C \sin(\text{theta of N th order}) = \text{lambda/(ND)}
D \sin(\text{theta of N th order}) = \text{lambda/d}


The N th order means the path difference of the two beams through any two adjacent slits is N times the wavelength lambda.

Here is a grating problem. How many lines per centimeter should a grating have if the first order spectrum (wavelength is 5000 A) is to occur at an angle of 90 degrees?

\text{Answer: 1 * 20000.}
A * TWENTY THOUSAND
ACTION
1 A
F !
I ?
F !
RIUSE SIN(THETA OF THE FIRST ORDER)*LAMBD/A/D.
THE SINE OF 90 DEGREES IS 1.
?
F !
RIUSE THE SAID FORMULA AND SOLVE FOR D. THE RECIPROCAL
OF D IS THE ANSWER, WHY?
?
R !
?
F !
A !

130 * TYPE = Q
TEXT
ANOTHER GRATING PROBLEM: A GRATING HAS 5000 LINES PER
CENTIMETER. THE SECOND ORDER SPECTRUM OF A CERTAIN
COLORED LIGHT OCCURS AT 30 DEGREES. THE WAVELENGTH OF
THIS LIGHT IS:
A 5000 A
B 10000 A
C 1250 A
D 2000 A

\ ANSWER
EXTRA OFF
A + A
MATCH 1
B = B C D
? 0
ACTION
A
F !
I B
F !
RIUSE WAVELENGTH*D SIN(THETA)/N AND REMEMBER THE UNIT
CONSISTENCY.
B
F !
RISIN(30 DEGREES) IS 0.5; TRY AGAIN.
B
F !
A !
@
Let us now study the thin film interference. A thin air wedge is usually formed with two perfectly uniform glass plates as shown in Slide 8. The condition for forming any two adjacent bright fringes as \( B(n) \) and \( B(n+1) \) in the slide is:

\[
T_2 - T_1 = \frac{1}{2} \text{ wavelength of the incident light.}
\]

Answer:

A: Half
B: 0.5
C: 1/2

Action:

A: 1
B: ?

Answer the blank by typing in a proper number.

To produce constructive interference with beam A and B, the path difference of these two beams has to be a whole wavelength of the incident light. It may not be true if the wedge is not air. Try again.

To give a whole wavelength path difference in traveling back and forth once in the wedge, \( T_2 - T_1 = \text{half wavelength} \).

Consider the contact point of the two glass plates; is it a [bright/dark] fringe over that point?

Answer:

A: Dark
B: Bright

Action:

A: F
B:
To understand why a dark fringe is produced in this question, let us study the phase change condition when a light beam is reflected. Please answer "bright" or "dark".

160

Slide 9
Text

No phase change occurs at any surface for transmitted light as is shown in Figure (B) in Slide 9. However, for the reflected light, the indices of the two media forming the boundary surface determine whether or not the phase of the incident beam will change (reverse). Whenever the beam reaches an optically denser (greater index of refraction) medium from an optically lighter (smaller index of refraction) medium, the reflected beam inverts its phase (the wave should have had a downward amplitude, but backs up upward) as shown at the surface 2 in Figure (C). For the opposite case, the opposite is true as shown at surface 1 in the same figure. Then, a complete cancellation occurs to give the dark fringe as indicated in Figure (A).

165

W=INT(10*SR+1)*1E3
T=10*W/2*1E-8

170

Slide 9
Text

Let us apply this information to the following problem: When a light of wavelength \( \lambda = 10 \) Angstroms is reflected from an air wedge formed by two flat glass plates, the bright fringes are found to be 0.50 centimeters apart. How thick is the air wedge at a distance of 5.0 centimeters from the line of contact of the plates? Answer this question in centimeters. Remember that, for simplicity, we always assume that the wedge is illuminated with light at normal incidence.

Answer
\[ 0.34 \cdot 0.03 \cdot T \]

1 + T
2 + T, CM
3 + T, CENTIMETERS
ACTION
1 2 3
FI
SIOFF
1?
FI
R: THE DIFFERENCE OF WEDGE THICKNESS IS HALF WAVE-LENGTH BETWEEN TWO ADJACENT FRINGES, \n? 
FI
S110
SION
R: SEE SLIDE 10, AND TRY AGAIN, \? 
RI
? 
FI
F: THE TOTAL NUMBER OF FRINGES ON THE PLATE IS 10 AND EVERY TWO ADJACENT FRINGES GIVE A HALF-WAVELENGTH DIFFERENCE OF THE WEDGE THICKNESS, \ A!

180 TYPE=Q
PAGE
TEXT
IF THE WAVELENGTH OF THE INCIDENT LIGHT IS 4000 ANGSTROMS, REPEAT THE ABOVE PROBLEM WHEN THE WEDGE IS FILLED WITH WATER RATHER THAN AIR. THE INDEX OF REFRACTION OF WATER IS 4/3. \
\ ANSWER
1 + 0.00015, CM
2 + 0.00015, CENTIMETERS
3 + 0.00015
ACTION
1 2 3
FI
1?
FI
R: LIGHT WAVELENGTH IN WATER IS SMALLER THAN IT IS IN AIR. \?
FI
S111
SION
R: (WAVELENGTH IN WATER) = (WAVELENGTH IN AIR) / (INDEX OF REFRACTION OF WATER). THIS IS PROVED ON SLIDE 11.
REPRODUCED WITH PERMISSION OF THE COPYRIGHT OWNER. FURTHER REPRODUCTION PROHIBITED WITHOUT PERMISSION.
REPRODUCTION OF THE COATING), TRY AGAIN,\
B
F1
FMINIMUM THICKNESS=(WAVELENGTH OF LIGHT IN COATING)/4\A1\
R1

200 TYPE=Q
TEXT
REPEAT THE ABOVE PROBLEM IF THE INDEX OF REFRACTION OF
THE COATING IS 1.5 WHILE THAT OF THE LENS IS 1.25,
CHOOSE YOUR ANSWER FROM THE MULTIPLE CHOICE ANSWERS
IN THE LAST PROBLEM,
\ANSWER
EXTRA OFF
A + D
MATCH 1
B = A B C E F
? Ø
ACTION
A1
F1
1 B
F1
R; THERE IS NOW NO PHASE CHANGE AT THE SURFACE BETWEEN
THE COATING AND THE LENS, WHY?
B
F1
R; THE MINIMUM THICKNESS OF THE COATING HAS TO BE
HALF OF THE WAVELENGTH OF THE LIGHT IN THE COATING
WHICH HAS A GREATER INDEX OF REFRACTION (1.5) THAN
THAT OF THE GLASS, TRY AGAIN,\
B
F1
R; ALTHOUGH THE TOTAL PATH DIFFERENCE BETWEEN BEAMS A
AND B IS NOW A WHOLE WAVELENGTH, BEAM A CHANGES
PHASE BUT B DOES NOT, THUS A COMPLETE CANCELLATION
OCCURS BETWEEN THEM,\
B
F1
A1
Ø
R1

210 TYPE=Q
PAGE
SLIDE 13
TEXT
LET US CONSIDER SINGLE-SLIT DIFFRACTION NOW. DIFFRACTION IS A PHENOMENON THAT THE LIGHT BEAM PASSING THROUGH A SMALL OPENING OR SMALL OBJECT CHANGES ITS DIRECTION. IT IS RELATED TO THE RELATIVE MAGNITUDES OF OPENING WIDTH AND THE LIGHT WAVELENGTH, SEE SLIDE 13. WHEN YOU FINISH WITH THIS SLIDE, TYPE "GO".

ANSWER
A 0 GO
? 0
ACTION
A
R: TYPE "GO" TO CONTINUE.

PAGE 220 TYPE=Q
SLIDE 14
TEXT
THIS SLIDE DESCRIBES WHY THE BRIGHT AND DARK BANDS ARE FORMED. CAN YOU DERIVE A GENERAL FORMULA FOR THE DARK BANDS PRODUCED BY SINGLE-SLIT DIFFRACTION? CHOOSE YOUR ANSWER FROM:
A \[ \sin(\theta) = \frac{M\lambda}{(2w)} \]
B \[ \sin(\theta) = \left(\frac{M+1}{2}\right)\frac{\lambda}{w} \]
C \[ \sin(\theta) = \left(\frac{M-1}{2}\right)\frac{\lambda}{w} \]
D \[ \sin(\theta) = \frac{M\lambda}{w} \]

WHERE M=1,2, ...

ANSWER
EXTRA OFF
T + D
MATCH 1
U - A B C
? 0
ACTION
T
!
U
!
F
WHENEVER THE PATH DIFFERENCE OF THE TWO LIGHT RAYS PASSING THROUGH THE EDGES OF A SINGLE SLIT IS A MULTIPLE OF THE WAVELENGTH, A DARK FRINGE IS FORMED ON THE SCREEN.

U
F
A
@
230 TYPE-Q TEXT
FROM THE MULTIPLE CHOICE ANSWERS IN THE LAST QUESTION, CHOOSE THE CORRECT GENERAL EXPRESSION FOR THE BRIGHT BANDS PRODUCED BY SINGLE-SLIT DIFFRACTION.

ANSWER
EXTRA OFF
T + B
MATCH 1
U = A C D
? 0
ACTION
T
F
I
U
WHENEVER THE PATH DIFFERENCE OF THE TWO LIGHT RAYS PASSING THROUGH THE EDGES OF A SINGLE SLIT IS AN ODD MULTIPLE OF HALF WAVELENGTH OF THE LIGHT, A BRIGHT FRINGE IS FORMED ON THE SCREEN.

F
A
I
R

240 TYPE-Q PAGE
TEXT
NOW, LET US CONSIDER X-RAY DIFFRACTION. NO MAN-MADE SLIT IS NARROW ENOUGH TO PRODUCE DIFFRACTION WHEN X-RAYS ARE USED, THIS IS BECAUSE X-RAYS HAVE VERY SHORT WAVELENGTH (ABOUT ONE ANGSTROM), ONLY NATURAL ATOMIC SPACINGS IN A CRYSTAL CAN BE USED FOR THIS PURPOSE.

250 TYPE-Q SLIDE 15
TEXT
SLIDE 15 SHOWS THE X-RAY DIFFRACTION USING A CRYSTAL. WHICH OF THE EXPRESSIONS AS LISTED IN THIS SLIDE REPRESENTS THE GENERAL FORMULA FOR REINFORCED REFLECTION IN X-RAY DIFFRACTION?

ANSWER
EXTRA OFF
X + C
MATCH 1
Y = A 8
7 0
ACTION
X
I Y
FI
I

R1 CONSIDER THE PATH DIFFERENCE BETWEEN THE TWO ADJACENT REFLECTED BEAMS;
Y
FI
R1
Y
FI
A1
@R1

255 TYPE=C
W=INT(10*$R+1)
D=W/(2*3,8)

260 TYPE=Q
PAGE
TEXT
PROBLEM: A BEAM OF X-RAYS IS REFLECTED FROM A CRYSTAL. THE GRAZING ANGLE Theta FOR THE STRONGEST REFLECTION (FIRST ORDER) IS 53 DEGREES. IF THE WAVELENGTH OF X-RAYS IS \( \lambda \) ANGSTROMS, WHAT WOULD BE THE SMALLEST POSSIBLE SPACE BETWEEN ATOMS IN THIS CRYSTAL? THE SINE OF 53 DEGREES IS 4/5; GIVE YOUR ANSWER IN ANGSTROMS.

\ ANSWER
0 $\% = 03 + D
1 + D
2 + D, A
3 + D, ANGSTROMS
ACTION
1 2 3
FI
SIOFF
S10
L1 THIS IS THE END OF LESSON 2. SEE YOU LATER. 
R1

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R: USE THE CORRECT EXPRESSION IN THE LAST QUESTION.

S: OFF

THIS IS THE END OF LESSON 2. SEE YOU LATER.
Slide 1. Objectives.

Having completed this lesson, the student should be able to:

1. define "interference" and "diffraction" in words,

2. interpret the patterns of "interference" and "diffraction" in terms of wave motion,

3. list three basic requirements in performing Young's experiment,

4. apply the property of "interference" and "diffraction" of light in measuring wave length using the grating spectrometer or double-slit experiment,

5. determine the minimum thickness of a nonreflecting coating on an optical lens, and

6. determine the atomic spacing in a crystal by the method of x-ray diffraction.
Slide 2. Identical waves can reinforce or cancel each other, depending on their relative phase.

A, B in phase

(A)  

A, B out of phase by $1/2 \lambda$

(B)  

A, B out of phase by $\lambda$

(C)
Slide 3. Young's double-slit experiment.
Slide 4. Using a double-slit interference pattern to measure the wavelength of light.
Slide 5. A schematic diagram of a grating spectrometer. When the telescope is rotated on the arc of a circle, an image of the slit is formed by interference at an angle $\theta$. 
Slide 6. The plane diffraction grating.
Slide 7. Grating interference has different orders.

(A) The condition to form the first order maximum is when $AB = \lambda$

(B) The condition to form the second order maximum is when $AB = 2\lambda$
Slide 8. Thin air wedge film formed by two flat glass plates.
Slide 9. Reflected light inverts its phase at the surface of an optically denser medium.

(A) Two reflected light rays A and B cancel each other as the air film is very thin. (It approaches to zero thickness.)

(B) No phase change occurs for transmitted light at any boundary surface.

(C) No phase change occurs to the reflected wave (broken line), since the incident wave (solid line) is reflected at surface 1 which is formed by an optically lighter medium of air. But there is a phase change to the reflected wave (dotted line), since the reflection occurs at surface 2 which is formed by an optically denser medium of glass relative to the air film.
Slide 10. Short length measurement using thin-film interference.
Slide 11. The relationship between wavelength of light and the index of refraction.

Two basic formulas:

(A) (Speed of light) = (Frequency)(Wavelength)

(B) (Index of refraction) = (Speed of light in vacuum or air)/(Speed of light in medium)

When light travels in the air, from (A), then

\[ C = F \lambda_a \]  \hspace{1cm} (1)

When light travels in the water, from (A), then

\[ V = F \lambda_w \]  \hspace{1cm} (2)

From (B), (1) and (2)

\[ n = \frac{C}{V} = \frac{(F \lambda_a)}{(F \lambda_w)} = \lambda_a / \lambda_w \]

or \[ \lambda_w = \frac{\lambda_a}{n} \]
Slide 12. Thickness determination of nonreflecting material over lens.
Slide 13. The degree of diffraction depends on the relative dimension of opening width and the wavelength.
Slide 14. Single-slit diffraction. Alternating bright and dark fringes are formed by the interference from corresponding sources in adjacent regions.
Question:
Which of the following three formulas is the path difference between the two reflected beams A and B?

A \[ D \sin \theta = N \lambda \]
B \[ 2D \cos \theta = N \lambda \]
C \[ 2D \sin \theta = N \lambda \]

where \( N \) is the order of the reinforced reflection and \( \lambda \) is the wavelength.
"LEARN LESSON LISTING"

LESSON: LESSN3
DATE: 2/17/75
TIME: 14:13
PPI: 24000, 24005

10 TYPE=Q
TEXT
IS YOUR TERMINAL
1 TTY
2 TEK 4010
3 TEK 4002
\ ANSWER
1 0 1
2 0 2
3 0 3
? 0
ACTION
1 2 3
C15D=S A=1
\ PLEASE TYPE 1, 2 OR 3 ACCORDING TO THE CLASSIFICATION
OF YOUR TERMINAL.\n
20 TYPE=Q
PAGE
REVIEW ON>
STORE ON>
HINT ON>
TEXT
LESSON 3: PHOTOELECTRIC EFFECT AND PARTICLE WAVES.
THIS LESSON MAKES USE OF A SET OF SLIDES ENTITLED "PHOTO-
ELECTRIC EFFECT AND PARTICLE WAVES". THESE SLIDES SHOULD
BE MOUNTED ON THE PROJECTOR, AND THE SLIDE TRAY SHOULD BE
POSITIONED TO SLIDE ZERO. BE SURE THAT THE PROJECTOR IS
TURNED ON TO THE FAN POSITION, THEN, TYPE "READY".
\ ANSWER
PHONIC ON
A 0 READY
? 0
ACTION
A
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When the incident photon energy which is absorbed only by a single atomic electron is more than the work function, the electron will take up the surplus energy over the work function as its kinetic energy after leaving the target material. See slide 4. When you finish with this slide, type "GO".

Slide 5 shows the relationship between the variables involved in the photoelectric effect, which one of the following equations is the correct photoelectric equation that can be derived from the plot in slide 5?

A. F = hK + W
B. F = hK = W
C. K = hF + W
D. K = hF = W

Answer: Extra Off
A + 0
Match 1
B = A B C
? 0
Action
The magnitude of work function is a function only of the type of target material, which graph in Slide 6 represents the photoelectric effect correctly for three different target materials?

Answer:
A + A
B = B C D E

Action:
A
B

Different materials give different work functions, but they always give the same slope which equals Planck's constant in magnitude.

Critical or threshold wavelength is the longest wave.
LENGTH OF THE INCIDENT PHOTON THAT HAS JUST ENOUGH ENERGY TO PRODUCE THE PHOTOELECTRIC EFFECT. WHEN AN INCIDENT BEAM HAS THE THRESHOLD WAVELENGTH, WHICH OF THE FOLLOWING EQUATIONS IS CORRECTLY DEDUCED FROM THE PHOTOELECTRIC EQUATION, K=hf-w?

A  K=w
B  hf=w
C  hf=k

\ ANSWER
A + B
MATCH 1
B - A C
? Ø

ACTION
A
F: 1 B

AT CRITICAL WAVELENGTH OF THE INCIDENT BEAM, THE ELECTRON IS BARELY TORN OFF THE TARGET MATERIAL AND HAS ZERO KINETIC ENERGY AFTER LEAVING THE SURFACE OF THE TARGET PLATE,

B  R: WRONG! AT THE CRITICAL WAVELENGTH, THE PHOTOLUMINESCENT HAS ZERO KINETIC ENERGY IN K=hf-w. TRY AGAIN.

B
F: 1 A

TEXT
ASSUME THAT THE FREQUENCY F OF THE INCIDENT PHOTONS IS GREATER THAN THE CRITICAL OR THRESHOLD FREQUENCY. FROM SLIDE 7, WHICH OF THE FOLLOWING STATEMENTS IS CORRECT?

A  FIGURE A WILL HAVE GREATER PHOTOELECTRIC CURRENT
B  FIGURE B WILL HAVE GREATER PHOTOELECTRIC CURRENT
C  FIGURE C WILL HAVE GREATER PHOTOELECTRIC CURRENT
D  FIGURES A, B AND C WILL HAVE THE SAME CURRENT.

