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ABSTRACT

A computer assisted mathematics review unit was designed for students enrolled in a community college physical science survey course, who had severe mathematical deficiences in their backgrounds. The CAI program (written in BASIC) covered multiplication and division of numbers written in scientific notation. Thirty-five students who scored zero percent on a diagnostic test on exponential notation made up the experimental group using the CAI, while 82 other students received the traditional lecture approach over the same material. Findings showed that the CAI program was successful in meeting the course objectives. The investigator reported that the CAI group performed at an acceptable level of competence as compared to those students covering the material through the traditional approach, and that the cost of the CAI program compared favorably with other methods of individualized instruction. Appendices include a complete listing of the CAI program, details of the unit (including rationale, objectives, and a description of learning activities), and a copy of the diagnostic test. (DT)

# Ed.D. Program for Community College Faculty

November 1975



# Nova University

# THE DEVELOPMENT OF A COMPUTER ASSISTED MATH REVIEW FOR PHYSICAL SCIENCE SURVEY STUDENTS AT BREVARD COMMUNITY COLLEGE

JOEL F. SHERMAN

A MAJOR APPLIED RESEARCH PROJECT
PRESENTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF EDUCATION

NOVA UNIVERSITY

1975

The study revealed a need to develop more elementary and detailed remedial mathematics instruction for a large percentage of these students and the need for diagnostic exams to determine the mathematical skills of the students at time of enrollment in the physical science survey sequence. The CAI program will be expanded into other areas of basic mathematics. In this particular set of circumstances CAI has been shown to be effective when used as an adjunct to the more traditional methods of instruction.

Abstract of a Major Applied Research Project Presented to Nova University in Partial Fulfillment of the Requirements for the Degree of Doctor of Education

# THE DEVELOPMENT OF A COMPUTER ASSISTED MATH REVIEW FOR PHYSICAL SCIENCE SURVEY STUDENTS AT BREVARD COMMUNITY COLLEGE

By
Joel F. Sherman

December, 1975

The purpose of this study was to develop a computer assisted math review unit designed for students enrolled in the physical science survey course at Brevard Community College. The program was designed for students entering the science course with severe mathematical deficiencies in their backgrounds. The CAI program was written, using the BASIC computer language, over a seven month period in 1974 and field tested with physical science students in January, 1975. The computer facilities consisted of a Honeywell 6000-series computer system owned by Fulton Data Systems of Atlanta and accessed via a time-share teletype terminal.

It was found that the CAI program was highly successful in meeting the course objectives of the chosen unit of study which consisted of an introduction to the use of exponents and exponential notation. The students accepted this method of instruction and performed at an acceptable level of competence as compared to a control group covering the same material in a standard lecture setting. The cost of the program compared favorably with other methods of individualized instruction which would have been needed to successfully raise the level of mathematical competency of these students.

ACKNOWLEDGEMENTS

I am greatly indebted to the staff of the math-science division for their help during the field-test period of this study. I would also like to express my appreciation to those students enrolled in Physical Science Survey I who participated in the study. Finally, I would like to express my gratitude to my wife Sandy who provided moral support and helped prepare this report.

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## Chapter I

## INTRODUCTION

### Statement of the Problem

The purpose of this study was to develop a method of instruction which would enable the student entering the physical science survey sequence with poor mathematical background to achieve success in the course. The method employed was the development of a computer assisted instructional program in remedial mathematics designed specifically for the science course. The computer program's degree of success in meeting the goals of this study was determined by means of a field test in January 1975.

### Introduction

The community college system in the State of Florida has brought at least two years of higher education within commuting distance of any resident completing a high school education or its equivalent. With the advent of an open door policy arises the immediate concern for providing quality general education to students with a wide range of interests and educational backgrounds. The problem is particularly acute when one examines closely the case of the uncommitted student; the student who has not set any specific career goals and has yet to decide on a major field of study.

It is the responsibility of the college to pay particular attention to the degree requirements for this student for two major reasons. In the first case this student may be enrolled in a two year terminal program and the courses offered him will be the last formal education that the student will be exposed to. Another alternative is that the student will find an area of interest from among the college parallel programs. In the latter case the general education curriculum should be designed such that the student encounters the minimum number of obstacles when he finally decides on a course of study.

With these factors in mind the majority of the state community colleges have designed their general education requirements to include basic language skills, basic number manipulations, humanities, and general science. The science requirement usually consists of courses in both the biological and physical sciences. For a number of reasons it is the general science requirement in the physical sciences which is often viewed with a great deal of distaste by the student and approached with a high level of anxiety. Colleges throughout the country are finding it necessary to closely examine their science requirements and make decisions as to their relevance and importance to the general education programs.

## Significance of the Study

Brevard Community College is no exception to the uncertainty and turmoil which arises whenever the relevancy of general education requirements becomes a topic raised for faculty consideration. The State Articulation Agreement, between the community colleges and the senior institutions of higher learning, only loosely defines the transfer requirements, and therefore the courses required for an Associate of Arts degree. During the height of the space program, when most residents of Brevard County were employed by space-related industries, there was no thought of reducing the science requirements in any way at Brevard Community College. It was only after the success of the Apollo Program, and the resulting massive aerospace layoffs, that the relevancy of the science program was questioned and that members of the faculty in the areas of humanities and the behavioral sciences began to legislate for reduction or elimination of the science requirement.