\ ANSWER
A + D
MATCH 1
B = A B C
? Ø
THE PHOTOELECTRIC CURRENT IS NOT A FUNCTION OF PHOTON ENERGY ONCE THE ENERGY IS GREAT ENOUGH TO PRODUCE THE CURRENT, TRY AGAIN.


\[ \lambda \] 
\[ v = \frac{1240}{\lambda} \] 
\[ n \text{, } \text{ where } c = 3 \times 10^8 \text{ m/sec} \text{, } f \text{ is frequency, and } \lambda \text{ is wavelength.} \]
SLIDE 8 SHOWS INCIDENT BEAMS OF THE SAME FREQUENCY OF $10^8$ CYCLES PER SECOND WITH DIFFERENT INTEENSITIES. ASSUME THE CRITICAL FREQUENCY OF THE TARGET MATERIAL IS $10^7$ CYCLES PER SECOND. WHICH OF THE FOLLOWING STATEMENTS IS CORRECT?

A. FIGURE A WILL PRODUCE GREATER CURRENT
B. FIGURE B WILL PRODUCE GREATER CURRENT
C. FIGURE C WILL PRODUCE GREATER CURRENT
D. FIGURES A, B AND C WILL PRODUCE THE SAME CURRENT
E. NONE OF FIGURES A, B AND C WILL PRODUCE CURRENT.

ANSWER
A: C
MATCH 1
B: A B D E
10
ACTION
A
1 B
F1

PHOTOELECTRIC CURRENT IS PROPORTIONAL TO THE INTENSITY OF THE INCIDENT PHOTONS ONCE THE PHOTON FREQUENCY IS GREATER THAN THE CRITICAL FREQUENCY OF A PARTICULAR TARGET MATERIAL.

B
F1
THE INTENSITY OF PHOTONS IS THE NUMBER OF PHOTONS INCIDENT ON A UNIT AREA OF THE TARGET PLATE PER UNIT TIME. TRY AGAIN.

B
F1
A
R1

CUT-OFF OR STOPPING POTENTIAL IS DEFINED AS THE POTENTIAL THAT IS AGAINST THE MOVEMENT OF PHOTOELECTRONS AND IS
JUST HIGH ENOUGH TO PREVENT PHOTOELECTRONS FROM REACHING THEIR COLLECTOR; IN OTHER WORDS, THE CUT-OFF POTENTIAL IS JUST HIGH ENOUGH TO STOP PHOTOELECTRONS BEFORE THEY FORM PHOTOELECTRIC CURRENT. SEE SLIDE 9 AND NOTICE THE POLARITY OF THE BATTERY, WHEN THE CUT-OFF POTENTIAL IS APPLIED, WHICH OF THE FOLLOWING STATEMENTS IS CORRECT?

A. (CUT-OFF POTENTIAL)(ELECTRONIC CHARGE)=WORK FUNCTION
B. (CUT-OFF POTENTIAL)(ELECTRONIC CHARGE)=PHOTON ENERGY
C. (CUT-OFF POTENTIAL)(ELECTRONIC CHARGE)=ELECTRON'S KINETIC ENERGY
D. CUT-OFF POTENTIAL=ELECTRON'S KINETIC ENERGY

\ANSWER A+C
MATCH 1
B = A B D
? 0
ACTION A
F1
I B
F1
R \HINT: THINK ABOUT THE DEFINITION OF THE CUT-OFF POTENTIAL.
D
F1
R \USE THE GENERAL RELATION: (POTENTIAL)(CHARGE)=ENERGY, TRY AGAIN.
B
F1
A 1
R 1

145 TYPE=C
V=INT(10*SR+1)
L=INT(10*SR+1)*1E3
H=6.63E-34
C=3E8
E=H*C/(L*1E-10)
A=C/(L*1E-10)
W=E-V*1.6E-19
X=INT(10*SR+1)
Y=INT(10*SR+1)*1E2
K=H*C/(X*1E-10)-V*1.6E-19
S=K*6.25E18

150 TYPE=Q

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A cut-off potential is measured to be \( V \approx 1.0 \) volts.

What is the kinetic energy of the photoelectron?

Give your answer in electron volts (eV).

Answer:

Extra on:

1 + \( V \), electron volts
1 + \( V \), eV

Action:

1
1
1?

The charge of an electron is one unit of electronic charge. Try again.

1

The kinetic energy in eV = (cut-off potential in V)(1 electronic charge).

120 Type-0

Slide 10 gives you a summary of the photoelectric effect. You are going to do a few more numerical problems about the photoelectric effect. Thus you may need to review this summary.

What is the energy of a photon with a wavelength of \( \lambda = 1.0 \) angstroms? Give your answer in joules.

Answer:

Extra on:

1 + \( E \), joules
1 + \( E \), J
2 - A

Action:

1
2

This is not the energy but the frequency of a photon.
TRY AGAIN.

I?

IF USE $E_{HF} = \hbar c / L$ WHERE $\hbar = 6.63 \times 10^{-34}$ J-SEC, $c = 3 \times 10^8$ M/SEC, AND $L$ IS THE GIVEN WAVELENGTH IN METER.

@.

$AE = \hbar c / L$.

190 TYPE-Q

PAGE TEXT

IF THE CRITICAL PHOTON WAVELENGTH FOR A CERTAIN MATERIAL IS \(\lambda_{1.01}\) ANGSTROMS, WHAT WILL BE THE WORK FUNCTION OF THIS MATERIAL? GIVE YOUR ANSWER IN JOULE.

\[ \text{ANSWER} \]

\[ 0 \times \hbar c, 03 \times E \]

\[ 1 \times E, \text{JOULES} \]

\[ 1 \times E, \text{J} \]

ACTION

1.

1?

IF SINCE $K = 0$ IN $K_{HF-W}$ AT THE CRITICAL WAVELENGTH, USE $W_{HF}$. TRY AGAIN.

1.

@.

FI AT CRITICAL WAVELENGTH; THE WORK FUNCTION EQUALS THE PHOTON ENERGY.

A!

200 TYPE-Q

PAGE TEXT

IF THE CUT-OFF POTENTIAL MEASURED USING \(\lambda_{1.01}\) ANGSTROM LIGHT IS \(V_{1.01}\) VOLTS, WHAT WILL BE THE WORK FUNCTION OF THE TARGET MATERIAL? GIVE YOUR ANSWER IN JOULE.

\[ \text{ANSWER} \]

\[ 0 \times \hbar c, 03 \times W \]

\[ 1 \times W \]

\[ 1 \times W, \text{JOULES} \]

\[ 1 \times W, \text{J} \]
What will be the kinetic energy of a photoelectron when \( \lambda = 1.0 \) Angstrom x-rays are shone on a metal surface which has a work function of \( \phi = 1.0 \) electron volts? Give your answer in joules.

\[
\text{Answer} \quad 0.03 \text{ joules}
\]

ACTION

F:

? R:

F: Use \( k \cdot H = k \cdot H \cdot W \) and solve for \( W \).

? R:

F: In \( k \cdot H = k \cdot H \), use \( k = q \) where \( q = 1.6 \times 10^{-19} \text{ coul} \), \( h = 6.63 \times 10^{-34} \text{ J} \cdot \text{sec} \), and \( c = 3 \times 10^8 \text{ m/sec} \). Try again.

? F:

A: \( W = k \cdot H / q \cdot W \)

210 TYPE=Q
PAGE TEXT

Following the last question, what will be the stopping potential for the photoelectron? Give your answer in ...

? R:

F:

A: \( k \cdot H = W = H \cdot C \)
VOLTS:
\ANSWER
\0 \%=-03*5
1 + S
1 + S*VOLTS
1 + S*V
\ACTION
1
? F1
F1
RIUSE 1 J=6.25E18 EV TO EXPRESS PHOTOELECTRON'S KINETIC ENERGry IN EV AND USE EV=(ELECTRONIC CHARGE)(VOLTAGE):
?
RI
@ F1 A1

240 \TYPE=C
M=INT(10*S*R+1)*1E1
V=INT(10*S*R+1)*1E2
L=H/(M*1E-3*V)

250 \TYPE=Q
\PAGE
\SLIDE 11
\TEXT
SLIDE 11 GIVES YOU A SUMMARY ABOUT PARTICLE WAVES, YOU MAY NEED TO REVIEW THIS SUMMARY IN ANSWERING THE LAST QUESTION.
WHAT IS THE WAVELENGTH ASSOCIATED WITH A __4__-GRAM BULLET FIRED WITH A SPEED OF __17__ METERS PER SECOND? GIVE YOUR ANSWER IN METERS:
\ANSWER
\0 \%=-03*6
2 + L
2 + L* METERS
2 + L* M
\ACTION
2 F1
? F1
RIUSE L=H/(MV):
?
ARE YOU USING THE PROPER UNIT SYSTEM? TRY AGAIN.

270 TYPE=Q
PAGE
TEXT
THIS IS THE END OF THIS LESSON, SEE YOU LATER.
SLIDE OFF
SLIDE 0
ACTION
LI
Slide 1. Objectives.

Having completed this lesson, the student should be able to:

1. interpret the photoelectric effect in terms of Einstein's photoelectric equation, and
2. calculate

   (1) the photon energy when photon's wavelength or frequency is given,
   (2) the kinetic energy of a photoelectron when photon energy and work function are given,
   (3) the critical or threshold wavelength when the work function of a material is given and vice versa,
   (4) the stopping or cut-off potential of photoelectrons when their kinetic energy is known, and
   (5) the wavelength of a particle wave when the particle's mass and speed are known.
Parallel metal plates

Battery Galvanometer

Slide 2. Photoelectric effect is produced when energetic photons are shot at a solid metal as shown in (B).
Slide 3.

The work function of a substance is the quantity of energy that is just large enough to free an atomic electron from the atom. The photon action in freeing the atomic electron is shown in (A), and a potential well representation of this action is shown in (B).
The photon energy equals the work function in (A), but the photon energy is greater than the work function in (B).
Slide 5.

A graphical representation of Einstein's photoelectric equation.

- $K$ (Kinetic energy of photoelectron in joule)
- $F$ (Frequency of the incident photon in cycle per second)
- $-W$ (W is a positive quantity representing work function of a particular substance, in joule)

Slope = $H$ (Planck's constant)
Slide 6. Which graph correctly represents Einstein's photoelectric effect for three different target substances? \( K \) = photoelectron's kinetic energy, and \( F \) = photon's frequency.

(A) \( K \) vs. \( F \)

(B) \( K \) vs. \( F \)

(C) \( K \) vs. \( F \)

(D) \( K \) vs. \( F \)

(E) \( K \) vs. \( F \)
Slide 7. What is the relationship between the frequency of the incident photons and the magnitude of photoelectric current?
Slide 8. What is the relationship between the incident beam intensity and the magnitude of photoelectric current?
Slide 10. A summary of photoelectric effect.

1. Not all electromagnetic waves can produce the photoelectric effect. It is produced only when the wavelength (frequency) of the incident wave is shorter (greater) than the critical wavelength (frequency).

2. Once the photoelectric effect is produced, the photoelectric current increases when the intensity of the incident beam increases.

3. The major formulas involved in the photoelectric effect are:

   (1) Photon energy
       \[ E = HF \]
       where \( E \) = photon energy in joules
                       \( H \) = Planck's constant
                       \( F \) = photon frequency in cycle/sec

   (2) Einstein's photoelectric equation
       \[ K = HF - W \]
       \( K \) = photoelectron's kinetic energy in joules
               \( W \) = work function in joules

   (3) Wavelength and frequency relation of electromagnetic waves
       \[ C = FL \]
       \( C \) = speed of light in vacuum
               \( L \) = wavelength in meters

   (4) Photoelectron's kinetic energy and cut-off potential relation
       \[ K = QV \]
       \( Q \) = electronic charge in coulombs
               \( V \) = cut-off potential in volts

4. Conversion factors:

   (1) \( 1 \) electron volt = \( 1.6 \times 10^{-19} \) joules

   (2) \( 1 \) joule = \( 6.25 \times 10^{18} \) electron volts

   (3) \( 1 \) angstrom = \( 10^{-10} \) meters
Slide 11. A summary of particle waves.

1. Any moving particle or object also has wave properties. De Broglie waves and matter waves are the other names of the particle wave. It is not an electromagnetic wave, therefore, it is treated differently from that of electromagnetic waves.

2. The formulas involved in particle waves are:

   (1) Wavelength of a particle wave \[ L = \frac{H}{P} \]
   where \( L \) = wavelength of particle wave in meters
       \( H \) = Planck's constant
       \( P \) = particle's momentum in kg.m/sec
   \[ L = \frac{H}{\sqrt{2ME}} \]

   (2) Particle's (kinetic) energy \[ E = \frac{1}{2} MV^2 \]
   \( M \) = particle's mass in kilograms
   \( E \) = particle's kinetic energy in joules
   \( V \) = particle's speed in m/sec

   (3) Particle's momentum \[ P = MV \]

3. Whenever the speed of a moving particle approaches the speed of light, the mass of the particles in the above formulas should be corrected by the following expression:

   \[ M = \frac{M_0}{\sqrt{1 - (V/C)^2}} \]
   where \( M \) = relativistic mass of the particle in kilograms
   \( M_0 \) = rest mass of the particle in kilograms

4. As with the electromagnetic waves, the longer the wavelength of the particle wave, the more evident the wave properties of the moving particle will be. The opposite is also true.
LESSON 4: BOHR'S ATOM AND ATOMIC SPECTRUM.

THIS LESSON MAKES USE OF A SET OF SLIDES ENTITLED "BOHR'S ATOM AND ATOMIC SPECTRUM". THESE SLIDES SHOULD BE MOUNTED ON THE PROJECTOR, AND THE SLIDE TRAY SHOULD BE POSITIONED TO SLIDE ZERO. BE SURE THAT THE PROJECTOR IS TURNED ON TO THE FAN POSITION, THEN, TYPE "READY".
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ANSWER
$0.03 \times V$
$1 \times V$
$1 \times \text{meters per second}$
$1 \times \text{meter/second}$
$1 \times \text{m/sec}$

ACTION
1

? 

RIEQUATE THE COULOMB FORCE TO THE PRODUCT OF THE ELECTRON'S MASS AND ITS ACCELERATION WHICH IS EXPRESSED IN TERMS OF THE ELECTRON'S SPEED,

? 

RICEHCK FOR CORRECT UNIT OF THE TWO CHARGES (USE COULOMBS) AND THE UNIT OF THE RADIUS (USE METERS) OF THE ELECTRON'S CIRCULAR PATH. TRY AGAIN.

$AIV = \sqrt{KQ_1Q_2/(MR)}$

80 TYPE=Q
PAGE
SLIDE 3
TEXT
SLIDE 3 SHOWS THE ASSUMPTIONS BOHR MADE WHEN HE DEVELOPED HIS THEORY USING RUTHERFORD'S NUCLEAR MODEL OF ATOMS. WHEN YOU FINISH WITH THIS SLIDE, TYPE "GO".

<table>
<thead>
<tr>
<th>ANSWER</th>
<th>A 0 GO</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTION</td>
<td>A 0</td>
</tr>
<tr>
<td>RITYPE &quot;GO&quot; TO CONTINUE,</td>
<td></td>
</tr>
</tbody>
</table>

100 TYPE=Q
PAGE
SLIDE 4
TEXT
THE THEORY OF BOHR'S ATOM IS SUMMARIZED WITH SEVERAL EQUATIONS AS SHOWN IN SLIDE 4, YOU ARE GOING TO USE THEM TO SOLVE A FEW TYPICAL PROBLEMS ABOUT BOHR'S ATOM. BE SURE YOU UNDERSTAND THE NOTATIONS AND THEIR UNITS
USED IN THESE EQUATIONS, IF YOU ARE INTERESTED IN THEIR DERIVATION, TYPE "DERIVE". OTHERWISE, TYPE "GO" TO CONTINUE THE LESSON.

ANSWER
A 0 GO
B 0 DERIVE
? 0
ACTION
A
B
110

R: IF YOU WANT TO GO THROUGH THE STEPS OF THE DERIVATION OF THE EQUATIONS SHOWN IN SLIDE 4, TYPE "DERIVE". IF YOU WANT TO SKIP THEM, TYPE "GO".

SLIDE 5
TEXT
SLIDE 5 SHOWS THE DERIVATION OF THE EQUATION WHICH GIVES THE RELATIONSHIP BETWEEN THE ENERGY OF THE ATOMIC ELECTRON AND ITS PRINCIPAL QUANTUM NUMBER, WHEN YOU FINISH WITH THIS SLIDE, TYPE "GO".

ANSWER
A 0 GO
? 0
ACTION
A
RI "GO" TO CONTINUE,

SLIDE 6
TEXT

ANSWER
A 0 GO
? 0
ACTION
A
RITY ~E "GO" TO CONTINUE.\n
130 TYPE-Q
PAGE
SLIDE 7
TEXT
SLIDE 7 SHOWS THE DERIVATION OF THE EQUATION WHICH GIVES THE RELATIONSHIP BETWEEN THE WAVELENGTH OF THE EMITTED PHOTON FROM THE ELECTRON TRANSITION AND THE TWO PRINCIPAL NUMBERS OF THE INITIAL AND FINAL STATES OR ENERGY LEVELS. WHEN YOU FINISH WITH THIS SLIDE, TYPE "GO". \n\nANSWER
A 0 GO
? 0
ACTION
A
RITY "GO" TO CONTINUE.\n
140 TYPE-Q
PAGE
SLIDE 8
TEXT
SLIDE 8 SHOWS THE ENERGY LEVEL DIAGRAM OF HYDROGEN ATOM. WHEN YOU FINISH WITH THIS SLIDE, TYPE "GO". \n\nANSWER
A 0 GO
? 0
ACTION
A
RITY "GO" TO CONTINUE.\n
150 TYPE-Q
PAGE
SLIDE 9
TEXT
SLIDE 9 SHOWS THE PRINCIPLE OF THE ATOMIC ABSORPTION SPECTRUM. WHEN YOU FINISH WITH THIS SLIDE, TYPE "GO". \n\nANSWER
A 0 GO
? 0
ACTION
NOW, LET US DO SOME PROBLEMS CONCERNING BOHR'S ATOMS:

WHAT IS THE WAVELENGTH OF THE FIRST (THE SHORTEST) LINE OF THE LYMAN SERIES IN CENTIMETERS?

ANSWER

1. $2 \times 10^{-7} \text{ cm}$
2. $1.22 \times 10^{-5} \text{ cm}$
3. $3.65 \times 10^{-5} \text{ cm}$

ACTION

1. PI
2. PI
3. PI

RIDID YOU FORGET THE SQUARE TERM IN EQUATION (C) IN SLIDE 4? TRY AGAIN.

RICHCK THE VALUE OF THE SECOND PARENTHESIS IN EQUATION (C) IN SLIDE 4. TRY AGAIN.

RU$E$ EQUATION (C) IN SLIDE 4.

RICHCK FOR THE PROPER UNITS IN YOUR CALCULATION. TRY AGAIN.

180 TYPE-Q

PAGE

TEXT

CONSIDER THE SINGLY POSITIVE-CHARGED HELIUM ION. WHAT
IS THE ENERGY OF THE REMAINING ELECTRON IN THIS HELIUM ION IF THE ELECTRON IS IN THE SECOND ENERGY LEVEL (N=2)? GIVE YOUR ANSWER IN ELECTRON VOLTS.

\ACTION
1 + 13.6
1
F:
F:
R\I\S\E \E\Q\U\A\T\I\\N (A) IN SLIDE 4 WITH \( z=2 \) AND \( N=2 \).

190 \TYPE=Q
\TEXT
FOLLOWING THE LAST QUESTION, WHAT WOULD BE THE RADIUS IN ANGSTROMS OF THE ELECTRON'S ORBIT?

\ACTION
0 \%=0.05
1 + 1.06
1 + 1.06, ANGSTROMS
1 + 1.06, A

200 \TYPE=Q
\TEXT
FOLLOWING THE LAST QUESTION, WHAT WOULD BE THE ENERGY OF THE EMITTED PHOTON WHEN THIS ELECTRON FALLS BACK TO ITS GROUND STATE? GIVE YOUR ANSWER IN ELECTRON VOLTS.

\ACTION
0 \%=0.3
1 + 40.8
1 + 40.8, ELECTRON VOLTS

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1 + 40.8 eV
ACTION
1 F
3? F
RICALCULATE THE ENERGIES OF THE TWO LEVELS (N=1 AND N=2) USING EQUATION (A) IN SLIDE 4, THEN, USE EQUATION (D) TO FIND THE ENERGY OF THE EMITTED PHOTON.
3 F
RID YOU CORRECTLY IDENTIFY THE INITIAL AND FINAL STATES OF THE ELECTRON? TRY AGAIN.
0
F
A
220 TYPE=O
PAGE TEXT
IT IS MEASURED THAT THE INCIDENT PHOTON ENERGY HAS TO BE 91.8 ELECTRON VOLTS FOR EXCITING AN ATOM OF A CERTAIN SUBSTANCE FROM THE GROUND STATE TO ITS FIRST EXCITED STATE. WHICH OF THE FOLLOWING COULD BE THE SUBSTANCE?
A HYDROGEN
B SINGLY CHARGED HELIUM ION
C DOUBLY CHARGED LITHIUM ION

ANSWER EXTRA OFF
A + C
MATCH 1
B = A B
? 0
ACTION
A F
1 B F
R FROM EQUATION (A), WE CAN SEE THAT IF X EV OF EXCITATION ENERGY IS REQUIRED FOR HYDROGEN, THEN 4X EV MUST BE SUPPLIED TO THE SINGLY CHARGED HELIUM ION; AND 9X EV TO THE DOUBLY CHARGED LITHIUM ION.
B F
A
0
R
When Bohr's theory is extended by wave mechanics, four quantum numbers must be used to assign the atomic electrons to different states. Slide 10 gives the meaning of these four quantum numbers. It also gives an example of the electron distribution in the atom using these quantum numbers following the Pauli exclusion principle.

Here is one typical question concerning the atomic electrons: distribution.

How many electrons can exist in the second shell (N=2 shell)?

Answer
1 + 8

Action
1
1
F1

Follow the branching method used in the example in Slide 10.

Repeat the last question for the fourth shell.

Answer
1 + 32

Action
1
1
F1

Follow the branching skill given in Slide 10.
SLIDE 11 GIVES A REVIEW ABOUT HEAT AND JOULE'S LAW; YOU MAY NEED THIS INFORMATION TO ANSWER THE FOLLOWING TWO QUESTIONS.

AN X-RAY TUBE OPERATES AT \[ \sqrt{1050} \] VOLTS WITH A CURRENT OF \[ \frac{100}{11} \] MILLIAMPERES BOMBARDING THE TARGET PLATE. HOW MUCH HEAT IS PRODUCED IN THE PLATE PER SECOND?

GIVE YOUR ANSWER IN CALORIES PER SECOND.

\[ \text{Answer} \]

\[ \theta = e^{0.3e_p} \]

\[ 1 + P \]

\[ 1 + P \text{, Calories per second} \]

\[ 1 + P \text{, Calorie/second} \]

\[ 1 + P \text{, Cal/sec} \]

\[ \text{ACTION} \]

1.

\[ \text{F:} \]

1.

1.

2.

\text{RISE THE UNIT RELATIONSHIP}:

\[ \text{(Joule/Second)} = (\text{Amperes})(\text{Volt}) \]

1. \text{Calorie} = 4.2 \text{ Joules; \}

3.

\[ \text{RECHECK YOUR CALCULATION FOR PROPER UNITS, TRY AGAIN.} \]

1.

1.

275 TYPE=C

\[ V = \text{INT}(10 \text{SR} + 1) \times 10^3 \]

\[ I = \text{INT}(10 \text{SR} + 1) \times 10^2 \]

\[ P = 1 \times 10^2 \div \sqrt{4.2} \]

\[ M = \text{INT}(10 \text{SR} + 1) \times 10^2 \]

\[ S = \text{INT}(10 \text{SR} + 1) \times 10^1 \]

\[ T = 60 \div (M \times S) \]

\[ X = \frac{7}{60} \]

\[ Y = 60 \times P \]

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CALORIE PER GRAM PER DEGREE OF CENTIGRADE.
WHAT TEMPERATURE RISE WOULD OCCUR IN 1.0 MINUTE IF NO
HEAT IS LOST? GIVE YOUR ANSWER IN DEGREES CENTIGRADE.

ANSWER
0 \%=0.03\%T
1 + T
1 + T, DEGREES
1 + T, C
2 = X
2 = X, DEGREES
2 = X, C
3 = Y
3 = Y, DEGREES
3 = Y, C
ACTION
1
2
3
THIS IS THE TEMPERATURE RISE PER SECOND RATHER
THAN PER MINUTE. TRY AGAIN.
3
THIS IS THE HEAT DEVELOPED PER MINUTE RATHER
THAN THE TEMPERATURE RISE PER MINUTE. TRY AGAIN.
1
? REUSE H=MST TO SOLVE FOR T.
? RECHECK FOR THE PROPER UNITS IN YOUR CALCULATION.
TRY AGAIN.
? REUSE H=MST TO SOLVE FOR T WHERE H=HEAT IN CALORIE,
M=MASS IN GRAM, S=SPECIFIC HEAT IN CAL/DEG=GM, AND
T=TEMPERATURE CHANGE IN DEGREE OF CENTIGRADE.

280 TYPE=Q
SLIDE OFF
SLIDE 0
TEXT
THIS IS THE END OF THIS LESSON, SEE YOU LATER.
ACTION
L1
Slide 1. Objectives.

Having completed this lesson, the student should be able to:

1. apply Bohr's theory to a single-electron atom or a single-electron ion in calculating:
   (1) the radius of any quantized orbit of an atomic electron,
   (2) the energy at any of the states of the atom or the ion,
   (3) the ionization energy of the atom or the ion, and
   (4) the energy, wavelength, and frequency of a photon emitted
       or absorbed by an atom or an ion during its transition or
       excitation process.

2. determine the distribution of atomic electrons according to the Pauli
   exclusion principle and the quantum numbers.
Slide 2. Formulas used in circular motion.

Newton's second law:

\[ F_c = m \frac{v^2}{r} \]

where \( F_c \) = centripetal force in newtons
\( m \) = mass of the moving object in kilograms
\( V \) = constant speed of the moving object in m/sec
\( r \) = radius of the circular path in meters

Coulomb's law:

\[ F_e = k \frac{Q_1Q_2}{r^2} \]

where \( F_e \) = Coulomb's force in newtons
\( Q_1, Q_2 \) = charges in coulombs
\( r \) = distance between two point charges in meters
\( k \) = Coulomb's constant = \( 9 \times 10^9 \text{N} \cdot \text{m}^2/\text{coul}^2 \)

Electric potential energy due to a point-charge field:

\[ U = k \frac{Q_1Q_2}{r} \]

where \( U \) = potential energy in joules
\( Q_1, Q_2, r \), and \( k \) are the same as above

Period of circular motion with constant speed:

\[ T = \frac{2\pi r}{V} = \frac{1}{\text{freq}} \]

where \( T \) = period
\( \text{freq} \) = frequency
1. The atomic electron rotates about a stationary nucleus in a circular orbit with the coulomb
   force as the centripetal force.
2. Newton's second law is valid in the atomic domain.
3. The atomic electron does not radiate any electromagnetic waves when it is rotating in any one
   of its quantized orbits of which the radii are quantized by a series of multiple values of
   the electron's constant momentum. In other words, the electron's orbital length is measured
   by multiple numbers of the de Broglie wavelength of the electron.
4. The emission of electromagnetic waves occurs only when the transition of the atomic electron
   from outer to inner orbits takes place. Transition takes place spontaneously. The emitted
   photon carries an energy which equals the energy difference between the initial and final
   states over which the electron has made its transition.
5. Bohr's theory was derived based upon a single-electron atom (hydrogen atom), therefore, this
   theory can be applied to the hydrogen atom or to any single-electron ions, such as the singly
   charged helium ion and the doubly charged lithium ion.

1. The relationship between level-energy and the principal quantum number (\(E_N - N\) relation)

\[E_N = -13.6 \left(\frac{Z}{N}\right)^2\]  \(\ldots \ldots \) (A) 

where \(E_N =\) level-energy in electron volts 
\(Z =\) atomic number 
\(N =\) principal quantum number

2. The relationship between the electron's orbital radius and the principal quantum number (\(R_N - N\) relation)

\[R_N = 0.531 \left(\frac{N^2}{Z}\right)\]  \(\ldots \ldots \) (B) 

where \(R_N =\) orbital radius in angstroms 
\(Z, N\) are as above

3. The relationship between the wavelength of the emitted photon and the principal quantum number (\(L - N\) relation)

\[\frac{1}{L} = 109678Z^2\left(\frac{1}{P^2} - \frac{1}{N^2}\right)\]  \(\ldots \ldots \) (C) 

where \(L =\) photon wavelength in centimeters 
\(P, N\) assume integers greater than zero 
\(Z =\) atomic number as above

(Note: For hydrogen atom (\(Z=1\)) the first three series of line spectrum are Lyman series when \(P=1, N=2, 3, 4 \ldots\), Balmer series when \(P=2, N=3, 4, 5 \ldots\), and Paschen series when \(P=3, N=4, 5 \ldots\))

4. The energy of photon emitted during transition

\[\text{HF} = E_i - E_f\]  \(\ldots \ldots \) (D) 

where \(H =\) Planck's constant 
\(= 6.63 \times 10^{-34}\) joule.seconds 
\(F =\) photon's frequency in cycle per second 
\(E_i =\) initial-state energy in joules 
\(E_f =\) final-state energy in joules

5. The energy of photon absorbed during excitation

\[\text{HF} = E_f - E_i\]  \(\ldots \ldots \) (E)

6. The relationship between the energy and wavelength of a photon (\(E - L\) relation)

\[EL = 12400\]  \(\ldots \ldots \) (F) 

where \(L =\) Photon's wavelength in angstroms 
\(E =\) Photon's energy in electron volts
Slide 5. The derivation of the equation: \( E_N = -13.6 \left( \frac{Z}{N} \right)^2 \)

From Coulomb's law for a single-electron atom or a single-electron ion with an atomic number \( Z \), we have

\[
F = \frac{kZe^2}{R^2}
\]

Newton's second law:

\[
F = m\frac{V^2}{R}
\]

(1) = (2)

\[
mV^2 = \frac{kZe^2}{R}
\]

From (3), the kinetic energy of the electron will be \( KE = \frac{1}{2} mV^2 = \frac{kZe^2}{2R} \)

The potential energy of the electron in the nucleus electric field is \( PE = \frac{kZe^2}{R} \)

The total energy of the electron (or atom) is \( E = KE + PE \)

From (4), (5), and (6),

\[
E = -\frac{kZe^2}{2R}
\]

From the assumption that the electron's orbital length is a multiple number of the electron's de Broglie wavelength, then \( 2\pi R = NL = N \frac{H}{F} = N \frac{H}{mV}, \text{ or } V = \frac{2\pi Rm}{NH} \)

Substitute (8) into (3) and solve for \( R \), then substitute \( R \) into (7),

\[
E = -\left( 2\pi^2 k^2 e^4 Z^2 m/H^2 \right) \left( 1/N^2 \right)
\]

When proper values are substituted into (8), the final result is

\[
E_N = -13.6 \left( \frac{Z}{N} \right)^2 \text{ where } E_N \text{ is used for } E \text{ and it is in electron volts.} \]
Slide 6. The derivation of the equation \( R_N = 0.531(N^2/Z) \)

From Coulomb's law for a single-electron atom or a single-electron ion with an atomic number \( Z \),

\[
F = \frac{kze^2}{R^2}
\]  \hspace{1cm} (1)

From Newton's second law, \( F = m \frac{v^2}{R} \)

\[
(1) = (2) \hspace{1cm} m\frac{v^2}{R} = \frac{kze^2}{R}
\]  \hspace{1cm} (2)

From the assumption that the electron's orbital length is a multiple number of the electron's de Broglie wavelength, then

\[2\pi R = NL = N \frac{\hbar}{p} = N \frac{\hbar}{mv} \]

or

\[v = \frac{2\pi Rm}{NH}\]

(4)

Substitute (4) into (3) and solve for \( R \)

\[R = \left( \frac{\hbar^2}{4\pi^2 e^2 mk} \right) \frac{(N^2/Z)}{}\]

(5)

When proper values are substituted into (5), the final result is:

\[R_N = 0.531(N^2/Z)\]

where \( R_N \) is in angstroms.
Slide 7. The derivation of the equation \(\frac{1}{L} = 1096782 \left(\frac{1}{P^2} - \frac{1}{N^2}\right)\)

From equation (7) in slide 5,
\[E = -\frac{kZ\varepsilon^2}{2R}\]  \hspace{1cm} (1)
\[R = \frac{\hbar^2}{4\pi^2 \varepsilon^2 mk} \left(\frac{N^2}{Z}\right)\]  \hspace{1cm} (2)

From equation (5) in slide 6,

The energy of the emitted photon can be expressed as
\[\text{HF} = E_N - E_P\]
or
\[\frac{\text{HC}}{L} = E_N - E_P\]  \hspace{1cm} (3)

where N and P are the two different numbers of energy levels involved in the transition.

For level N, equations (1) and (2) can be written as
\[E_N = -\frac{kZ\varepsilon^2}{2R_N}\]  \hspace{1cm} (4)
\[R_N = \frac{\hbar^2}{4\pi^2 \varepsilon^2 N \mk} \left(\frac{N^2}{Z}\right)\]  \hspace{1cm} (5)

For level P, equations (1) and (2) can be written as
\[E_P = -\frac{kZ\varepsilon^2}{2R_P}\]  \hspace{1cm} (6)
\[R_P = \frac{\hbar^2}{4\pi^2 \varepsilon^2 P \mk} \left(\frac{P^2}{Z}\right)\]  \hspace{1cm} (7)

Substitute (4) and (6) into (3) and then eliminate \(R_N\) and \(R_P\) using (5) and (7),
\[\frac{1}{L} = \frac{2\pi^2 Z^2 \varepsilon^4 \mk^2}{\hbar^3 C} \left(1/P^2 - 1/N^2\right)\]  \hspace{1cm} (8)

When proper values are substituted into (8), the final result is
\[\frac{1}{L} = 1096782 \left(1/P^2 - 1/N^2\right)\]

where the wavelength is in centimeters.
Slide 8.

Energy level diagram of the hydrogen atom

Continuous spectrum
Paschen series
Balmer series
Lyman series
Slice 9.

The quantization of photon energy when it is absorbed by an atomic electron.
Slide 10. The distribution of atomic electrons according to the four quantum numbers.

- **n**: Principal quantum number which specifies energy level or shell.
- **l**: Orbital quantum number which specifies the shape of the orbital or subshell.
- **m_l**: Magnetic quantum number which specifies the orientation of the orbital.
- **m_s**: Spin quantum number which specifies the direction of the electron's spin.

The general rule to determine the values of quantum numbers:

- \( n = 1, 2, 3, \ldots \)
- \( l = 0, \pm 1, \pm 2, \ldots \pm (n - 1) \)
- \( m_l = 0, \pm l \)
- \( m_s = \pm 1/2 \) for each \( m_l \)

An example of \( n = 3 \) is shown on the left.

1. The temperature of a substance increases when it absorbs heat. The opposite is also true. The following equation gives the relation between the heat absorbed (or released) by a body which has a mass M and specific heat of S and the temperature rise (or drop):

\[ H = MS(T_f - T_i) \]

where

- \( H \) = heat absorbed (or released) in calories
- \( M \) = mass of the substance in grams
- \( T_i \) = initial temperature of the substance in degrees centigrade
- \( T_f \) = final temperature of the substance in degrees centigrade

2. Joule's Law: Heat is energy. The relationship between calories and joules is:

1 calorie = 4.2 joules
"LEARN LESSON LISTING"

LESSON: LESN5
DATE: 2/17/75
TIME: 14:13
PPN: 24000, 24005

10 TYPE=Q
PAGE
TEXT
IS YOUR TERMINAL
  1 TTY
  2 TEK 4010
  3 TEK 4002

\ANSWER
1 0 1
2 0 2
3 0 3
\ACTION
1 2 3
\CISD=#A=1

PLEASE TYPE 1, 2 OR 3 ACCORDING TO THE CLASSIFICATION
OF YOUR TERMINAL.

20 TYPE=Q
PAGE
REVIEW ON>
STORE ON>
HINT ON>
TEXT
LESSON 5: COULOMB'S LAW AND ELECTRIC FIELDS

THIS LESSON MAKES USE OF A SET OF SLIDES ENTITLED
"COULOMB'S LAW AND ELECTRIC FIELDS". THESE SLIDES SHOULD
BE MOUNTED ON THE PROJECTOR, AND THE SLIDE TRAY SHOULD BE
POSITIONED TO SLIDE ZERO. BE SURE THAT THE PROJECTOR IS
TURNED ON TO THE FAN POSITION, THEN, TYPE "READY".