For over three years the question of general education requirements has sharply divided the academic faculty at BCC and resulted in the formation of seemingly endless numbers of committees with a resulting waste of both faculty and administrative time and effort. There have been no decisions made to this date regarding changes in the requirements. major difficulty is that there is no real justification for reducing the science requirement and the continuing pressure to do so is the work of a relatively small, but vocal minority of students who have experienced difficulty in the physical science survey sequence. If student anxieties concerning the science requirement can be reduced it should also be possible to resolve the conflicts among the faculty.

This study showed that the negative attitude on the part of the students is primarily a result of insufficient preparation for the course and, in particular, due to deficiencies in the students' mathematical background. An alternative method of instruction was designed to eliminate this problem and produce success in the course on the part of students entering with this deficiency.

Background of the Problem

Physical Science Survey I (PHS 101) is the first of a two term sequence which can be used to satisfy the general education science requirements at BCC. Those students leaving high school with a limited, or non-existent, science and math background are usually advised to elect this option in order to satisfy the science requirements. A previous study has shown that there is a high degree of correlation between the Florida 12th grade English and mathematics test scores and student success in this course (Tillman, 1973).

The course is taught by a number of different instructors and the following discussion will therefore be restricted to the procedures utilized by the author of this study. In 1973 the course was redesigned and styled after a behavioral objective based format (Sherman, 1973). The course material was divided into eleven instructional units. After utilization of this format for a two year period the student success rate in this course appears to have stabilized at 70%. This figure also represents the approximate norm for all general education requirements at BCC. Lack of success in this course has been generally attributed to difficulties on the part of the student in applying basic mathematical principles to the physical principles presented in the course. This conclusion is based on examination of student quizzes, discussions with students, and on an attitudinal survey completed by all physical science students (Sherman, 1974).

The survey showed that many students attributed their difficulty with science courses, and their resulting dislike of such courses, to the "high" degree of mathematical sophistication required in the coursework. In actuality, numerical manipulation beyond extremely basic mathematics plays a relatively limited role in the course, but since this particular skill is needed at the beginning of the course a lack of success tends to result in discouragement and apathy as regards the remainder of the course work.

As in any survey course, physical science survey attempts to cover a broad range of topics with no intention of in-depth coverage of any one topic. For this reason it is impractical for the instructor to spend more than a few class hours in a review of basic mathematics or numerical manipulations. There is no pre-requisite for this course as is true for all general education courses at BCC. The fairly heavy instructional load, five classes of 40 students per class, makes it difficult for the instructor to give the individual student extensive instruction in mathematical skills.

One possible way to implement a parallel program of remedial math development along with the development of physical concepts within the course would be to utilize a computer assisted instructional program (CAI) to develop the student's math background. This program would be used only for those students who enroll in the course with serious mathematical deficiencies as exhibited in a diagnostic examination.

## Chapter II

## REVIEW OF THE LITERATURE AND RESEARCH QUESTIONS

### Review of the Literature

The growth of computer applications to education has been tremendous over the last ten years. To deal with the almost overwhelming list of publications in the area of computer applications a separate study became necessary simply to organize the material into distinct categories. This study took the form of a NOVA practicum (Sherman, 1974) and divided the educational applications into the three areas of computation, simulation and CAI. The separate area of computer graphics was not considered at that time. The study was based on a search through the last ten years of the American Journal of Physics. This particular publication has reported consistently on applications in the areas of science and math. In addition an ERIC computer search was undertaken, restricting the search to the areas of undergraduate mathematics and CAI.

It became immediately obvious that the bulk of the work being investigated in the area of CAI was taking place on a fairly large scale at the major universities and that very little was being done at the community college level. In a report by the Carnegie Commission on Higher Education, (Levien, 1970) it is somewhat discouraging to see that one author describes a "small local facility" as one serving 100 to 300 terminals. One wonders what to call a college's single terminal facility. in this same report Peter G. Lykos of Illinois Institute of Technology notes that, "...very few junior college faculty in the hard and soft sciences and in business have any training or interest in the computer and its effects on their disciplines." In general this trend predominates throughout the literature. The research in this area of CAI is designed for large university systems of multi-user computer networks.

CAI represents the most controversial area of computer application to education. Educators were quick to recognize the value of the computer in the administrative areas of registration and bookkeeping in general, but there was a reluctance to bring the computer into the classroom. A survey of the use of computer systems in education found that there were some factors inhibiting the use of computers which did not affect science, business, and government to the same degree (Goodlad, 1966). Chief among these was the feeling among educators that automation of any part of education appeared to be somehow degrading and dehumanizing. The objecttion of many students and faculty to the issuance of student numbers was part of this general feeling that the "system" was acting to reduce everyone to a statistic.

Ruth Davis (1973) of the National Bureau of Standards has made the following observations on the subject of dehumanization and the computer:

> "...these same computers are making some deprived students feel human and happy perhaps for the first time. Surveys have shown that inner-city and female students prefer computer-aided instruction to the traditional human teacher. They feel that they are treated like everyone else when computers are the 'teacher'. Certainly we have never been able to program prejudice into a computer so that it can differentiate its output on the basis of concern or lack of concern with human values."