\ANSWER
A 0 READY
? 0
\ACTION
A
180

CONSULTANT. O T H E R W I S E, T Y P E "R E A D Y" (N O Q U O T A T I O N M A R K)
/

30 T Y P E = Q
PAGE
SLIDE 1
SLIDE ON
TEXT
READ I N G, T Y P E "G O", 
/
ANSWER
A 0 G O
? 0
ACTION
A
P I
*
P L E A S E T Y P E "G O" T O C O N T I N U E (N O Q U O T A T I O N M A R K)
/

40 T Y P E = R
VECTOR A D D I T I O N

50 T Y P E = Q
SLIDE 2
TEXT
T W O V E C T O R S. W H E N Y O U F I N I S H W I T H T H I S S L I D E, T Y P E "G O", 
/
ANSWER
A 0 G O
? 0
ACTION
A
C I F S E E N ( 1 0 5 0 ) = 0, B I 6 0
R I T Y P E 
"# C" T O G E T B A C K W H E R E Y O U L E F T O F F; 
*
R I T Y P E "G O" T O C O N T I N U E ;
/

60 T Y P E = C
A = I N T ( 1 0 0 * S R + 1 0 )
B = I N T ( 1 0 0 * S R + 1 0 )
X = A * A + B * B
R = S Q R T ( X )
D = A T A N D ( A / B )

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VECTOR A OF \[
\begin{bmatrix} 1 \\ 0 \end{bmatrix}
\] UNITS POINTS NORTH AND VECTOR B OF \[
\begin{bmatrix} 0 \\ 1 \end{bmatrix}
\] UNITS EAST, FIND THE MAGNITUDE OF THEIR RESULTANT.

ANSWER

\[
\begin{align*}
0 &= \sqrt{0.03} \\
1 + R &= 1 + R \text{ UNITS} \\
0 &= \sqrt{0.01} \times X \\
2 &= X \text{ UNITS}
\end{align*}
\]

ACTION

1

2

THIS IS THE SQUARE OF THE RESULTANT, TRY AGAIN.

1

2

R = \sqrt{A \times A + B \times B}, TRY AGAIN.

1

2

WRONG! R = \sqrt{A \times A + B \times B} =

WHAT IS THE ANGLE IN DEGREE OF THE ABOVE RESULTANT, IF IT IS MEASURED FROM THE EAST?

ANSWER

\[
\begin{align*}
0 &= \sqrt{0.03} \times D \\
1 + D &= 1 + D \text{ DEGREES} \\
0 &= \sqrt{0.01} \times Y \\
2 &= Y \text{ DEGREES}
\end{align*}
\]

ACTION

1

2
1. Switch the positions of A and B in your formula.
   Try again.
2. Use the fourth equation in Slide 2 to find the angle.
3. Wrong! \( \text{Angle} = \text{atan}(A/B) \)

90 Type-R

VECTOR RESOLUTION

100 Type-Q

SLIDE 3

Text:
SLIDE 3 shows the procedure of how to resolve a vector into two perpendicular components. When you finish with this slide, type "go".

\[ \text{Answer} \]
\[ \text{A \ 0 \ GO} \]
\[ \text{? \ 0} \]
\[ \text{Action} \]
\[ \text{A} \]
\[ \text{PI} \]
\[ \text{IF \ SEEN(1100)=0, B110} \]
\[ \text{R1 Type "#C" to get back where you left off.} \]
\[ \text{@} \]
\[ \text{R1 Type "GO" to continue.} \]

110 Type-R

Another method of adding vectors

120 Type-Q

SLIDE 4

Text:
SLIDE 4 shows vector addition by resolving all vectors into components along X and Y axes first, then adding the two reduced perpendicular resultants vectorially. When you finish with this slide, type "go".

\[ \text{Answer} \]
\[ \text{A \ 0 \ GO} \]
Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
SLIDE 6 ILLUSTRATE THE RELATIONSHIP BETWEEN ELECTRIC FORCE AND ELECTRIC FIELD DUE TO POINT CHARGES. WHEN YOU FINISH WITH THIS SLIDE, TYPE "GO".

\ANSWER
A 0 GO
? 0
ACTION
A
R1

TYPE "GO" TO CONTINUE.

160 TYPE=C
Q1=INT(10*SR+1)*1E-7
Q2=INT(10*SR+1)*1E-7
X1=INT(100*SR+10)
X2=INT(100*SR+10)
Q3=INT(10*SR+1)
E=9E9*(Q2/X2+2-Q1/X1+2)
E1=9E9*(Q2-X2-Q1/X1)
E2=9E9*(Q2/X2+2+Q1/X1+2)
F=Q3*E

170 TYPE=Q
PAGE
text
two point charges Q1 of \{Q1[1.0]\} and Q2 of \{Q2[1.0]\} coulombs are placed on the X-axis with coordinates X1 of \{X1[1.0]\} and X2 of \{X2[1.0]\} meters respectively. what is the electric field in newtons per coulomb at the origin?

\ANSWER
0 %E=0.3*E
1 + E
1 + E, N/C
1 + E, newton/coulomb
1 + E, newton per coulomb
I \ Uo,U\cdot \varepsilon_2
\begin{align*}
2 &= \varepsilon_2 \\
2 &= \varepsilon_2 \cdot \text{N/C} \\
2 &= \varepsilon_2 \cdot \text{NEWTON/Coulomb} \\
2 &= \varepsilon_2 \cdot \text{NEWTON PER COULOMB} \\
\end{align*}
I \ Uo,U\cdot \varepsilon_1
\begin{align*}
3 &= \varepsilon_1 \\
3 &= \varepsilon_1 \cdot \text{N/C} \\
3 &= \varepsilon_1 \cdot \text{NEWTON/Coulomb} \\
3 &= \varepsilon_1 \cdot \text{NEWTON PER COULOMB} \\
\end{align*}
ACTION
1
2
F:
R: CONSIDER THE SIGNS OF THE CHARGES. TRY AGAIN.
3
F:
R: YOU FORGOT TO USE THE SQUARE OF DISTANCES IN THE CALCULATION. TRY AGAIN.
? 
F:
R: USE EQUATION (C) IN SLIDE 6 TO FIND THE TWO E'S AT THE ORIGIN AND ADD THEM VECTORIALLY.
? 
F:
R:
1 \times 10^9 \times (\frac{-Q_1}{(x_1+2)^2} + \frac{-Q_2}{(x_2)^2}) = \\

180 \text{ TYPE-Q}

\text{TEXT}
\text{FOLLOWING THE LAST QUESTION, IF A POSITIVE CHARGE Q_3 OF |Q_3|=0.01 \text{ COULOMBS IS PLACED AT THE ORIGIN, WHAT WOULD BE THE ELECTRIC FORCE IN NEWTONS ACTING ON Q_3?}}
\text{ANSWER}
\begin{align*}
0 \times 10^9 \times 0.03 &= \\
1 + F &= N \\
1 + F &= \text{NEWTONS} \\
\end{align*}
\text{ACTION}
1
F:
? 
F:
R: USE EQUATION (B) IN SLIDE 6 TO FIND F. 
?
Slide 7 shows the positions of the two point charges $Q_1$ at $[1, 0]$ and $Q_2$ at $[2, 0]$ coulombs separated by a distance $R$ of $1$ meter. What would be the net electric field in N/C at the point $P$?

\[
\begin{align*}
\text{E}_1 &= 9 \times 10^7 \text{E}_2 \\
\text{E} &= \sqrt{(\text{E}_1^2 + \text{E}_2^2 + 2 \text{E}_1 \text{E}_2 \cos 120)} \\
\text{E} &= 9 \times 10^7 \text{E}_2
\end{align*}
\]

Slide 7 shows the positions of the two point charges $Q_1$ at $[1, 0]$ and $Q_2$ at $[2, 0]$ coulombs separated by a distance $R$ of $1$ meter. What would be the net electric field in N/C at the point $P$?

\[
\begin{align*}
\text{E}_1 &= 9 \times 10^7 \text{E}_2 \\
\text{E} &= \sqrt{(\text{E}_1^2 + \text{E}_2^2 + 2 \text{E}_1 \text{E}_2 \cos 120)} \\
\text{E} &= 9 \times 10^7 \text{E}_2
\end{align*}
\]
? R1 @ F1
A1=E1=9E9*Q1/R1+2} E2=-9E9*Q2/R2+2} AND
E=SQRT(E1*E1+E2*E2+2*E1*E2*COSD(120))=\n
210 TYPE=Q
TEXT
IF A POSITIVE POINT CHARGE Q3 OF \Q3[N1,0]\ COULOMBIS IS
PLACED AT P IN SLIDE 7, WHAT WOULD BE THE ELECTRIC FORCE
IN NEWTONS ACTING ON THIS Q3?
\ANSWER
0 $%=,03+\F
1 + F
1 + F; N
1 + F; NEWTONS
ACTION
1 F;
PI
? ?
F1
R1 USE F=Q3*E TO FIND F;\n? R1 @
A1; WRONG! F=Q3*E=\nPI

213 TYPE=R
FORMULAS OF ELECTRIC FIELDS

215 TYPE=Q
SLIDE 8
TEXT
SLIDE 8 GIVES YOU A SUMMARY OF THE FORMULAS ABOUT
ELECTRIC FIELDS, WHEN YOU FINISH WITH THIS SLIDE,
TYPE "GO".
\ANSWER
A 0 GO
? 0
ACTION
A
C1:IF SEEN(1215)=0,B1217

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RITYPE "#C" TO GET BACK WHERE YOU LEFT OFF.
@ RITYPW "GO" TO CONTINUE.

217 TYPE=C
0*INT(10*SR+1)*1E-7
M=INT(10*SR+1)*1E-8
Z=INT(10*SR+1)*1E-9
R=INT(10*SR+1)
E1=-9E9*200/M/R
E2=2*3,14*9E9*Z
E3=9E9*Q/R*2
E=E1+E2
E=SGRT(E3+E3+E6E)

219 TYPE=Q

PAGE
SLIDE 9
TEXT

IN SLIDE 9, THE UNIFORM CHARGE DENSITY ON THE ROD IS \[ \sigma = 1.0 \text{ C/m} \] AND ON THE LARGE PLANE IS \[ \sigma = 1.0 \text{ C/m} \] COULOMB PER SQUARE METER. THE TOTAL CHARGE UNIFORMLY DISTRIBUTED ON THE SURFACE OF THE SPHERE IS \[ Q = 1.0 \text{ C} \] COULOMBS. WHAT IS THE MAGNITUDE OF THE ELECTRIC FIELD IN N/C AT THE POINT P, IF R IS \[ R = 1.0 \text{ m} \] METERS?

\]

ANSWER
0 5% 0.03*E

1 + E

1 + E, NEWTON/COULOMB

1 + E, NEWTON PER COULOMB ACTION

1

F1

! ?

F1

RECOMPUTE THE ELECTRIC FIELDS DUE TO THE THREE ITEMS;
THEN, ADD THEM TOGETHER VECTORIALLY.
?

F1

USE THE CORRECT FORMULAS IN SLIDE 8. TRY AGAIN.
?

R1

F1

A1E1=-9E9*200/R1 E2=2*3,14*9E9*Z2 E3=9E9*Q/R*2 AND
E=SGRT((E1+E2)+2*E3+2).

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220 TYPE-Q
PAGE
TEXT
THIS IS THE END OF THIS LESSON, SEE YOU LATER;
\ACTION
S1OFF
S10
L1
Slide 1. Objectives.

Having completed this lesson, the student should be able to:

1. add vectors,
2. resolve a vector,
3. calculate the electric field and electric force due to
   (1) point charges, and
   (2) uniformly distributed charges.
Slide 2. Vector addition.

To add vectors, draw the arrow tail to the arrow head. The resultant vector runs from the first tail to the last head.

\[
\begin{align*}
\theta = 0 & \\
\begin{tikzpicture}
\draw[->] (0,0) -- (1,0) node[right] {A} ;
\draw[->] (1,0) -- (2,0) node[right] {B} ;
\end{tikzpicture} & \\
\begin{tikzpicture}
\draw[->] (0,0) -- (1,0) node[right] {A} ;
\draw[->] (1,0) -- (2,0) node[right] {B} ;
\draw[->] (2,0) -- (3,0) node[right] {R} ;
\end{tikzpicture} & R = A + B
\end{align*}
\]

\[
\begin{align*}
\theta = 180^\circ & \\
\begin{tikzpicture}
\draw[->] (0,0) -- (1,0) node[right] {A} ;
\draw[->] (1,0) -- (2,0) node[right] {B} ;
\end{tikzpicture} & \\
\begin{tikzpicture}
\draw[->] (0,0) -- (1,0) node[right] {A} ;
\draw[->] (1,0) -- (2,0) node[right] {B} ;
\draw[->] (2,0) -- (0,0) node[left] {R} ;
\end{tikzpicture} & R = A - B
\end{align*}
\]

\[
\begin{align*}
\theta = 90^\circ & \\
\begin{tikzpicture}
\draw[->] (0,0) -- (1,0) node[right] {A} ;
\draw[->] (0,0) -- (0,1) node[right] {B} ;
\end{tikzpicture} & \\
\begin{tikzpicture}
\draw[->] (0,0) -- (1,0) node[right] {A} ;
\draw[->] (0,0) -- (0,1) node[right] {B} ;
\draw[->] (0,0) -- (1,1) node[right] {R} ;
\draw[->] (1,1) -- (1,0) node[right] {A} ;
\end{tikzpicture} & R = \sqrt{A^2 + B^2} \\
\text{and} & \\
\theta = \tan^{-1} \frac{A}{B}
\end{align*}
\]

\[
\begin{align*}
\theta = \text{any angle} & \\
\begin{tikzpicture}
\draw[->] (0,0) -- (1,0) node[right] {A} ;
\draw[->] (0,0) -- (0,1) node[right] {B} ;
\end{tikzpicture} & \\
\begin{tikzpicture}
\draw[->] (0,0) -- (1,0) node[right] {A} ;
\draw[->] (0,0) -- (0,1) node[right] {B} ;
\draw[->] (0,0) -- (1,1) node[right] {R} ;
\draw[->] (1,1) -- (1,0) node[right] {A} ;
\end{tikzpicture} & R = \sqrt{A^2 + B^2 - 2AB \cos \theta} \\
\text{and} & \\
\theta = \tan^{-1} \frac{A \sin \theta}{B + A \cos \theta}
\end{align*}
\]
Step 1. Draw the vector and indicate its direction.

Step 2. Draw a straight line through the tail in the direction of one of its components desired.

Step 3. Draw a perpendicular line through the head to the first straight line.

Step 4. Draw in the arrow heads in such an order that every head is followed by a tail with all arrows leading to the original arrow head.

\[ A_x = A \cos \theta_a \]
\[ A_y = A \sin \theta_a \]
\[ B_x = B \cos \theta_b \]
\[ B_y = B \sin \theta_b \]
\[ C_x = C \cos \theta_c = 0 \]
\[ C_y = C \sin \theta_c = -C \]

\[ R_x = A_x + B_x + C_x \]
\[ R_y = A_y + B_y + C_y \]
\[ R = \sqrt{R_x^2 + R_y^2} \]
\[ \theta = \tan^{-1} \frac{R_y}{R_x} \]
Slide 5. A problem of vector addition.

1. Electric force

\[ F = k \frac{Q_1 Q_2}{R^2} \]  \hspace{1cm} (A)

\[ F = E Q \]  \hspace{1cm} (B)

2. Electric field due to a point charge

\[ E = k \frac{Q}{R^2} \]  \hspace{1cm} (C)

Note:

- \( k = 9 \times 10^9 \text{ Nm}^2/\text{coul}^2 \)
- Q's = point charges in coulomb
- R = distance in meters
- The sign of the charge must be used in the above equations. Positive force is a repulsive force and a negative force is attractive.
Slide 7. A problem of electric field.
Slide 8. A summary of formulas of electric field.

1. Field due to a point charge

\[ E = k \frac{Q}{R^2} \]

where \( E = \text{electric field in N/coul} \)
\( k = 9 \times 10^9 \text{ Nm}^2/\text{coul}^2 \)
\( Q = \text{point charge in coulombs} \)
\( R = \text{distance in meters from Q to the point P at which E is being sought} \)

2. Field due to uniformly distributed charges over a metal sphere or shell

\[ E = k \frac{Q}{R^2} \]

where \( R = \text{distance in meters from the center of the sphere to point P outside the sphere (E = 0 everywhere inside the sphere or shell)} \)

The rest of the variables are the same as stated above.

3. Field due to uniformly distributed charges on a long, thin and straight rod

\[ E = k \frac{\sigma}{R} \]

where \( \sigma = \text{charge density in coul/m} \)

The rest of the variables are the same as stated above.

4. Field due to uniformly distributed charges over a plane sheet

\[ E = 2\pi k \sigma \]

where \( \sigma = \text{charge density in coul/m}^2 \)

The rest of the variables are the same as stated above.

5. Field between two uniformly, equally but oppositely charged parallel plates

\[ E = 4\pi k \sigma \]

All variables are the same as stated above.
Slide 9. A problem of electric field.
LEARNING LESSON LISTING

LESSON: LESSON 6
DATE: 2/17/75
TIME: 14:14
PPNI: 24000,24005

10 TYPE=Q
PAGE
TEXT
IS your TERMINAL
  1 TTY
  2 TEK 4010
  3 TEK 4002
\ANSWER
1 0 1
2 0 2
3 0 3
? 0
ACTION
1 2 3
CISD$A=1

PLEASE TYPE 1, 2 OR 3 ACCORDING TO THE CLASSIFICATION
OF YOUR TERMINAL:

20 TYPE=Q
PAGE
REVIEW ON>
STORE ON>
HINT ON>
TEXT
LESSON 6: OHM'S LAW AND DC CIRCUITS#2
THIS LESSON MAKES USE OF A SET OF SLIDES ENTITLED
"OHM'S LAW AND DC CIRCUITS", THESE SLIDES SHOULD BE
MOUNTED ON THE PROJECTOR; AND THE SLIDE TRAY SHOULD BE
POSITIONED TO SLIDE ZERO; BE SURE THAT THE PROJECTOR IS
TURNED ON TO THE FAN POSITION, THEN, TYPE "READY".
\ANSWER
A 0 READY
? 0
ACTION
A

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If you are having a problem with the projector, see the consultant. Otherwise, type "ready" (no quotation mark).

30 TYPE-Q
PAGE
SLIDE 1
SLIDE ON
TEXT
READ THE OBJECTIVES OF THIS LESSON, WHEN YOU FINISH
YOUR READING, TYPE "GO".
\ ANSWER
A @ GO
? @
ACTION
A @
R I TYPE "GO" TO CONTINUE (NO QUOTATION MARK).
\n
40 TYPE-Q
PAGE
SLIDE 2
TEXT
THIS LESSON IS RESTRICTED TO METALLIC CONDUCTORS THAT
OBEY OHM'S LAW. THIS MEANS THAT RESISTANCE REMAINS
CONSTANT WHEN VARIOUS POTENTIALS ARE APPLIED TO THE SAME
RESISTOR. IN SLIDE 2, WHICH GRAPH REPRESENTS OHM'S LAW?
\n\ ANSWER
EXTRA OFF
A + D
MATCH 1
B = A B C
? @
ACTION
A F1
I B
F1
R I CONSTANT SLOPE MEANS CONSTANT RESISTANCE;
B B
? R1
@ F1
F I CONSTANT SLOPE (V/I) MEANS CONSTANT RESISTANCE;
A I
In Slide 3, which graph indicates that the resistance of R1 is as large as 4 times the resistance of R2?

\[ \text{Answer}
\]
\[ \text{Extra Off}
\]
\[ \text{A + A}
\]
\[ \text{Match 1}
\]
\[ \text{B = B C D E F G}
\]
\[ ? \ 0
\]
\[ \text{Action}
\]
\[ A\]
\[ F\]

1. Resistance is directly proportional to the length and inversely proportional to the cross-sectional area of a resistor.

2. The area of a circle is proportional to the diameter squared.

Choose and type the letter preceding the correct expression in Slide 4.

\[ \text{Answer}
\]
\[ \text{Extra Off}
\]
\[ \text{A + A}
\]
\[ \text{Match 1}
\]
\[ \text{B = BC}
\]
\[ ? \ 0
\]
\[ \text{Action}
\]
\[ A\]
\[ F\]
\[ B\]
\[ B\]
\[ R\]
Firesistance is independent of the applied potential for ohmic resistors such as most metallic conductors.

70 TYPE=Q
PAGE
TEXT
WHICH OF THE FOLLOWING UNITS IS THE UNIT OF POWER?
A J/C
B C/S
C J/S
D WH (OR WATT HOUR)

ANSWER
EXTRA OFF
A + C
MATCH 1
B = A B D
? 0
ACTION
A
F
I B
F
POWER IS THE WORK DONE PER UNIT TIME.
B A
R I
?
R I
F
POWER IS THE WORK DONE PER UNIT TIME.
A I

80 TYPE=Q
PAGE
TEXT
ONE WATT HOUR EQUALS
A 746 WATTS
B 3600 J
C 60 J
D 1 J
E 1000 J

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ANSWER
EXTRA OFF
A • B
MATCH 1
B • A C D E
? 0
ACTION
A
F1
F?
F1
R1 WATT=1 J/S, 1 HOUR=3600 S, AND POWER=(WORK)/(TIME):
B B B
R1
?
R1
?
F1
F11 WH=(1 J/S)(3600 S):
A1

B5 TYPE-Q
PAGE
TEXT
WHICH OF THE FOLLOWING STATEMENTS IS INCORRECT IN
STATING THE MEANING OF THE ELECTROMOTIVE FORCE, EMF?
A EMF IS THE WORK DONE TO A UNIT CHARGE BY THE
ELECTRIC SOURCE,
B EMF IS THE TERMINAL POTENTIAL DIFFERENCE WHEN THE
ELECTRIC SOURCE IN NOT IN A CLOSED CIRCUIT,
C EMF IS GREATER THAN THE TERMINAL VOLTAGE WHEN THE
ELECTRIC SOURCE IS IN A CLOSED CIRCUIT,
D EMF IS A FORCE SO THAT IT HAS THE UNITS OF NEWTONS;
E EMF IS THE ELECTRIC ENERGY GIVEN TO A COULOMB OF
CHARGE WHEN THE CHARGE PASSES THROUGH THE ELECTRIC
SOURCE.

\ ANSWER
EXTRA OFF
A • D
MATCH 1
B • A B C E
? 0
ACTION
A
F1
F1
B B B
R1

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RE生产量是能量分配给电荷单位的数量，

BY THE SOURCE DEVICE, \( Q \)

FORMULAS OF DC CIRCUIT

SLIDE 5
TEXT
SLIDE 5 GIVES YOU A SUMMARY OF FORMULAS, WHEN YOU
FINISH WITH THIS SLIDE, TYPE "GO".

\[ a \]
\[ a \]
\[ a \]

ACTION
A
\[ a \]
\[ a \]
\[ a \]

RITYPE "C" TO GET BACK WHERE YOU LEFT OFF.

RITYPE "GO" TO CONTINUE.

SLIDE 6
TEXT
FROM THE CIRCUIT IN SLIDE 6, WHICH OF THE FOLLOWING
EXPRESSIONS IS CORRECT?

\[ a \]
\[ a \]
\[ a \]

\[ a \]
\[ a \]
\[ a \]

\[ a \]
\[ a \]
\[ a \]

ACTION
A
\[ a \]
THIS IS A SERIES CIRCUIT.\n
THE CURRENT IS EVERYWHERE THE SAME IN A SERIES CIRCUIT.\n
REFER TO SLIDE 6 AGAIN. WHICH OF THE FOLLOWING EXPRESSIONS IS CORRECT?

A \( V_1 = V_2 = V_3 = V_4 \)
B \( V_1 > V_2 > V_3 > V_4 \)
C \( V_1 = V_2 + V_3 = V_4 \)
D \( V_1 > V_2 + V_3 + V_4 \)

ANSWER EXTRA OFF
A + C
MATCH 1
B = A B D
\( \neq \) 0

ACTION:
A
FI
I B
FI
RIV = IR,\nB B B
RI
? 
R1 \( \neq \)
FI
RIV = IR AND THE CURRENT IS CONSTANT IN THIS SERIES CIRCUIT.\n
120 TYPE=C
R = INT(10*SR+1)
R1 = 8*R
R2 = 1 / (1 / R1 + 1 / (2 * R) + 1 / (4 * R))
E = INT(100 * $R + 10)
T = INT(100 * $R + 10)
I = E / R1
P = I * I * 7 * R

130 TYPE = Q
PAGE
TEXT
IN SLIDE 6, IF R EQUALS \
R1, OHMS, WHAT WOULD BE
THE EXTERNAL EQUIVALENT RESISTANCE?

\ ANSWER
0 %%, 03 * 7 * R
1 * 7 * R
1 - 7 * R, OHMS
2 - 8 * R
2 - 8 * R, OHMS
3 = R2
3 = R2, OHMS
ACTION
1
2
F

IF YOUR ANSWER IS THE TOTAL RESISTANCE OF THE ENTIRE
CIRCUIT RATHER THAN THE EXTERNAL RESISTANCE, TRY AGAIN.
3
F
IF THE RESISTORS ARE IN SERIES RATHER THAN IN
PARALLEL, TRY AGAIN.
1 ?
F
IF THE THREE EXTERNAL RESISTORS ARE IN SERIES,
? ?
R
F
A\EQUIVALENT EXTERNAL RESISTANCE = R * 2 * R * 4 * R

140 TYPE = Q
TEXT
FOLLOWING THE LAST QUESTION, WHAT WOULD BE THE POWER
DEVELOPED IN THE EXTERNAL RESISTORS IF THE BATTERY
HAS AN EMF OF \
E1, OHMS? GIVE YOUR ANSWER IN WATTS.
\ ANSWER
0 %%, 03 + P
1 + P
1 + P\cdot WATTS
2 = I\cdot I\cdot 8\cdot R
2 = I\cdot I\cdot 8\cdot R\cdot WATTS

**ACTION**
1
2
3

1) YOU SHOULD NOT INCLUDE THE INTERNAL RESISTANCE FOR EXTERNAL EQUIVALENT RESISTANCE. TRY AGAIN.
2
3

R1 USE P=(CURRENT SQUARED)(EXTERNAL RESISTANCE).
2
3

R1 = I\cdot I\cdot 7\cdot R\cdot \\n
150 TYPE=Q

**PAGE**

**SLIDE 7**

**TEXT**

FROM SLIDE 7, WHICH OF THE FOLLOWING EXPRESSIONS IS CORRECT?

A 11 \cdot 12 = 13 \cdot 14
B 11 \cdot 12 > 13 \cdot 14
C 11 \cdot 12 = 13 \cdot 14
D 11 > 12 > 13 > 14

**ANSWER**

**EXTRA OFF**

A + B

MATCH 1
B = A C D

? 0

**ACTION**

A

F1
B

F1

THINK OF THIS CIRCUIT AS A WATER PIPE.

B

R1

? 0

F1

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160 TYPE=Q
PAGE
SLIDE 7
TEXT
REFER TO SLIDE 7 AGAIN. WHICH OF THE FOLLOWING EXPRESSIONS IS CORRECT?
A V3>V4
B V3≠V4
C V3<V4

ANSWER
EXTRA OFF
A ≠ A
MATCH 1
B = B C
? Ø
ACTION
A
F1
I B
F1
RESISTORS 2R AND 4R ARE IN PARALLEL.
B
R1
? R1
? F1
THE POTENTIAL ACROSS ANY NUMBER OF ELEMENTS IN PARALLEL IS ALWAYS THE SAME FOR EACH ELEMENT.
A

170 TYPE=Q
PAGE
SLIDE 7
TEXT
CONCENTRATE ON THE TWO RESISTORS IN PARALLEL IN SLIDE 7. WHICH OF THE FOLLOWING EXPRESSIONS IS CORRECT AS TO THE POWER DEVELOPED IN THE RESISTOR 2R (NAMED P3) AND IN THAT OF 4R (NAMED P4)?
A P3=P4
B P3=(1/2)P4
C P3=2P4
D P3=(1/4)P4
E P3=4P4
R1: THE TWO RESISTORS HAVE THE SAME POTENTIAL ACROSS THEM; B B B R1
R1

F: BOTH RESISTORS HAVE THE SAME POTENTIAL ACROSS THEM; BUT 13=214.
A!

180 TYPE=C
R=INT(10*SR+2)
E=INT(10*SR+6)
T=INT(100*SR+60)
R4=1/(1/(2*R)+1/(4*R))
R1=R4
R2=R+R1
I=E/R2
W=I*I*R1*R
R3=R+2*R+4*R
R5=1/(1/R+1/(2*R+4*R))

190 TYPE=Q
PAGE
SLIDE 7
TEXT
WHAT IS THE EXTERNAL EQUIVALENT RESISTANCE IN OHMS OF THE CIRCUIT IN SLIDE 7, IF R IS \( R_{1,0} \) OHMS?

ANSWER
0 $%*%3*R1
1 * R1
1 + R1, OHMS
2 = R3
2 = R3, OHMS
4 = R2
4 = R2 0HMS
5 = R5
5 = R5 0HMS
ACTION
1
2
F
R THE RESISTORS 2R AND 4R ARE IN PARALLEL,
THEIR EQUIVALENT RESISTANCE IS IN SERIES WITH THAT OF R.
TRY AGAIN.
4
F
R YOUR ANSWER IS THE TOTAL RESISTANCE OF THE ENTIRE CIRCUIT RATHER THAN THE EXTERNAL EQUIVALENT RESISTANCE.
TRY AGAIN.
5
F
R YOU USED THE WRONG FORMULAS, TRY AGAIN.
F
1
R RESISTOR 2R IS IN PARALLEL WITH 4R, AND THEIR EQUIVALENT RESISTANCE IS IN SERIES WITH R.

\[ R_{\text{E}} = \frac{1}{1/(2R) + 1/(4R)} \]

200 TYPE=Q
PAGE SLIDE 7
TEXT
IN SLIDE 7, WHAT IS THE HEAT IN JOULES DEVELOPED IN THE EXTERNAL RESISTORS IN \[\text{1.0}\] SECONDS, IF THE BATTERY HAS AN EMF OF \[\text{1.0}\] VOLTS?

\[ \text{ANSWER} \]
\[ \text{0.03}\text{W} \]
1 + W, J
1 + W, JOULES
ACTION
1
F
P
1
F
R \[ W = \text{I}\times\text{R}\times\text{T} \], WHERE R STANDS FOR EXTERNAL RESISTANCE.
RI
0
FI
F I W = I R T, WHERE R STANDS FOR EXTERNAL RESISTANCE.
A I
FI

205 TYPE=R
KIRCHHOFF'S RULES

210 TYPE=Q
SLIDE 8
TEXT
SLIDE 8 GIVES YOU A SUMMARY OF KIRCHHOFF'S RULES.
WHEN YOU FINISH WITH THIS SLIDE, TYPE "GO".
\ ANSWER
A 0 GO
? 0
ACTION
A
IF SEEN(1210) #0, B 1220
R TYPE "#C" TO GET BACK WHERE YOU LEFT OFF;
R TYPE "GO" TO CONTINUE.

220 TYPE=Q
PAGE
SLIDE 9
TEXT
WHICH THREE EQUATIONS IN SLIDE 9 ARE CORRECT WHEN KIRCHHOFF'S RULES ARE APPLIED TO THE CIRCUIT IN THAT SLIDE?
A A, D, AND E
B A, D, AND F
C A, C, AND E
D A, C, AND F
E B, C, AND E
F B, C, AND F
\ ANSWER
EXTRA OFF
A C
B = A B D E F
? 0
ACTION
A
Apply Kirchhoff's rules to this circuit.

B B B B

KIRCHHOFF'S RULES TO THIS CIRCUIT.

230 TYPE=C

R=INT(10*R+2)
E=INT(1000*R+10)
I2=E/(69*R)

240 TYPE=G


\ANSWER
0 \%=ABS(.03*I2)
1 + I2
1 + I2,A
1 + I2,AMPERES
2 0 =I2
2 0 -I2,A
2 0 -I2,AMPERES

ACTION
1
F

YOUR ANSWER IS OF THE CORRECT MAGNITUDE. IS THE ANSWER POSITIVE OR NEGATIVE? TRY AGAIN.

1 ?

USE EQUATIONS (A), (C), AND (E) TO SOLVE FOR I2.\n
? F

SUBSTITUTE I1 IN EQUATION (C) BY EQUATION (A); THEN SOLVE FOR I3 USING THE NEW EQUATION (C) AND EQUATION (E) RESPECTIVELY. EQUATE THESE TWO I3'S AND SOLVE FOR I2.\n
? ?
If you apply Kirchhoff's rules to the circuit shown in Slide 10, which equation in that slide is incorrect?

Answer extra off

A + G

Match 1

B = A B C D E F H

? 0

Action A

Z B

F 1

If according to the directions of the currents and the loops indicated in the slide, use Kirchhoff's rules to check out the given equations,

B B B B B B

R 1

? R 1

@ F 1

A 1

260 Type=Q

Page

Text

This is the end of this lesson. See you later.

Action	S I OFF

S I 0

L 1
Having completed this lesson, the student should be able to solve the problems in connection with DC circuits using Ohm's law and Kirchhoff's rules. The problems include the calculation of:

1. resistance in series or parallel circuit,
2. potential drop across a resistor or equivalent resistance,
3. current through a circuit element,
4. power consumed in a circuit element, and
5. work or heat developed in a circuit element.
Slide 2. Which graph represents Ohm's law?
Slide 3. Compare resistors made of the same material but in different lengths or diameters.
Slide 4. Two different potentials are applied to two identical resistors. Which of the following expressions for their resistance-relationship is correct?

(A) $R_1 = R_2$

(B) $R_1 > R_2$

(C) $R_1 < R_2$
Slide 5. A summary of formulas concerning DC circuits.

1. Ohm's law
   \[ I = \frac{V}{R} \]
   where \( I \) = current in amperes, \( V \) = potential difference in volts, \( R \) = resistance in ohms

2. Resistance formula
   \[ R = \frac{\rho L}{A} \]
   where \( L \) = length in meter of a resistor (or in ft), \( A \) = cross-section area in m² of a resistor (or in cm), \( \rho \) = conductivity ohm m (or in ohm cm/ft)

3. Equivalent resistance
   \[ R = R_1 + R_2 + R_3 + \cdots \] (Resistors in series)
   \[ \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots \] (Resistors in parallel)

4. Electric work or heat
   \[ W = QV = IVt = I^2Rt = \frac{V^2}{R}t \]
   where \( W \) = electric work or heat in joules, \( Q \) = charge in coulombs, \( t \) = time in seconds
   The rest of variables are the same as stated above.

5. Power developed in a circuit element
   \[ P = \frac{W}{t} = IV = I^2R = \frac{V^2}{R} \]
   where \( P \) = power in watts or J/sec
   The rest of variables are the same as stated above.
Slide 6. A problem of DC circuit.

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Slide 7. Another problem of DC circuit.

The first rule: The sum of the currents flowing into a junction is equal to the sum of the currents flowing out of the junction.

At a junction: $\sum I = 0$  
Note: $I_{in}$ is positive  
$I_{out}$ is negative

The second rule: The sum of the emf's around a loop is equal to the sum of the IR potential drops around the loop.

Around a loop: $\sum E = \sum IR$  
Note: When the positive terminal of a battery points along the loop, its emf is positive, otherwise the emf is negative. When the direction of the preset current is along the loop, it is positive. Otherwise, the current is negative.

Application procedure:  
Step 1. Assign directions to the currents at each junction point.  
Step 2. Assign direction to each loop either clockwise or counter-clockwise.  
Step 3. Write out and solve the simultaneous equations.

(A) \[ I_1 = I_2 + I_3 \]
(B) \[ I_2 = I_1 + I_3 \]
(C) \[ E - 2E = I_1(R + 3R) + I_2(R + 6R) \]
(D) \[ E + 2E = I_1(R + 3R) + I_2(R + 6R) \]
(E) \[ 2E - 4E = -I_2(R + 6R) + I_3(R + 9R) \]
(F) \[ -2E - 4E = -I_2(R + 6R) + I_3(R + 9R) \]
Slide 10. Another application of Kirchhoff's rules.