The Carnegie Commission Study also points out that more and more secondary school students are acquiring experience with computer augmented education and will come to college expecting to find similar techniques being actively used. A study by Patrick Suppes at Stanford (1971) predicts that by 1980 about 15% of students on all grade levels in the United States will be in daily contact with a computer for some aspects of their instruction.

The teaching machine, and its most sophisticated form, the digital computer, has its early roots in the work of B. F. Skinner in the 1940's. Programmed learning is essentially a way of controlling patterns of learning. The work of Skinner and Holland in the 1950's was essentially based on the following principles (Fry, 1963).

1. Each response must be reinforced immediately. This is the most obvious advantage of CAI. The student does not have to wait for an instructor to grade and return an exam but is given immediate reinforcement by the computer.

2. Errors adversely affect learning. Learning should take place in the absence of aversive stimuli. Skinner insisted that a successful program have a low error rate in student responses.

3. The student's observing behavior should be controlled. During the learning process distracting stimuli should be avoided. Unlike student behavior when a text is used, the student is forced to concentrate on a single item when CAI is employed.

Two types of CAI approaches that are being used are remedial sequencing and predicted sequencing. Remedial sequencing involves the use of a linear program, one in which all students follow the same path until a deficiency is detected. Then the student is lead through a branch until the deficiency is corrected and then back to the main program. Predicted sequencing involves a completely different program tor each student by attempting to predict the best path for each student (Coulson, 1962).

The rapid growth of computer utilization in education has led to a number of national and state conferences to update educators on the many possibilities available to utilize the computer as a learning aid. It is unfortunate that the majority of these conferences have addressed themselves primarily to large scale use of the computer in the universities and to computer applications at advanced levels of instruction. At the conference on Computers in the Undergraduate Curricula (Iowa, 1970) all papers presented in the area of mathematics were concerned with courses at the calculus level and, in addition, most applications required programming ability on the part of the students. The Conference on Computers in Undergraduate Science Education held later that summer (Chicago, 1970) followed a similar pattern. One result of this conference was the introduction of computer utilization to the physics courses at BCC in the areas of computation and simulation. Two years later when this author attended the Conference on Computers in Undergraduate Curricula (Atlanta, 1972) with the hope of finding an increased emphasis on applications to academic problems of the community college, again, only one paper, by Thomas Ralley of Ohio State University, was in the area of introductory algebra. That particular application not only required programming ability on the part of the student but was designed for mathematics majors.

There are some studies in the area of basic mathematics but these were not adaptable for the purposes set forth in this study. Theron D. Rockhill (1971) has developed and evaluated an instructional program in pre-calculus mathematics covering the areas of set theory, relations and functions, algebra, trigonometry, and analytic geometry. Objectives for the program were set by experienced calculus teachers. The programs diagnosed student difficulties and printed out instructional materials for each objective not satisfied by the student. No significant difference in achievement was found between the CAI group and a control group.

In a program developed by Stanford University and used in a number of colleges throughout the country (Stanford, 1969), the subject of mathematics is broken into 14 areas and is tackled one at a time in the specific areas of logic and algebra. It was found that 74% of the students in the computer-based group performed better than the best student in the conventional class.

Dartmouth University has played a major role in the application of CAI to instruction through the use of time-share techniques. The language BASIC (Beginners All-Purpose Symbolic Instruction Code) was developed by John Kemeny at Dartmouth and was the language used in this study. At the Chicago meeting it was pointed out that almost 80% of the students at Dartmouth are using the computer in one of its modes of application. Project COEXIST (Computer Oriented Experiment in Science Teaching) was funded at Dartmouth by the National Science Foundation and has as its main goal the development of a carefully coordinated calculus, elementary physics, and introductory engineering course (Danver, 1972).

Summary and Statement of Research Questions

To ascertain the effectiveness of using a computer-based math review instructional unit as a part of a required physical science survey course for students who are seriously weak in mathematics preparation, the study sought answers to the following questions:

1. What effect is there in terms of academic performance of such a CAI math learning unit on students in a required physical science course who are seriously weak in mathematics preparation?

2. What findings are there as a result of developing and testing a CAI math learning unit within a physical

science course that affect student and faculty preparation for CAI, scheduling considerations, cost analysis, and proper teletype and other equipment needs?

In respect to the first question, a study of prior utilization of CAI has shown that it can be quite effective when used on a large scale at major universities, and, when working with students majoring in science, math, or engineering. These students are, of course, more highly motivated and science oriented. How well will a similar approach work with students who are "forced" into science courses as part of their general education science requirements? The lack of enthusiasm on the part of students in this category has been a matter of concern to all serious science educators. Glenn Liming of Mississippi State University (1972) observes that, "Students enter the course as a 'captive audience'; they are primarily concerned with 'doing their time' in a physical science requirement...". Similarly, C.R. Cothern of the University of Dayton (1973) writes that, "To many non-science majors, the required science course is uninteresting, of no value to them (so they think), dry, and in general unappealing. They have a number of negative attitudes toward science, and science courses, ranging from hostility and rejection to fear or a kind of reverence for the scientific genius". The study seeks to provide needed information on a critically important community college student population.