(A) \( I_1 = I_2 + I_3 \)

(B) \( I_2 + I_4 = I_5 \)

(C) \( I_3 = I_4 + I_6 \)

(D) \( I_5 + I_6 = I_1 \)

(E) \( E_1 = I_1 R + I_3 R_2 + I_6 R_4 \)

(F) \( -E_2 = -I_4 R - I_3 R_2 + I_2 R_1 \)

(G) \( E_2 = I_4 R + I_5 R_3 + I_6 R_4 \)

(H) \( E_1 = I_1 R + I_2 R_1 + I_5 R_3 \)
LESSON 7: MAGNETIC FIELDS AND MAGNETIC FORCE

This lesson makes use of a set of slides entitled "MAGNETIC FIELDS". These slides should be mounted on the projector, and the slide tray should be positioned to slide zero. Be sure that the projector is turned on to the fan position, then, type "READY".

ANSWER
PHONIC ON
A 0 READY
? 0
ACTION
IF YOU ARE HAVING A PROBLEM WITH THE PROJECTOR, SEE THE CONSULTANT. OTHERWISE, TYPE "READY" (NO QUOTATION MARK).

30 TYPE=R
PAGE
SLIDE 1
SLIDE ON
TEXT
READ THE OBJECTIVES OF THIS LESSON. WHEN YOU FINISH YOUR READING, TYPE "GO".

\ ANSWER
A 0 GO
? 0
ACTION
A P
RPLEASE TYPE "GO" TO CONTINUE (NO QUOTATION MARK).

35 TYPE=R
FORMULAS OF MAGNETIC FIELDS

40 TYPE=R
SLIDE 2
TEXT
SLIDE 2 SHOWS THE FORMULAS OF MAGNETIC FIELDS. WHEN YOU FINISH WITH THIS SLIDE, TYPE "GO".

\ ANSWER
A 0 GO
? 0
ACTION
A C1IF SEEN(1040)=0,B150
RITYPE "#C" TO GET BACK WHERE YOU LEFT OFF.
@ RITYPE "GO" TO CONTINUE.

50 TYPE=R
PAGE
SLIDE 3
TEXT
HERE IS A PROBLEM CONCERNING THE DIRECTION OF A MAGNETIC
FIELD, in Slide 3, to which quadrant would the resultant magnetic field at the center of the coil point?

A  I
B  II
C  III
D  IV
E  positive x
F  negative x
G  positive y
H  negative y

\ ANSWER
EXTRA OFF
A + G
\ MATCH 1
B - A B C D E F H
\ ? 0
\ ACTION
A
F
I B
F
\ USE RIGHT HAND WITH THUMB POINTING TO THE CURRENT DIRECTION, THE OTHER FINGERS WILL POINT IN THE FIELD DIRECTION:
B B B B B B
R I
? R
H
\ BOTH COMPONENTS OF THE MAGNETIC FIELD ARE POINTING IN THE POSITIVE Y DIRECTION:
A 1

60 TYPE=Q
PAGE
SLIDE 3
TEXT
WHICH ANSWER WOULD YOU CHOOSE IN THE LAST QUESTION, IF THE COIL IS TURNED 90 DEGREES CLOCKWISE ABOUT THE VERTICAL AXIS THROUGH THE CENTER OF THE COIL?
\ ANSWER
EXTRA OFF
A + A
\ MATCH 1
B - B C D E F G H
\ ? 0
ACTION
A
F: B
F:
RI USE VECTOR ADDITION,
B B B B B
R I
? R I
? F:
THE FIELD DUE TO THE LONG WIRE IS POINTING IN THE
POSITIVE Y DIRECTION, WHILE THE FIELD DUE TO THE
COIL IS IN THE POSITIVE X DIRECTION, ADD THESE TWO
FIELDS VEKTORIALLY,
A!
70 TYPE=C
I=INT(10*$R+2)
R=INT(10*$R+1)*1E-1
B1=2E-7*I/(2*R)
B2=2*3.14E-7*I/R
B=B1+B2
80 TYPE=G
PAGE
SLIDE 3
TEXT
IF, IN SLIDE 3, R IS \( R \) METERS AND I IS \( I \) AMPERES, WHAT WOULD BE THE MAGNITUDE OF THE RESULTANT
MAGNETIC FIELD AT THE CENTER OF THE COIL? GIVE YOUR
ANSWER IN T OR N/A-M.
\ANSWER
0 \% 03*B
1 + B
ACTION
1 F:
!? F:
RI USE THE PROPER FORMULAS IN SLIDE 2, AND ADD !2 TWO
COMPONENT FIELDS VEKTORIALLY,
? ? ?
R I
F!
90 TYPE=Q
PAGE
SLIDE 4
TEXT
THE MAGNETIC FIELD INSIDE THE SOLENOID AS SHOWN IN SLIDE
4 IS
A UNIFORM AND POINTING TO THE RIGHT
B UNIFORM AND POINTING TO THE LEFT
C NONUNIFORM AND POINTING TO THE RIGHT
D NONUNIFORM AND POINTING TO THE LEFT

\ANSWER
\EXTRA OFF
A + B
\MATCH 1
B = A C D
? Ø
\ACTION
A
F1
B
F1

\USE YOUR RIGHT HAND TO DETERMINE THE FIELD DIRECTION FROM THE CURRENT DIRECTION,
? R1
\WITH THE FINGERS POINTING IN THE CURRENT DIRECTION;
YOUR THUMB WOULD POINT IN THE DIRECTION OF THE MAGNETIC FIELD INSIDE THE SOLENOID,
A1

100 TYPE=Q
PAGE
SLIDE 4
TEXT
IF THE SOLENOID SHOWN IN SLIDE 4 IS USED AS A BAR MAGNET,
WHICH END [LEFT/RIGHT] WILL ACT LIKE A NORTH POLE?

\ANSWER
A + LEFT
A = LEFT END
B = RIGHT
B = RIGHT END
? Ø
ACTION
A
FI
B
FI
THE LINES OF MAGNETIC FORCE RUN FROM THE NORTH POLE OUTSIDE THE SOLENOID TO SOUTH POLE, THEN RETURN TO THE NORTH POLE THROUGH THE INSIDE OF THE SOLENOID."
A1

110 TYPE=C
1=INT(100*SR+2)
L=INT(100*SR+1)*1E1
N=INT(1000*SR+100)
B=4*3.14E-7*N*I/L
B1=4*3.14E-7*I*L/N
B2=N*I/L

120 TYPE=Q
PAGE
SLIDE 4
TEXT
A 1:1 METER UNIFORMLY WOUND SOLENOID HAS N[1.0]\ TURNS. WHAT IS THE MAGNITUDE OF THE MAGNETIC FIELD IN N/A*M INSIDE THE SOLENOID, IF THE CURRENT I IS N[1.0]\ AMPERES?
\A
ANSWER
0 $%#,03#B
1 + B
1 + B,T
1 + B,N/A=M
0 $%#,03#B1
2 = B1
2 = B1,T
2 = B1,N/A=M
0 $%#,03#B2
3 = B2
3 = B2,T
3 = B2,N/A=M
ACTION
1
FI
2
FI
RIYOU INVERTED N/L, TRY AGAIN, \
3
FI

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YOU LEFT OUT THE CONSTANT COEFFICIENT IN THE FORMULA. TRY AGAIN.

? ?

REUSE THE PROPER FORMULA IN SLIDE 2 TO ANSWER THIS QUESTION.

? ?

\[ A = 4 \times 10^{-3} \, \text{N} \times \text{m/I} \]

130 TYPE=Q

SLIDE 4

TEXT

FOLLOWING THE LAST QUESTION, WHAT WOULD BE THE MAGNETIC INTENSITY \( H \) INSIDE THE SOLENOID? GIVE YOUR ANSWER IN A/M.

\[
\begin{align*}
\text{ANSWER} & \quad 0 \% = 0.03 \times B/(4 \times 10^{-3}, 14E-7) \\
1 & = B/(4 \times 10^{-3}, 14E-7), A/M \\
0 \% = 0.03 \times B = 3, 14E-7 \\
2 & \quad - B = 4 \times 10^{-3}, 14E-7 \\
2 & \quad = B = 4 \times 10^{-3}, 14E-7, A/M \\
\text{ACTION} & \quad 1 \\
& \quad 2 \\
& \quad \text{REUSE } H = B/(\mu) \\
& \quad \text{REUSE } H = B/(\mu) \\
& \quad \text{REUSE } H = B/(\mu) \\
& \quad ? ?
\end{align*}
\]

ACTION

1

2

REUSE \( H = B/(\mu) \)

? ?

REUSE \( H = B/(\mu) \)

? ?

REUSE \( H = B/(\mu) \)

? ?

4 \times 10^{-3}, 14E-7)

140 TYPE=Q

PAGE

SLIDE 5

TEXT

WHICH GRAPH IN SLIDE 5 CORRECTLY INDICATES THE PERPENDICULAR COMPONENT (DASHED LINE) OF VECTOR \( V \) TO VECTOR \( B \)?

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\ ANSWER
EXTRA OFF
A + A
MATCH 1
B = B C D
? 0
ACTION
A
FI
I B
FI
\ RESOLVE VECTOR V INTO TWO PERPENDICULAR COMPONENTS
WITH ONE OF THEM IN THE DIRECTION OF VECTOR B.
\ B B B
RI
? 1
RI
? 0
FI
A

150 TYPE=Q
PAGE
SLIDE 5
TEXT
IN SLIDE 5, IF THE ANGLE BETWEEN VECTORS V AND B IS X,
THE COMPONENT OF V PERPENDICULAR TO B IS
A V SIN X
B V COS X
C V TAN X
D B SIN X
E B COS X
F B TAN X
\ ANSWER
EXTRA OFF
A + A
MATCH 1
B = B C D E F
? 0
ACTION
A
FI
I B
FI
\ SIN X = (OPPOSITE)/(HYPOTENUSE),
\ B B B B
RI

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SLIDE 6 GIVES YOU TWO ALTERNATIVES IN DETERMINING THE MUTUALLY PERPENDICULAR RELATIONS OF THREE VECTORS.  

SUPPOSES THAT AT A CERTAIN PLACE ON EARTH THE GEOMAGNETIC FIELD IS HORIZONTAL POINTING TO THE NORTH. AT SOME TIME, A PROTON IS MOVING FROM WEST TO EAST. IN WHICH DIRECTION WOULD THE MAGNETIC FORCE BE EXERTED ON THE PROTON?  

A) E-W  
B) W-E  
C) S-N  
D) N-S  
E) UPWARD  
F) DOWNWARD  

ANSWER  
EXTRA OFF  
A + E  
MATCH 1  
S = A B C D F  
? Ø  
ACTION  
A  
F1  
B  
F1  

USE THE RIGHT-HAND RULE AS SHOWN IN SLIDE 6.  

FROM THE RIGHT-HAND RULE IN SLIDE 6, THE ANSWER IS E.  

REPEAT THE LAST QUESTION, IF THE MOVING PARTICLE IS AN
ELECTRON RATHER THAN A PROTON.

ANSWER

EXTRA OFF

A + F

MATCH 1

B = A B C D E

? 0

ACTION

A

F

! B

R: CONSIDER THAT THE ELECTRON IS NEGATIVELY CHARGED IN USING THE RIGHT-HAND RULE.

B B B B

R: ?

R: @

F:

F: USE THE RIGHT-HAND RULE IN SLIDE 6 FOR A NEGATIVELY CHARGED PARTICLE (REVERSE THE DIRECTION OF V).

A!

180 TYPE=C

B=INT(10*SR+1)*1E-2

V=INT(1000*SR+200)

F=1.6E=19*V=B*0.6

F1=V=B*0.6

F2=1.6E=19*V=B

190 TYPE=Q

PAGE

SLIDE 6

TEXT

THE INSTANTANEOUS VELOCITY OF AN ELECTRON IS V[1.0]

M/SEC MOVING FROM THE ORIGIN (0,0) TOWARD A POINT (4,3) IN A UNIFORM MAGNETIC FIELD OF B[1.2] T POINTING TOPOSITIVE X. WHAT IS THE MAGNETIC FORCE IN NEWTONS ACTING ON THE ELECTRON?

A!

ANSWER

0 $% .03 * F

1 + F; N

1 + F; NEWTONS

0 $% .03 * F1
AN ELECTRON BEARS A NEGATIVE CHARGE OF $1.6 \times 10^{-19}$ COULOMBS. TRY AGAIN.

YOU FORGOT CALCULATING THE PERPENDICULAR COMPONENT OF THE VELOCITY TO THE MAGNETIC FIELD. TRY AGAIN.

I?

USE $F = qvB \sin \theta$ WHERE $\theta$ = THE ANGLE BETWEEN $V$ AND $B$.

? ?

$F = qvB \sin(37 \, \text{DEGREES})$, AND $\sin(37 \, \text{DEGREES}) = 0.6$.

A

200 TYPE=0 PAGE SLIDE 7 TEXT IN SLIDE 7, AN ELECTRON ENTERS A UNIFORM MAGNETIC FIELD. AS SOON AS IT ENTERS THIS FIELD, THE ELECTRON WILL

A MOVE STRAIGHT FORWARD
B BEND UPWARD
C BEND DOWNWARD
D BEND AWAY FROM YOU
E BEND TOWARD YOU

\ ANSWER EXTRA OFF A + C
B = B MATCH 1 C = A D E ? 0 ACTION A
Electron is negatively charged. Try again. A
C

Use the right-hand rule but remember that electron is a negatively charged particle. A
C

From the right-hand rule for a negatively charged particle, the answer is C. A

210 Type=C
V=INT(1000*SR+200)
B=INT(10*SR+1)*1E-9
R=9.11E=31*V/(1.6E-19*B)

220 Type=Q

If the electron (M=9.11E-31 kg, Q=1.6E-19 C) in the last question has a speed of \( \sqrt{1.0} \) m/sec, and the uniform magnetic field is \( B[1.0] \) T, what would be the radius in meters of the electron's circular path in the field? A

\[ 0 \% 0.03R \]

\[ 1 + R \]

\[ 1 + R/\text{METERS} \]

Action

1

? ?

Use the magnetic force as the electron's centripetal force. A

? ?

R

A From \( QV = MV/\text{B} \), \( R = MV/(QB) \).
If we wish the electron in Slide 7 to go straight forward, a uniform electric field (two oppositely but equally charged plates) must be added to the magnetic field with the positive plate:

A. On the top of the magnetic field
B. On the bottom of the magnetic field
C. On the farther side from you
D. On the nearer side from you

Answer: extra off
A ≠ A
B = B
Match 1
C = C
D ≠ 0
Action
A
F:
B:
R: Electron is a negatively charged particle, try again.
I C
F:
R: Use the right-hand rule for a negatively charged particle.
C
R
R
R:
F: Since the magnetic force deflects the electron downward, an opposite electric force to the magnetic force must be applied.
A
P:

Magnetic force on a current and torque on a loop
Slide 8 gives you a summary of the formulas of the magnetic force and torque. When you finish with this slide, type "GO".

\Answer
A 0 GO
? 0
\Action
A

If seen(1240) 0, B1260
\Type "#C" to get back where you left off.
? 0
\Type "GO" to continue.

260 Type=0
Page
Slide 9
Text

In slide 9, the magnetic force pushes the wire
A upward
B downward
C to the left
D to the right

\Answer
Extra off
A + B
B = A
\Match 1
C = C D
? 0
\Action
A
F1
B
F1
\The direction of the magnetic field is from north pole to south pole. Try again.
! C
F1
\Use the right-hand rule in slide 6.
C
? F1
? 0
F1
A1
IN SLIDE 9, IF THE CURRENT IS \[ I[1,0] \] AMPERES, THE CONDUCTOR HAS A LENGTH OF \[ L[1,1] \] METERS, AND THE MAGNETIC FIELD IS OF \[ B[1,0] \] T, HOW MANY NEWTONS OF MAGNETIC FORCE WILL ACT ON THAT CONDUCTOR?

ANSWER

\[ 0 \times 1.03 \times F \]

\[ 1 + F, N \]

\[ 1 + F, NEWTONS \]

ACTION

1

? ?

? ?

F

F

F

\[ \text{SINCE THE CONDUCTOR IS PERPENDICULAR TO THE FIELD,} \]

\[ F=ILB. \]

\[ \text{THE CURRENT LOOP IN SLIDE 10 WOULD ROTATE [CLOCKWISE/} \]

\[ \text{COUNTERCLOCKWISE]?} \]

\[ \text{ANSWER} \]

\[ \text{PHONIC ON} \]

\[ A + \text{COUNTERCLOCKWISE} \]

\[ B = \text{CLOCKWISE} \]

? ?

ACTION

A

F
B
FIND! IT IS COUNTERCLOCKWISE.
• RITYPE EITHER "CLOCKWISE" OR "COUNTERCLOCKWISE".

280 TYPE=0
PAGE
TEXT
THIS IS THE END OF THIS LESSON, SEE YOU LATER.
\ ACTION
SIOFF
S:0
LI
Slide 1. Objectives.

Having completed this lesson, the student should be able to calculate:

1. the magnetic field
   (1) at the center of a circular coil,
   (2) around a long straight wire,
   (3) within a solenoid

2. the magnetic force
   (1) on a moving charged particle,
   (2) on a current, and

3. the torque on a current-carrying loop in a magnetic field.
Slide 2. A summary of formulas of magnetic field.

1. The magnetic field at the center of a current loop

\[ B = \frac{\mu I}{2R} \]

where \( B \) = magnetic field in T (tesla) or N/A-m

\( I \) = current in amperes

\( R \) = radius in meter of the loop

\( \mu \) = permeability of the medium in T·m/A

\( B = 2\pi \times 10^{-7} \frac{I}{R} \) in vacuum or air

2. The magnetic field around a long straight current

\[ B = \frac{\mu I}{2\pi S} \]

where \( S \) = perpendicular distance from the point where magnetic field is sought to the current (in meters)

\( B = 2 \times 10^{-7} \frac{I}{S} \) in vacuum or air

The rest of the variables are the same as stated above.

3. The magnetic field inside a solenoid

\[ B = \mu \frac{N}{L} I \]

where \( N \) = number of turns of wire

\( L \) = length of the solenoid in meters

\( B = 4\pi \times 10^{-7} \frac{N}{L} I \) in vacuum or air

The rest of the variables are the same as stated above.

Note: \( \mu_0 = 4\pi \times 10^{-7} \) T·m/A = 1.257 \times 10^{-6} T·m/A for vacuum or air.
Slide 3. A problem of magnetic field.
Slide 4. Another problem of magnetic field.
Slide 5. How to resolve a vector for its component perpendicular to another vector?
Slide 6. The two ways to determine the directions of magnetic force (F), magnetic field (B), and the velocity (V) of a positively charged particle (or a current).