In respect to the second question, much data needs to be developed on a broad front and conclusions drawn from this data in order for the instructor, the department, and college leadership to consider the feasibility of computer assisted instruction. This study based upon experimentation in one course unit sought to provide specific information useful for future planning.

Many related concerns bear upon this second question of the study and provided a focus to the investigation. How will the student react to the computer as instructor? This may be entirely a matter of the student's feelings about the subject matter and the degree of student motivation. A student may do well in the stimuli-restricted environment of CAI or may well resent the high degree of "instructor" control of material. Is the individualized aspect of the CAI approach an asset or is the social stimulus provided by the standard classroom learning situation a necessary part of instruction? How well will any learning which occurs as a result of the CAI program transfer to future learning situations using this material as a basis? In other words, will there be an improvement in the student's attitude toward mathematically-based instructional material in later units of this course, and in other future courses?

Attention must be given to the pre-requisites or preparation that will be needed before launching the student on a CAI program. It was assumed that the student's only deficiencies were in the area of mathematics covered by the CAI program. Will more serious and basic problems arise which prevent the student from being able to utilize the program and necessitate remedial work at an even lower level?

There is the all-important question of acceptance of this technique by other members of the instructional staff. What are the present feelings concerning utilization of CAI as an instructional tool and will a successful demonstration of the use of CAI lead other science and math instructors to adopt this technique in applicable cases. With the state of the economy and predicted cutbacks in educational funding there is little chance that an individual instructor would be allowed to use this technique on a continuing basis without strong support from the rest of the members of his department.

Scheduling may present a major problem. The department's single teletype is used for multiple purposes by both the chemistry and physics instructors at BCC. If a large number of students need to use the teletype within a relatively short period of time, will this create chaos within the department and produce ill feelings on the part of the other members of the instructional staff? We must also consider the sometimes erratic behavior of a commercial time-share computer service. Frequently, all phone lines are busy which would require re-scheduling of student time on the computer. Will this factor ultimately require an "in-house" computer for extensive use of CAI?

What cost factors need to be considered when using CAI? There is really no useful guide to answering this question since the majority of the studies examined involved large multi-terminal facilities with use of a university owned computer as opposed to our single terminal and time-share computer. Bunderson (1971) compared the cost of mainline instruction, where an entire course is CAI-based, to adjunct utilization and finds that preparation costs presently run from $5,000 to $10,000 per student course hour but notes that future costs can be reduced. It may be found as a result of this study, that the only practical way to utilize CAI is with one's own computer rather than leasing time.

The teletype to be utilized for information transfer is itself under question as a means of "student-instructor" interaction. A study by Dr. Bernard J. Luskin (1972) found that users complained that the teletype was restrictive in terms of its ability to present materials properly. Teletypes were described as "painfully slow, mechanical, subject to wear, and noisy". It may be necessary to sacrifice the ability of the teletype to provide the student with a permanent copy of his work, for the quietness and speed of a cathode ray tube output (CRT).

## Chapter III

## PROCEDURES AND METHODOLOGY

In order to answer the two research questions the study was designed to do the following:

1. Develop a computer assisted mathematics learning unit for a portion of a physical science course, utilizing a program partially prepared by the author in 1974.

2. Apply this program in a field test situation during the winter term of 1975 for students selected as seriously weak in mathematics preparation, comparing their academic performance with that of students not so selected who follow the regular course procedures.

3. Collect data and draw conclusions bearing upon student and faculty preparation for CAI, scheduling considerations, cost analysis, and proper teletype and other equipment needs.

In this chapter the characteristics are first indicated of the computer based instructional program to be developed, followed by procedures to achieve the above second and third objectives.

### The CAI Program

The actual program utilized was partially developed by the author of this study over the time period from June to December, 1974. The educational objectives met by the study through the use of this program were as follows:

1. Define the terms "exponent" or "power" and the term "raising to a power".

2. Multiply or divide any two numbers raised to a power when the numbers have the same base.

3. Express any number, whether greater than or less than unity, in scientific (exponential) notation.

4. Multiply any two numbers written in exponential notation and express the result in standard form.

5. Divide any two numbers written in exponential notation and express the result in standard form.

The program written to meet these objectives was written in BASIC. This language is readily available to any user of a commercial time-share facility and is one of the easier languages to work with due to its lack of rigid formatting as is found with a language such as FORTRAN.

The computer utilized is situated in Atlanta and is owned by Fulton Data Systems. A teletype provides a time-share link to their two Honeywell 6000 series computers. The college's teletype is a standard 10cps (110 Baud) model 33 teletype leased from Carterphone of Merritt Island, Florida.

There are a number of ways in which CAI can be used as a course supplement. One procedure is to use the computer to direct outside study and provide tests to the student when necessary. At Florida State University an IBM 1500 system is used to control all instructional activities of the student such as assigning reading, but does not actually present the textual material to the student (Kromhout, 1969, 1973).

The alternate approach is to provide all of the textual material at the computer terminal along with frequent quizzes to control the student's progress. It is this latter approach that was chosen for this study due to the nature of the students who will be using this program. As previously discussed there is a motivational problem with this group and a closely structured program with continued guidance was necessary to insure the best chance of success. The best approach was to present the material in small digestible bits and receive feedback from the student as often as possible. For convenience in modification and improvement of the program, based on student response data, it has been written as a data file names PHSFIL. This program includes indicators to the main program as to when to change from text mode to test mode. The material in PHSFIL is not essentially different from the material on exponential notation presented to the class in the more traditional form. The primary difference lies in the inclusion of instructions on how to respond to questions via the teletype and instructions on writing exponents using the teletype.

In order to keep a detailed record of student progress which includes time on line, student name, scores on all quizzes, number of times material was repeated and time spent on each section of the program, a second data file called

RECORDS was incorporated into the system. This file was accessed by the instructor at the end of each day and then erased when all necessary material had been recorded.

The main program, NOVAFIL, carries the major responsibility for all testing and branching functions. This program called on PHSFIL and RECORDS when necessary and had the additional function of generating all quizzes and controlling student progress based on quiz scores (Appendix A).

The quizzes are primarily multiple choice in nature. This type of test enables highly specific computer responses to incorrect choices of answer. A random number generator, which is part of the computer's software package, generated a totally different quiz each time that one was required complete with a new set of variable names. The answers for multiple choice quizzes were also generated using this technique such that each answer represented a commonly occurring type of error on the part of students working with material of this nature. When an incorrect response was chosen by the student he was told of the probable reason for his error and was then given an opportunity to correct his answer. If he again gave an incorrect response, the reason for the incorrectness of the response was explained once more and then the correct answer was provided. The student was never left with an incorrect answer in front of him before proceeding to a new problem.

If the student scored less than 50% on a quiz he was informed of his score and then branched through a review of the material under discussion. After this he was again tested. If he was again unsuccessful he was asked by the computer to consult with his instructor and show the instructor his work to date. At this point the program was terminated until a later date. At all times an assistant was available to the student to aid in any difficulties encountered in using the teletype.

Application of the CAI Program and Analysis of Data

The newly developed CAI program was applied in a field test situation during a second unit of the survey course. The second unit consists of a mathematical review which includes the topics of exponents and exponential notation (Appendix B). Before entering this unit all students were given a mathematical diagnostic test which covered the areas of algebraic substitution, use of exponents and exponential notation. The latter topic is divided into the two areas: expression of numbers in standard exponential form, and the manipulation of numbers written in exponential form (Appendix C).

The group used for this study was chosen from among the students enrolled in the four sections of the course taught by the author of the study in the winter term of 1975. The experimental group consisted of all students scoring zero percent on the sections of the diagnostic test covering the areas of exponential notation. This resulted in an experimental group of 35 students. The remainder of the students, numbering 82, were used as the control group and received the traditional lecture approach over the same material. The experimental group did not attend classes and had no contact with their instructor concerning the material being studied until completion of the CAI program.

It was necessary to take precautions to insure that the treatment of the control group did not significantly differ from the way in which past groups of students were taught the same material. The unit tests are completely objective and therefore instructor bias did not enter into the grading procedure. In addition a norm for student performance on this material was established by analyzing the scores on the Unit II tests for students enrolled in the course in August 1973, January 1974, and August 1974. These terms were chosen due to the fact that they all represent a normal 16 week term, as opposed to a six week summer term and the same instructional method was utilized in each case.

Examination of these scores for a total of 273 students shows a mean score of 67.7% with a standard deviation of 23.0. A t-test was run between this group and the control group to insure that the control group did not have scores significantly lower than this standard. If the grades had been significantly lower, then they would have been normalized using the standard scores described above.

To determine the effectiveness of the CAI method of instruction a t-test was utilized between the normalized control group scores and the scores of the CAI group. If the CAI group has scores which are equivalent to or significantly higher than the control group we may conclude that CAI is a method of instruction successful in meeting course objectives with students having mathematically deficient backgrounds.

In order to answer the other questions concerning the effect of CAI on student attitudes and their reaction to an electronic instructor, two sources of information were used. After completion of the program the instructor interviewed the student and recorded his feelings about the experience while it was still fresh in his memory. In addition, the student was provided with the materials needed to keep a record of his experiences and asked to write down anything which he felt needed improvement concerning the program, method of presentation, clarity of instruction and general comments about the effectiveness of this method of instruction. These comments were not signed and allowed the student more freedom of expression than the interview. These comments will play a major role in the revision and improvement of the CAI program and in its method of utilization.

In order to familiarize the other instructors with the study, they were given the opportunity to try the program and then asked for comments regarding improvement and expansion of the material under consideration. In addition, a full report of the results of this study will be made to the division both orally and in writing.

The computer records were analyzed and an estimate of the cost of full implementation of the program with additional areas of instruction were made based on this analysis.

There is one possible area which could result in an error in this study and that concerns the use of the diagnostic test as an instrument to determine the control group. If a student has studied this material in the past but suffers from a lapse of memory he may score low on the test. When presented with the CAI material he could then quickly "re-learn" the subject and the program would then be utilized as a review rather than a presentation of totally new material. Based on previous experience, however, the number of cases in which this problem occurs should be small.