(A) Using left hand.  
(B) Using right hand.
Slide 7. A problem of a charged particle moving into a magnetic field.

Uniform magnetic field B (pointing away from you)
Slide 8. Formulas of force on a current and torque on a coil in a magnetic field.

1. Force on current element

\[ F = \text{ILB} \sin \theta \]

where \( F \) = magnetic force in newtons

- \( I \) = current in amperes
- \( L \) = length of conductor in meters
- \( B \) = magnetic field in T (N/A-m)
- \( \theta \) = angle between \( L \) and \( B \)

2. Force between parallel currents

\[ F = \frac{\mu I_1 I_2}{2\pi} \frac{L}{S} \]

(\( F = 2 \times 10^{-7} \frac{I_1 I_2 L}{S} \) in air)

where \( S \) = distance between the two currents in meters

- \( \mu \) = permeability of the medium in A-m/N

The rest of the variables are the same as stated above.

3. Torque on coil

\[ \tau = \text{INAB} \cos \theta \]

where \( \tau \) = torque in N-m

- \( N \) = number of turns of the coil
- \( A \) = cross-section area of the coil in \( m^2 \)
- \( \theta \) = angle between \( B \) and the plane of the coil

The rest of the variables are the same as stated above.
Slide 10. A problem of the torque on a coil in a magnetic field.
"LEARN LESSON LISTING"

LESSON: LESNB
DATE: 2/17/75
TIME: 14:14
PPN: 24000, 24005

10 TYPE=Q
PAGE
TEXT
IS YOUR TERMINAL
1  TTY
2  TEK 4010
3  TEK 4002

\ANSWER
1 0 1
2 0 2
3 0 3

\ACTION
1 2 3
CJSD=SA=1

PLEASE TYPE 1, 2 OR 3 ACCORDING TO THE CLASSIFICATION
OF YOUR TERMINAL:

20 TYPE=Q
PAGE
REVIEW ON>
STORE ON>
HINT ON>

TEXT

LESSON 9: ELECTROMAGNETIC INDUCTION
THIS LESSON MAKES USE OF A SET OF SLIDES ENTITLED
"ELECTROMAGNETIC INDUCTION", THESE SLIDES SHOULD BE
MOUNTED ON THE PROJECTOR, AND THE SLIDE TRAY SHOULD BE
POSITIONED TO SLIDE ZERO. BE SURE THAT THE PROJECTOR
IS TURNED ON TO THE FAN POSITION, THEN, TYPE "READY",

\ANSWER
A 0 READY

\ACTION
A
R1: IF YOU ARE HAVING A PROBLEM WITH THE PROJECTOR, SEE THE CONSULTANT. OTHERWISE, TYPE "READY" (NO QUOTATION MARK).

30 TYPE = Q
PAGE
SLIDE 1
SLIDE ON
TEXT
READ THE OBJECTIVES OF THIS LESSON. WHEN YOU FINISH YOUR READING, TYPE "GO".
\ ANSWER
A 0 GO
? 0
ACTION
A
R1: PLEASE TYPE "GO" TO CONTINUE (NO QUOTATION MARK).

40 TYPE = Q
PAGE
SLIDE 2
TEXT
WHICH GRAPH IN SLIDE 2 DOES NOT PRODUCE AN EMF?
\ ANSWER
EXTRA OFF
A + C
MATCH 1
B = A B D E F
? 0
ACTION
A
F1
P1
! B
F1
R1: HINT! THE CHANGE OF FLUX WITH TIME PRODUCES AN EMF:
B B B B
R1
? 1
R1
F1
F1: THERE ARE NO MAGNETIC LINES OF FORCE PASSING THROUGH THE LOOP IN GRAPH C.
A1

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50 TYPE=R
MOVING CONDUCTOR IN A MAGNETIC FIELD

60 TYPE=Q
SLIDE 3
TEXT
SLIDE 3 SHOWS HOW TO FIND THE MAGNITUDE AND THE DIRECTION OF AN EMF OR INDUCED CURRENT IN A MOVING WIRE, WHEN YOU FINISH WITH THIS SLIDE, TYPE "GO".

\(\text{ANSWER } A \quad \text{GO}\)
\(? \quad 0\)

ACTION
A
\(\text{C}! \text{F SEEN}(1060)=0,8170\)
\(\text{R}! \text{TYPE } "^C" \text{ TO GET BACK WHERE YOU LEFT OFF } ; \)
\(\ast\)
\(\text{R! \text{TYPE } "GO" \text{ TO CONTINUE}.}\)

70 TYPE=C
V=INT(100SR+20)
L=INT(100SR+1)
B=INT(100SR+1)*1E-6
E=L*V*B+0.5
E1=L*V*B

80 TYPE=Q
PAGE
SLIDE 3
TEXT
IF THE WIRE IN SLIDE 3 (A) HAS A LENGTH OF \(L[1.0]\) METERS AND MOVES DOWNWARD WITH A VELOCITY OF \(V[1.0]\) M/SEC; WHAT WOULD BE THE EMF IN VOLTS BETWEEN ITS TWO ENDS; WHEN THE MAGNETIC FIELD IS \(B[1.0]\) T? (SIN (30 DEGREES) \(=0.5\))
\(\text{ANSWER } 0 \quad \%=%,03\#E\)
1 \(\ast\) E
1 \(\ast\) E,V
1 \(\ast\) E,VOLTS
2 \(=\) E1
0 \(\%=%,03\#E1\)
2 \(=\) E1,V

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2 - E1: VOLTS

ACTION
1
F1
P1
2
F1
R1
YOU SHOULD CONSIDER THE ANGLE BETWEEN V AND B. TRY
AGAIN.
? ?
F1
R1
USE THE EQUATION IN SLIDE 3 TO FIND E,.
? ?
R1
@ W R O N G !  E = LV/2 =
P1

90 TYPE-R
PARADAY'S LAW AND LENZ'S LAW

100 TYPE=Q
SLIDE 4
TEXT
SLIDE 4 GIVES YOU A MORE GENERAL METHOD TO FIND THE INDUCED
EMF AND CURRENT IN A LOOP. WHEN YOU FINISH WITH THIS SLIDE,
TYPE "GO".
\ ANSWER
A 0 GO
? 0
ACTION
A
C IF SEEN(1100)=0, B110
R1 TYPE "#C" TO GET BACK WHERE YOU LEFT OFF;
@ R1 TYPE "GO" TO CONTINUE.

110 TYPE=Q
PAGE
SLIDE 4
TEXT
IF THE FLUX IN SLIDE 4 DECREASES, THE INDUCED CURRENT
IN THE LOOP WOULD BE IN THE [CLOCKWISE/COUNTERCLOCKWISE]
DIRECTION?
\ ANSWER
PHONIC ON
A + COUNTERCLOCKWISE
B - CLOCKWISE
? 0
ACTION
A
F1
B
FIND IT IS IN THE COUNTERCLOCKWISE DIRECTION BECAUSE OF
LIE' S LAW (THIS CURRENT WILL HELP PRODUCE MORE FLUX
TO OPPOSE THE DECREASE OF THE FLUX),

140 TYPE=C
N=INT(100*SR+50)
B=INT(10*SR+1)*1E=4
F=INT(100*SR+10)
L=INT(10*SR+1)*1E=1
E=N*B*L=2*3.140
E1=N*B*3.140*F

150 TYPE=O
PAGE
SLIDE 5
TEXT
SLIDE 5 SHOWS THE BASIC PRINCIPLE OF AN AC GENERATOR;
2
SUPPOSE A \(\frac{N1.0}{11} \) TURN SQUARE COIL WITH \(\frac{L[1.1]}{1} \) M ON
EACH SIDE ROTATES AS SHOWN IN SLIDE 5 AT \(\frac{F[1.0]}{1} \) \nREVOLUTIONS PER SECOND IN A UNIFORM MAGNETIC FIELD
OF \(\frac{B[1.0]}{1} \) T. WHAT WOULD BE THE MAXIMUM EMF IN VOLTS
BETWEEN THE TWO ENDS OF THE COIL?
\n
\ANSWER
0 $%#E03%E
1 * E
1 + E;V
1 + E;VOLTS
0 $#%E03%E1
2 = E1
2 = E1;V
2 = E1;VOLTS
ACTION
1
F1
2
F1
RI(ANGULAR VELOCITY IN RAD/SEC)^2(PI)(F) WHERE
PI=3.14 AND F= FREQUENCY OF ROTATION, TRY AGAIN,\n1?
RIUSE THE FIRST EQUATION IN SLIDE 5, \[ \text{R I F} \]
AIE\text{NBAW WHERE } W = \{ 2 \cdot 3, 14 \} (\text{FREQUENCY}) \#

160 TYPE=C
R1 INT(100 * R + 1)
E1 INT(1000 * R + 100)
V = E = 20
P = V * (E - V) / R
P1 = E * (E - V) / R

170 TYPE=Q
PAGE
SLIDE 6
TEXT
COMPARE A DC GENERATOR WITH A BATTERY AS SHOWN IN
SLIDE 6, AND THINK ABOUT THE DEFINITIONS OF EMF AND
TERMINAL VOLTAGE, THEN DO THE FOLLOWING PROBLEM:
THE ARMATURE OF A DC GENERATOR HAS A RESISTANCE OF
\[ R1 = 1 \text{ OHMS} \]. THE TERMINAL POTENTIAL DIFFERENCE OF
THE GENERATOR IS \[ E(1,0) \] V WITH NO LOAD AND \[ V(1,0) \] V WITH FULL LOAD, HOW MUCH POWER IN WATTS IS DELIVERED
BY THIS GENERATOR AT FULL LOAD?
\[ \text{AN} \text{SWER} \]
0 \[ 5 \% = 0.03 \times P \]
1 = P
1 = P, WATTS
1 = P, W
0 \[ 5 \% = 0.03 \times P1 \]
2 = P1
2 = P1, WATTS
2 = P1, W
ACTION
1
F1
2
F1
\text{RIUSE V=E=IR TO FIND I AND P=IV TO FIND P.} 

Which of the following statements is incorrect?

A. Every electric motor is also a generator.
B. The induced EMF in a motor armature is opposite in direction to the external applied voltage.
C. Back EMF is the induced EMF of a motor.
D. The existence of back EMF in a motor helps keep its speed constant.
E. The back EMF has a maximum value when a motor is just turned on.
F. The applied voltage equals the sum of back EMF and the IR product where R is the equivalent resistance of both armature and field resistances.

Answer: Extra off

Match 1

A B C D F

Action

A

Slide 7

Slide 7 gives you a general idea about the two differently wound DC motors. When you finish with this slide, type "GO".

Answer

A 0 GO

? 0
ACTION
A
PI
@
RTYPE "GO" TO CONTINUE.

200 TYPE=C
R1=INT(10*SR+1)
R2=INT(100*SR+10)
V=INT(1000*SR+100)
E=V-40
R=R1*R2/(R1+R2)
I=(V-E)/R
I1=V/R
H=I1*I*R
P=V*I
E1=(P-H)*100/P
E2=(V-H)/P
E3=E*3/4
E4=E*4/3

210 TYPE=Q
PAGE 8
TEXT
USE THE SUMMARY OF THE FORMULAS ABOUT DC MOTORS SHOWN
IN SLIDE 8 TO ANSWER THE FOLLOWING QUESTIONS.

A SHUNT-WOUND \[1,0]\ V DC MOTOR HAS AN
ARMATURE RESISTANCE OF \[R1,0]\ OHMS AND A FIELD
RESISTANCE OF \[R2,1,0]\ OHMS. AT NORMAL SPEED, THE
BACK EMF IS \[E1,0]\ V. WHAT IS THE CURRENT IN
AMPERES AT THIS NORMAL SPEED?

\ANSWER
0 $\%0.03\%
1 + I
1 + IA
1 + IA,AMPERES
ACTION
1
FI
! ?
FI
RIUSE V=E+IR TO FIND I.:
? ?
R1
?I
FI
212 TYPE-Q
SLIDE 8
TEXT
FOLLOWING THE ABOVE QUESTION, WHAT IS THE POWER IN
WATTS CONSUMED IN THE MOTOR?

\ANSWER
\[ R = \frac{(R_A \cdot R_F)}{(R_A + R_F)} \]
1 + H, H
1 + H, W
1 + H, WATTS
ACTION
1
F1
1 ?
F1
RIPC=I*I*R.
? ?
R1
@ AIWRONG! PC*I*I*R=

214 TYPE-Q
PAGE
SLIDE 8
TEXT
FOLLOWING THE ABOVE QUESTIONS, WHAT IS THE POWER IN
WATTS INPUT TO THE MOTOR?

\ANSWER
\[ P = \frac{1 + H}{1 + P} \]
1 + P
1 + P, W
1 + P, WATTS
ACTION
1
F1
1 ?
F6
RIP=IV,\n? ?
R1
@ AIWRONG! P=IV\n
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Following the above questions, what is the percent efficiency of the motor at its normal speed?

Answer

\[
\text{PERCENT} = \frac{\text{EFF}}{\text{PC}} \times 100\%
\]

Action

If you expressed the efficiency as a fraction:

\[
\text{PERCENT} = \frac{\text{EFF}}{\text{PC}} \times 100\%
\]

This is the end of this lesson. See you later.
Slide 1. Objectives.

Having completed this lesson, the student should be able to do problems concerning:

1. the induced emf and current using Faraday's law and Lenz's law for:
   (1) a moving wire,
   (2) a rotating coil,
   (3) a size-varying loop,
   (4) a stationary loop around a changing magnetic field

2. AC and DC generators,

3. DC motor, and

4. back emf.
Slide 2. Which of the following graphs will not produce induced emf?
Slide 3. The induced emf in a moving wire in a magnetic field.

\[ E = BLV \sin \theta \]

where

- \( E \) = induced emf in volts
- \( B \) = magnetic field in T
- \( L \) = length of wire in m
- \( V \) = speed of wire in m/sec
- \( \theta \) = angle between \( L \) and \( V \)
Slide 4. The determination of the magnitude and direction of induced emf and current.

1. Faraday's law

The induced emf in a wire loop is equal to the rate of change of the flux through it.

\[ E = -\frac{\Delta \Phi}{\Delta t} \]

where
- \( E \) = induced emf in volts
- \( \Delta \Phi \) = increase of lines of magnetic force in webers
- \( \Delta t \) = time interval in increasing flux in seconds

The minus sign implies that the induced current would be in such a direction that its own magnetic field would be in a direction that tends to decrease the change of the external magnetic field.

2. Flux density and flux in a uniform magnetic field

\[ \Phi = AB \]

where
- \( \Phi \) = flux or the total number of lines of magnetic force in webers
- \( A \) = cross-section area of a loop in \( \text{m}^2 \)
- \( B \) = magnetic field or flux density in T (N/A·m) or weber/m\(^2\)

3. Lenz's law

The direction of an induced current is always such that its own magnetic field opposes the changes in flux responsible for producing it.
Slide 5. The AC generator.

1. Maximum emf

\[ E_{\text{max}} = NBAw \]

where \( E_{\text{max}} \) = maximum emf in volts

- \( N \) = number of turns of armature
- \( B \) = magnetic field in T (N/A-m)
- \( A \) = cross-section area of armature in \( m^2 \)
- \( w \) = rotational speed of armature in rad/sec

2. Instantaneous emf

\[ E = E_{\text{max}} \cos 2\pi ft \]

where \( E \) = instantaneous emf in volts

- \( f \) = frequency of armature in number of revolutions per second
- \( t \) = time in seconds (\( t = 0 \), when the plane of armature is parallel to the magnetic field).
Slide 6. The DC generator.

Terminal voltage and emf

\[ V = E - Ir \]

where

- \( V \) = terminal voltage in volts
- \( E \) = emf of DC source in volts
- \( I \) = current in amperes
- \( r \) = internal resistance of the source in ohms
Slide 7. Differently wound DC motors.

"Shunt wound"

"Series wound"

Back emf: \( V = E_b + IR \) where
- \( V \) = impressed (applied) voltage in volts
- \( E_b \) = back emf in volts
- \( I \) = current in amperes
- \( R \) = total resistance in the circuit in ohms
Slide 8. Formulas concerning a DC motor.

1. At normal (operating) speed

   (1) General equation: \( V = E_b + IR \)  
       where \( V \) = impressed (applied) voltage in volts  
       \( E_b \) = back emf in volts  
       \( I \) = current in amperes  
       \( R \) = total resistance in ohms  
       \( R_a + R_f \) for series wound motor  
       \( 1/(1/R_a + 1/R_f) \) for shunt wound motor

   (2) Input power: \( P_i = IV \)  
       \( P_i \) = input power in watts (J/sec)

   (3) Consumed power: \( P_c = I^2 R \)  
       \( P_c \) = consumed power in watts

   (4) Efficiency: \( \text{Eff} = \frac{P_i - P_c}{P_i} \)  
       \( \text{Eff} \) = efficiency

   (5) Output power: \( P_o = P_i - P_c = IE_b \)  
       \( P_o \) = output power in watts

2. At the time of starting a motor

   (1) Back emf: \( E_b = 0 \)

   (2) Current: \( I = \frac{V}{R} \)

3. At other speed

   (1) Back emf: \( E_b' = nE_b \)  
       \( E_b' \) = back emf at this speed in volts  
       \( n \) = ratio of this speed to the normal speed

   (2) General equation: \( V = E_b' + IR \)
APPENDIX D

STUDENTS' COMMENTS
COMMENTS ON LESSON 1:

POINTS OUT INFORMATION THAT IS IMPORTANT IN CHAPTERS.
DIFFERENT WAY OF EXPLAINING MATERIAL NOT UNDERSTOOD IN CLASS.

The lesson gave further practice and a better understanding of light thru mirrors and lenses as each problem is taken step by step. The student can actually acquire more than 5 pts by increasing its value on his test.

The lesson was well planned and helped supplement the material in the text.
Make the student think. I learned a lot more than I got out of the book.
COMMENTS ON LESSON 1:

I feel this is a worthwhile method of studying. It was quite challenging for the first time.

Thought it was of much help in understanding light on mirrors and lenses. Look forward to Lesson 2.

I think that it should help me do well on the test & gave me a better understanding of lenses, and mirrors.

I think these lessons will help very much, especially in regards to problems showed me how much I hadn't learned. Very worthwhile.

Got a good understanding of how lenses & mirrors work.

Helped me attain a better understanding of how light "runs" through lenses & mirrors. It will help I'm sure.
COMMENTS ON LESSON 1:

You might try and get the slides more condensed but mainly it took so long because I am dumb.