## Chapter IV

## RESULTS OF THE STUDY

### Academic Performance

The first question to be answered by this study concerned the effect of a CAI program on the academic performance of students entering the course with mathematical deficiencies. At the completion of the lecture period on the material covered in Unit II of the physical science course the control group was given an examination similar to those given previous groups of students. To insure that the exam was no more difficult than those given to these previous groups a comparison was made between the control group results and the results of 273 students from three previous terms. A t-test showed that the control group scored significantly higher than the group of 273 students. (See Table 1 for a complete list of results). This was not totally unexpected due to the fact that the control group consisted of those students who had not exhibited severe mathematical deficiencies in their background. If the CAI group had not been removed from the control group it is expected that the overall grades would have been lower.

At the end of the two week period utilized for this study the grades for the CAI group were collected and analyzed. A complete list of these grades for each part of the CAI program can be found in Table 2. The first column

Table 1

A Comparison of Control Group Test Scores
With Those of Prior Groups of Students
in Physical Science Survey I

| Grade on Unit II Test (percentage) | CONTROL GROUP Number of Students | percent of total | PRE-1975 GROUP Number of Students | percent of total |
|---|---|---|---|---|
| 91-100 | 25 | 30.5 | 42 | 15.4 |
| 81-90 | 13 | 15.9 | 52 | 19.0 |
| 71-80 | 18 | 22.0 | 49 | 18.0 |
| 61-70 | 13 | 15.9 | 45 | 16.5 |
| 51-60 | 5 | 6.1 | 30 | 11.0 |
| 41-50 | 3 | 3.7 | 16 | 5.9 |
| 31-40 | 4 | 4.9 | 12 | 4.4 |
| 21-30 | 0 | 0.0 | 13 | 4.8 |
| 11-20 | 0 | 0.0 | 10 | 3.7 |
| 0-10 | 1 | 1.2 | 4 | 1.5 |

| | Control Group | Pre-1975 Group |
|---|---|---|
| | N = 82 | N = 273 |
| | Mean = 77.1 | Mean = 67.7 |
| | St. Dev. = 19.3 | ST. Dev. = 23.1 |

Table 2

Student Scores on Five Major CAI Quizzes

| Student Number | Use of Exponents * | Convert Numbers | Multip. of exp. | Division of Exp. |
|---|---|---|---|---|
| 1 | 70 | 70 | 100 | 80 |
| 2 | 100 | 100 | 90 | 70 |
| 3 | 80 | 100 | 90 | 90 |
| 4 | 90 | 100 | 90 | 80 |
| 5 | 100 | 100 | 100 | 0 |
| 6 | 90 | 100 | 100 | 100 |
| 7 | 100 | 100 | 100 | 90 |
| 8 | 100 | 100 | 100 | 100 |
| 9 | 100 | 100 | 90 | 90 |
| 10 | 100 | 100 | 100 | 100 |
| 11 | 100 | 100 | 80 | 100 |
| 12 | 80 | 100 | 90 | 90 |
| 13 | 100 | 100 | 90 | 90 |
| 14 | 100 | 100 | 100 | 70 |
| 15 | 90 | 100 | 100 | 100 |
| 16 | 100 | 100 | 100 | 90 |
| 17 | 100 | 100 | 90 | 90 |
| 18 | 100 | 100 | 90 | 100 |
| 19 | 100 | 100 | 90 | 80 |
| 20 | 100 | 100 | 100 | 90 |
| 21 | 70 | 100 | 90 | 90 |
| 22 | 90 | 100 | 90 | 70 |
| 23 | 100 | 100 | 100 | 90 |
| 24 | 100 | 100 | 90 | 100 |
| 25 | 100 | 100 | 90 | 80 |
| 26 | 90 | 100 | 70 | 60 |
| 27 | 100 | 100 | 100 | 100 |
| 28 | 90 | 100 | 70 | 60 |
| 29 | 90 | 100 | 100 | 80 |
| 30 | 100 | 100 | 100 | 80 |
| 31 | 100 | 100 | 100 | 80 |
| 32 | 80 | 100 | 70 | 70 |
| 33 | 100 | 100 | 100 | 90 |
| 34 | 90 | 100 | 100 | 100 |
| 35 | 100 | 100 | 90 | 80 |
| MEAN | 94.3 | 99.1 | 92.9 | 83.7 |
| Standard Deviation | 8.71 | 4.95 | 8.81 | 11.7 |

Five Quiz average...92.5
Average St. Dev. ...8.39

*Average of two tests.

of scores are the results of a comprehensive test on the use of exponents. Column 2 is an average score on the two tests which cover conversions from decimal to exponential notation. Column 3 refers to the test on multiplication of two numbers written in exponential form and the last column is the test on division using numbers in exponential form. On the latter two tests the student was required to choose the answer which was not only mathematically correct but correctly written in standard form. In order to collect the results in a form which can be compared to the results obtained by the control group they were divided into three general classifications as shown in Table 3. These are; use of exponents, writing numbers in exponential form, and manipulation of numbers (mathematical manipulation) written in exponential form. All scores listed in this table are expressed as percentages followed by the standard deviation for each group. In all cases the CAI group scored significantly higher than the control group as determined by a t-test.

An examination of the individual quiz scores shows that the CAI program achieved its greatest success in the area of converting numbers from decimal to exponential form. On both quizzes covering this material only one student scored less than 100% on the quizzes. However, even this individual was able to correctly respond to the questions within two attempts. The CAI group exhibited the lowest scores on the topic of division of numbers written in exponential form. It was this area, and the verbal responses given by the

Table 3

Comparison of Test Scores on Exponential Notation Tests Between CAI Group And Control Group

Use of Exponents

CAI Group..........94.3 ± 8.7

Control Group......82.0 ± 22.0

Writing Numbers in Exponential Form

CAI Group..........99.1 ± 5.0

Control Group......87.0 ± 24.0

Mathematical Manipulation of Numbers in Exponential Form

CAI Group..........88.3 ± 10.3

Control Group......65.0 ± 28.0

All scores listed above are percentages followed by the standard deviation. All CAI group scores were significantly higher as determined by a t-test. The CAI scores in the final group above are an average of the last two columns of scores in table 2.

students when questioned about their difficulty with this material, which show the need for some major changes in the approach to this course. This facet of the study will be expanded on in Chapter V.

To briefly summerize, the statistical data thus indicates that the CAI program can be used to successfully teach the student the fundamentals of exponential notation. This data represents, however, only one of a number of criteria which were used to determine the overall success of this approach.

Transfer of Learning Following Use of CAI

The second question raised in this study concerns transfer of learning. How well will any learning which takes place in the CAI environment transfer to future learning situations involving either subject matter based on the material covered by the CAI program or material similar to that covered in the CAI program? In some cases this may have been the first successful mathematical experience for this type of student. Has success increased the motivation of these students and given them the confidence necessary to succeed in future mathematically-based units of instruction within the PHS 101 course? In order to answer this question an examination of the student scores on the next three units of instruction was made. Only scores for students taking all three exams were included. All students, the CAI group and the control group, had the same lectures as a single combined group and had the same objective exams. A complete list of results is in Table 4.

Table 4

Performance of CAI Group Compared
to That of Control Group
on Later Instructional Units

CAI GROUP SCORES

| Unit III | Unit IV | Unit V |
|---|---|---|
| 30 | 25 | 47 |
| 33 | 25 | 47 |
| 41 | 31 | 47 |
| 44 | 56 | 60 |
| 14 | 38 | 47 |
| 38 | 81 | 67 |
| 58 | 69 | 53 |
| 22 | 50 | 73 |
| 17 | 19 | 67 |
| 90 | 75 | 87 |
| 33 | 13 | 53 |
| 10 | 50 | 27 |
| 27 | 25 | 53 |
| 0 | 25 | 40 |
| 58 | 75 | 60 |
| 20 | 38 | 47 |
| 48 | 50 | 33 |
| 70 | 94 | 60 |
| 97 | 94 | 80 |
| 55 | 100 | 47 |
| 37 | 69 | 53 |
| 86 | 75 | 60 |
| 75 | 69 | 67 |

Of the original 35 students in the CAI Group only 23 students were present for the next three units.

Of the original 82 students in the Control Group only 63 students were present for the next three units.

| Unit III | Unit IV | Unit V | |
|---|---|---|---|
| 43.6 | 54.2 | 55.4 | Mean Score for CAI Group. |
| 70.7 | 70.3 | 65.3 | Mean Score for Control Group. |

Unfortunately the data in this table shows that when returned to a typical lecture classroom setting the CAI group quickly reverted to their previous, pre-CAI, level of performance. The success of this group in mastering the material covered by the CAI program did not carry over to future units of instruction. This result can be interpreted in a number of ways:

1. The CAI experience may have been too short in this case to significantly affect the student's mathematical abilities and attitudes regarding mathematics-related instructional areas. It is possible that a longer program, covering many more areas, could be developed to provide a strong base in mathematics and at the same time alleviate the fears of the student regarding numerical manipulation.

2. It is possible that this type of student can learn only in the highly structured atmosphere of CAI and will never achieve success in this area of instruction under the conditions of more traditional lecture methods.

3. The student's grade in PHS 101 is based on the highest 9 scores out of a total of 11 unit exams. Some students automatically assume that their poorest grades will occur on the units with the greatest mathematical emphasis. They will therefore put little effort into mastering this material and hope that high grades on later, more descriptive, material will compensate for the early low grades, two scores of which will be eliminated. Therefore the scores on the three exams following the mathematics review may be a result of the particular system of grading being utilized in this course.

Effect of Student Background on CAI Performance

Statistically this program accomplishes its goal of successfully teaching the students the use of exponential notation. As a result of student comments, coupled with a close examination of the student's performance on individual CAI exams, some basic assumptions concerning the background and prior abilities of the students need serious consideration and re-evaluation.

Up to this point in time the student having difficulty in problems involving numerical manipulation is assumed to simply need either basic instruction or a review in the fundamentals of algebra. Implicit in this assumption is that the student is fully able to manipulate numbers in operations involving addition, subtraction, multiplication and division. The last units of the CAI program, and the student response to this material, show that this assumption is without foundation.

Two major weaknesses in mathematical ability resulted in student difficulty in completing the program. First, many students were totally unable to manipulate positive and negative numbers. A prior knowledge of the rules regarding positive and negative numbers is critical to total comprehension of the material covered by this program. Many students were attempting to master the use of such numbers by examining their usage within the examples in the program. This was difficult to do since the program was written assuming a prior knowledge of this area of mathematical manipulation and instruction in the use of positive and negative numbers was not a program objective.