This is an outstanding way for students to learn their Book material. This is a program that should be instituted in other classes.

This is a good way for the student to learn the subject. It makes it very interesting. The only thing I don't like is that you are pressed for time. For instance I had to wait for the teletype at the beginning of the lesson if a person was writing for it at the end of the lesson. I also am now late for my class. This makes me nervous. Therefore I couldn't perform as well as I could have.
Comments on Lesson 1:

Lesson was helpful to me in seeing that I don't know all about mirrors and lens. I think that it may help me in studying for test. Questions about mirrors and lens were good in the respect that it makes you have to think the answer out and be logical about it.

The lesson was very helpful. I thought that it thinks it will help a lot on the test.
COMMENTS ON LESSON 1:

...it going to help me
ameliorate the test tomorrow.
The lesson was very complete
and informative.

If the lecture exam follows this
test... then this test is very helpful
by running through their study problems
...many points were clarified to me
concerning the lecture material.
...I feel this type study session will
prove to be beneficial to me.

I'm only sorry I didn't take
advantage of this before the exam... The
material... I would suggest incorporating
...into 110 as well as expanding to all chapters
of books concerned with 111... I highly
recommend method for self-teaching aspect.
COMMENTS ON LESSON 1:

I can see that I should have studied more. As I look at it now I can see this would confirm whether I knew the material.  

Agree but a pleasant way to learn it from scratch, a then study, albeit wasteful of computer time. A. Baly

Excellent way to learn, it makes you think, and it is very challenging.  

I enjoyed working with the computer and at the same time learning how to do my physics. It seems easier to learn this way.  

Anthony Jacobson

I am sure that the computer study have given me a better understanding of the material we are now studying in Physics. This program I am sure will give me a little more incentive to study and learn Physics.  

John Orley

I learnt quite a bit from Lesson 1. Amita Tung

I thought the lesson a bit too long. But I feel I understand finding images better. Mary Piquiello

I understand the material better after completing the lesson but I felt that I was not prepared enough for some of the problems in which a few formulas were now do me.  

Dale Shelkto
COMMENTS ON LESSON 1:

This lesson was very helpful in learning how to draw different ray tracings for almost every condition. It also taught me to do ray tracings with lenses and mirror combinations which I knew nothing of before.

I enjoyed taking the lesson. I feel I learned from taking it, especially the part on the combination of lenses and mirrors. It makes it more fun getting to use the computer.
COMMENTS ON LESSON 1:

If I knew what I was doing this lesson would not have been easy, I didn't know the physics part of it so I got mixed up.

The material has been covered but I studied more diligently before coming. However I feel I have a much better understanding of the material than before and this will be very beneficial in my study for the exam. That's good.

I came into the lesson unsure of some concepts & ideas & the lesson really cleared them up. It put the material in a simpler way that can be understood & also applied to a more complicated problem.
COMMENTS ON LESSON 2:

I thought this lesson helped a lot. It cleared a lot of things up for me. Too long. Student should be able to leave a question without knowing the answer.

This lesson was much more difficult than lesson 1. But it did help me a lot.

It helped me to understand the concepts of "Wedges" and crystal X-ray which I totally lost in lecture. It was a hard one but a helpful one.

I learned a lot today because I really didn't finish reading the chapter so it benefited me a lot.

It was tough but fun. Learned the material better again.
COMMENTS ON LESSON 2:

Better preparation would have allowed me to benefit more fully from this lesson. I did however learn a great deal and also had a good time learning.

came in not fully understanding phase change through different indices and this lesson helped me understand through the slides & basic problems.

Having completed the lesson, I feel that it has helped and has shown me some errors in my understanding of some problems.

I’m still a little mixed up but it will help me a lot for the test. I think this lesson was too long also.

Since I knew nothing when I came in, it helped!

This lesson helped me to find what I must study before the exam.
COMMENTS ON LESSON 2:

Try to have formulas confirm to ones in book.
Sometimes I found the lesson hard to understand. I also felt the lesson was a little too long.

The equations were different than ones in the book. The lesson was too long and we should go over the chap in class before coming here and doing this work.

The lesson should give you the formulas and then let you work out the problems.

The lesson was good. I found it hard to understand because the material wasn't presented yet in class.
COMMENTS ON LESSON 3:

Lesson 3 study program was the most beneficial to me, all of them 3 close to date.
I had a much better understanding of the photoelectric effect after completing.
Lesson 3 helped me a great deal in the understanding and working of problems dealing with photoelectric effect.

This lesson helped me a lot to understand the problems we are to do.

I thought I knew this lesson well but I now see my mistake and will have them corrected by test time.

Best yet! I learned more this time than perhaps all previous put together. (Sr perfect.)
COMMENTS ON LESSON 3:

Lesson 3 was very helpful. The problem set at the end of the program helped to better understand the concepts that were formulated earlier in the program.

Lesson 3 was useful in the fact that it was not as difficult to understand as Lesson 2, therefore better knowledge was acquired. Preparations for the upcoming test will be much better as each chapter will be practiced.

Lesson 3 - I studied material before coming in and this helped in my speed. Additionally, lesson was helpful in my understanding various relationships and problems much better.

Lesson 3 - although the material was not studied extensively before coming in, the lesson helped me a great deal.
COMMENTS ON LESSON 3:

Very helpful lesson. I have been made aware of the different areas that I need to work on. Additional preparation is needed on my part before a complete understanding of this material is reached.

Helpful lesson, I now know what doesn't work on. Levee was a bit tough. Would have been great if I was the least bit prepared.

It was helpful, but some of the problems were hard.

I liked the way Lesson 3 was organized. It was like having an extra problem session. Since the tests are mostly problems, this helps greatly. Lesson 3 gave me more practical use of the formulas in this chapter and gave me a better understanding of the material.

Lesson 3 presented material in a unique fashion pretty hard but got message across very good.
COMMENTS ON LESSON 3:

The lesson was very clear in its explanations. I think it helped me understand the problems better in this chapter.

good lesson but it went slowly because I hadn't read the material. Probably the best one of the 3.

This lesson was very good. I didn't know much when I came in but know a lot more now.

I learned a lot from this lesson, the explanations are much clearer on the computer than those given in class.
COMMENTS ON LESSON 3:

LESSON 3 WAS HELPFUL FOR ME IN THAT THERE WERE CONVERSIONS TO BE MADE, AND IT MADE ME AWARE OF THAT. IT HELPED STRENGTHEN POINTS THAT I AM WEAK IN.

LESSON 3 WAS A GOOD REPRESER & STRENGTHENER IN THE EQUATIONS. THE FORMULAS ON THE SLIDES ARE PRESENTED BETTER THAN THE BOOK. AS ALSO STATED BY THE PERSON ABOVE THIS HELPED TO STRENGTHEN POINTS AS WAS WEAK IN.

GOOD BYE END PROGRAM.

Problems in Lesson 3 were a good selection of problems which helped in making conversions etc.
COMMENTS ON LESSON 4:

LESSN 4. I really needed these help sessions and very glad they were offered. It helped improve my grade and by learning my mistakes in advance.

LESSN 4. It helped me remember some old type problems that I had done before and it also helped me understand the new material better. My test grades have improved from doing these lessons.

These lessons have given me a better understanding of the material presented both in lectures and from the text. The lessons point out my weaknesses and illustrate different paths I might take in order to compensate for them. All in all a worthwhile experience.

This lesson (c) was one of the best and because it simplified the chapter's material, stated the main objective, & equations used, Bouch is very vague in this aspect. Very useful lesson and problems were very good to help benefit me in test.
COMMENTS ON LESSON 4:

Fewer examples and more description are in order.

IN LESSON 4 I LEARNED HOW TO USE THE IMPORTANT EQUATIONS, BUT I THINK IT IS A DISADVANTAGE TO USE THE COMPUTER WITHOUT THE PAPER, I LIKE TO TAKE THE LESSON WITH ME TO REVIEW.

Lesson 4 was the best yet learned more in this time. I still haven't done lesson 3 yet though.

Explanation was much better this time it cleaned up much of what our Physics book left unclear.

Lesson 4 helped with the problems that are to be done in the chapter, it cleaned a few things up for me.

Lesson 4 helped me more than any other lesson so far. Cleared up things that were unclear in class.
COMMENTS ON LESSON 4:

I thought this lesson was the best one we had. It contained a lot of information in the program.

Very helpful, particularly in using information & sheets for study purposes. I appreciate the conciseness & chance to make copies of slides to work & study with at leisure.

This lesson treated subject matter in such a way as to avoid confusion of the make up of the atom. It was not too long and not extremely difficult. I became familiar with the number of electrons capable in each shell and had good practice with this chapters equations. This lesson was extremely helpful in calculating problems dealing with Atomic structures, energies etc. It was direct to the point. I have gained worthwhile knowledge dealing with this material & it will benefit me greatly in the exam.
This lesson really helped me, it was easy to understand. It wasn't too long.

This one seemed shorter and it was appreciated. It was just as helpful as the other three. The whole program seems a good idea.

This lesson was shorter and that made it better. It helped me solve problems that I thought were difficult.

I thought this lesson was the best of all. It combined both easy and hard questions to keep my interest. This lesson (L) was the best organized. It was also much shorter which seemed good.
COMMENTS ON LESSON 4:

Lesson 4 - I thought it was of great help in understanding problems involved in Unit 6. Out of the 4 lessons involved this was the best explained & the most helpful for me.

Lesson #4 helped me a great deal in grasping the idea & concepts of Unit 6 and also a better understanding of working the problems.

Lesson #4 - The last yet!
Unit 6 was extremely difficult for me to understand. The 45 minute spent on the computer was more beneficial than the past 6 lectures (if you had read the material).

Lesson #4 was very informative. It asks various questions that are relevant to what we are studying.
COMMENTS ON LESSON 5:

I thought the 1st lesson was good, but I wasn't prepared enough on the use of vector addition.

Good expanded - Vector addition - It helped me alot.

The vector addition was very helpful. Also, an advantage was having suggestions on how to proceed programmed into the computer along with the "INCORRECT" notification! It gives you an idea of where to look to check your work.

Lesson 1 was quite helpful. Even though I was totally unprepared when I came (had read any of the assigned class reading), I was able to follow the program instruction quite easily. It should help me greatly with the tests.
COMMENTS ON LESSON 5:

I feel that this lesson was very helpful in understanding the electric problem in the chapters covered in lessons.

The section on vectors gave me a better understanding of principles involved and the problems on the electrical fields helped me to better understand them after a painful 95 minutes!

This lesson was very helpful in understanding the addition and resolution of vectors. It was helpful in illustrating the concepts and formulas of electric field. However, I was not well prepared for the comparative difficulty of the material and then I felt the session was a little lengthy. On the whole I feel it was worthwhile and improved my understanding of the material.

This lesson was very helpful to me, since it provided a good review of vectors. It was also helpful in reviewing some problem areas for me in the chapters on electricity.
COMMENTS ON LESSON 5:

The lesson helped with my understanding of the problems and formulas. Thanks S. Boges.
COMMENTS ON LESSON 6:

LESSON 2

This lesson helped develop the basic fundamentals in solving the various problems and this was very helpful.

This lesson was a good review for the upcoming test. Some of the problems were a bit lengthy. The error accepted by the computer was too close for photo rule accuracy.

This lesson helped me understand problems. The lessons should be understandable without reading material in text before working Lesson.
COMMENTS ON LESSON 6:

It was a good lesson.

Lesson was representative of the chapter in the book. However, this lesson was different from the first lesson in that it was difficult to perform without prior knowledge of the material. Very informative.

The lesson is quite nice for a student to get quick review for test or chap. Only wish that a choice of chapters would be available.

Lesson #2 was good but was not so much a programmed instruction as was lesson #1. Many of the questions could not have been answered without doing the assigned reading. In short, it was more like a test than a programmed instruction.
COMMENTS ON LESSON 6:

This season was very helpful to me in learning how to calculate resistance, power and EMF, along with associated ideas in Chaps 20 and 21.

This helped, but without Joe's help I'd never have made it.

Very frustrating!

Thanks for the help Joe. Without it, I wouldn't have finished. See you later.
COMMENTS ON LESSON 7:

Very good to help practice, which I need on vectors.
Thanks

Probably the best of the lessons so far.

Best lesson so far very helpful on vectors - easier to understand - may be do so feeling a little on computers work.

This lesson seemed to be easier than the others but the wording of the questions seemed to less clear than those of the past two lessons.

Very informative lesson, however some questions were worded ambiguously could have used some practice problems on topic, otherwise, quite representative of the material.
COMMENTS ON LESSON 7:

I feel that the unwritten formulas made the program time consuming.

Program was very helpful for reviewing with fairly hard problems but overall it was any good.

This type of exercise is good to prepare for the test. The degree of difficulty has been planned well.

This was an extremely well planned lesson. It has helped me immensely in understanding the concepts.

With the exception of a few unwritten formulas this lesson seems to have been the best planned and most helpful to date.
COMMENTS ON LESSON 8:

This was the most understandable program of the four I have studied.

11. Same As Above

I have the feeling that this lesson was too easy to be good preparation for the next test.

This lesson was quite clear in how to use the formulas and their relationship to the problems, but perhaps needed a little more practice problems.

These lessons were very helpful in understanding the material presented in the classroom and in book (text). The more of these lessons the better, one for each week of classes.
COMMENTS ON LESSON 8:

Lesson 4 was definitely the easiest of the 4 lessons. It will, however, help me considerably with the test on Friday.

Lesson 4 was in my opinion the best of the four. It helped me straighten out the needed formulas in my mind.

Lesson 4 was much closer to me than the previous three lessons. I feel I have learned a considerable amount. It has made some of the points in the test clear to me.

Lesson 4 was a very good lesson. I felt уверен thorough the paper as already been given it and helped clean things up.
APPENDIX E

QUESTIONNAIRE

300
THE QUESTIONNAIRE ABOUT LEARN LESSONS

Please check the 20 statements according to the following number code:
1--strongly agree, 2--agree, 3--neutral, 4--disagree, 5--strongly disagree.

1. The lessons helped me improve my test grades. __ __ __ __ __
2. The lesson materials are well organized. __ __ __ __ __
3. The lessons achieved the objectives set up at the beginning of each lesson. __ __ __ __ __
4. The lessons are useful for tutorial purposes. __ __ __ __ __
5. The lessons can be used for drill and practice purposes. __ __ __ __ __
6. The lessons can be used for remedial purposes. __ __ __ __ __
7. The lessons can be used for self-test purposes. __ __ __ __ __
8. The lessons helped me review the important concepts in the related chapters. __ __ __ __ __
9. The lessons reminded me of some important points that I had overlooked. __ __ __ __ __
10. The hints provided after a wrong answer helped me figure out the right answer. __ __ __ __ __
11. The lessons improved my ability to solve problems. __ __ __ __ __
12. The lessons correlated subtopics around major topics. __ __ __ __ __
13. The slides are very helpful in studying the lessons. __ __ __ __ __
14. The orientation lesson is helpful in instructing how to get on teletype terminals. __ __ __ __ __
15. I used calculation mode a lot. __ __ __ __ __
16. I prefer teletype to tektronix terminal. __ __ __ __ __
17. The lessons do cover the areas where students usually have difficulties.  

18. A lesson should be studied after the programmed material has been covered in lecture.  

19. "8" is about the right number of lessons in supplementing the teaching of the course Physics III.  

20. I did understand a frame of presentation before I moved on to the next.  

Suppose that you are the lesson author, please answer the following 3 questions:  

1. What would you do to improve or modify the lessons you have studied?  

Lesson 1, Mirror and Lens:  

Lesson 2, Interference and Diffraction:  

Lesson 3, Photoelectric Effect and Particle Waves:  

Lesson 4: Bohr Atom and Atomic Spectra:  

2. What are the 4 topics you would choose to study in optics and modern physics?  

3. What are the 4 topics you would choose to study in electricity and magnetism?  

Other comments:
APPENDIX F

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- **St. dev.:** 16.2 10.2 20.3 12.5 15.6 14.5 17.7 7.1 11.6 28.7 101.5 11.3
LEARN LESSON REPORT

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TIME:  12:10  
LAST UPDATE:  4/5/74  11:58  
DATE RANGES:  1/1/74 - 4/9/75  
STUDENT:  64227=64211  
FRAME RANGE:  300-900

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AVE. ELLIPSED TIME: 56 MINUTES  
AVE. TOTAL ANSWERING TIME: 40 MINUTES  
AVE. CPU TIME: 6.39 SECONDS  
TOTAL NO. OF RESPONSES: 139  
TOTAL NO. OF CORRECT RESPONSES: 93  
TOTAL NO. OF WRONG RESPONSES: 14  
TOTAL NO. OF NEUTRAL RESPONSES: 32  
TOTAL NO. OF TIME UPSI: 2  
ERROR RATE: 13.1 X

FRAME ANALYSIS

FRAME 92  TYPE = D  
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TOTAL NO. OF CORRECT RESPONSES: 3  
TOTAL NO. OF NEUTRAL RESPONSES: 3  
ERROR RATE: 0.32  
RESPONSE DISTRIBUTION: A-3

NO. OF TIMES CALC MODE WAS USED: 3  
AVERAGE ANSWERING TIME: 48 SECS

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ERROR RATE: 0.32  
RESPONSE DISTRIBUTION: A-3

NO. OF TIMES CALC MODE WAS USED: 3  
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308
APPENDIX H

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APPENDIX I

STUDENT REPORT
(SAMPLE)
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TIME: 23:59
LAST UPDATE: 4/5/74 11:58
DATE RANGE: 1/1/64 - 3/4/75

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<td>59</td>
<td>31</td>
<td>18</td>
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NO. LESSONS EXECUTED: 4
TOTAL ELAPSED TIME: 190 MINUTES
AVERAGE ERROR RATE: 39.2%

STUDENT: 64210

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<th>LESSON</th>
<th>DATE</th>
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<th>A.TIME</th>
<th>RIGHT</th>
<th>WRONG</th>
<th>NEUT</th>
<th>TIME UP</th>
</tr>
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<td>55</td>
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<td>LESN4</td>
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NO. LESSONS EXECUTED: 4
TOTAL ELAPSED TIME: 234 MINUTES
AVERAGE ERROR RATE: 37.1%

STUDENT: 64211

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NO. LESSONS EXECUTED: 2
TOTAL ELAPSED TIME: 141 MINUTES
AVERAGE ERROR RATE: 39.7%

NO. OF STUDENTS EXECUTING LESSONS: 3
BIBLIOGRAPHY


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