Even more serious was the fact that approximately 30% of the students (as determined by student comments) encountered difficulty in the last section of the program because of an inability to divide one number by another, particularly when one number contained a decimal part. In a problem such as $(1.2 \times 10^8)/(4 \times 10^6)$ the students would comment that they understood the rules for determining the power of ten needed for the answer but that they had no idea of how to divide 1.2 by 4. Many stated that they thought such a division impossible since the numerator was smaller than the denominator. All division problems had been designed such that the numerator would be an even multiple of the denominator with the decimal point displaced such that all numbers were in standard form (a number between one and ten multiplied by a power of ten). Closer questioning of these students revealed that many of them were not only ignorant of long division but were somewhat hazy regarding multiplication and were lost without a multiplication table.

The instructors in this course had been long aware of deficiencies in student mathematical training but problems of this magnitude, involving such basic mathematical manipulations had not been expected among such a large number of students.

A final and more easily understandable difficulty with the program concerned the use of numbers in "standard form".

Over 90% of the students commented that they felt that there should be a unit of instruction within the program giving drill and further explanation of the conversion of a number to standard form. The lack of more detailed information gave some of them difficulty in responding to the questions on the last two quizzes.

Student Perceptions of CAI

There were two sources of student feedback concerning the CAI program. First, the student was asked to record any comments concerning the learning experience as they came to mind while actually working with the program. These comments were to include his feelings about using the teletype as an input-output device, any ambiguities in instruction concerning either use of the teletype or operation of the CAI program, and his general feelings concerning the effectiveness of the program. This student feedback provided not only data for outcome-type evaluation of the student use of the CAI program, but also formative evaluation data useful for making adaptations as a part of the process of developing the unit.

As a second source of student perceptions an interview technique was used. At the completion of the program the student was interviewed by the instructor and his progress and scores discussed with him. If any area of instruction offered the student a particularly high degree of difficulty, as evidenced by quiz scores, the student was questioned concerning the reasons for any problems encountered in accessing or in using the program. The comments can be separated into two general areas: use of the teletype, and CAI as a method of instruction.

The teletype as an input-output device. The first group of student comments concerns the mechanics of utilizing the teletype and the student's feelings about the teletype itself. The students generally found the teletype to be noisy and somewhat frightening at first. The smallness of the room helped accentuate the noise. As the program progressed they appeared to accustom themselves to the noise level. A positive comment from some students concerning the noise is that it held their attention to the material presented and this was verified by the student assistant who noted that after a period of time the students became oblivious to all other distractions and exhibited a high degree of concentration in their approach to the program.

One unfortunate side effect of the noise problem was the result that two students tried to temporarily shut off the teletype in order to think and inadvertently cut themselves off the air requiring re-access of the computer. Following this a note was taped to the teletype instructing students not to touch any of the knobs other than the keyboard keys.

The students complained that the thin metal bar which holds the paper in place sometimes blocks the line of print preceding the line being typed and makes it awkward when trying to respond to questions. After the first few students registered this complaint an additional instruction was given to the students informing them that whenever desired they could manually advance the paper. This occasionally resulted in accidental overprinting of a line but otherwise the problem appears to have been corrected by this additional instruction.

Some students with previous typing experience found that the tendency to want to use the shift key occasionally produced typing errors. (All characters on the teletype used are upper case.) Those students with the least amount of typing experience had the least degree of difficulty in adapting to the teletype keyboard.

The teletype's speed of transmission, ten characters per second, rather than being too slow for CAI as anticipated prior to this study, was found to be too fast by most students. It became necessary to tell them that they were not required to read at the teletype's transmission speed but that they could follow the program at any pace comfortable to them. Many students indicated that they would wait for the teletype to type a full paragraph of textual material and then read the entire paragraph. They found this easier than line by line reading as typed.

Student perception of the CAI program. How does the student react when the traditional classroom lecture atmosphere is replaced by the more restrictive, closely monitored approach characteristic of CAI? The overwhelming feeling resulting from this method of instruction was extremely positive. A majority of the students commented favorably on the indiv-idualized aspect of this method of instruction. A second aspect which received favorable comment was the manner in which the material was presented in small, easily digestible bits rather than as a whole unit. A majority of the students commented that they wished that the remainder of the course material could be presented in this manner.

A negative aspect of this approach was that some of the group felt that they were rushed by the computer and were afraid of thinking about a specific problem for too great a period of time. There was a feeling that the computer was impatiently waiting for them to respond to a question so that it could proceed to new material. About halfway through the study period it was found that this particular anxiety could be somewhat alleviated by informing the students that they have a full ten minutes to answer any one question before the computer automatically terminates the program. It was found helpful to also alleviate concerns on the part of the students concerning the economic cost of the program. Many felt that "dead-air time" in which they were thinking about the answer to a problem was wasting money in terms of computer time.

One improvement that was suggested by a number of students concerned break points that should be incorporated into the program to give the student a chance to relax between quizzes. The program as presently designed has only one built-in break where the student can temporarily terminate the program.

One fact that was immediately outstanding was a lack of student comment concerning the de-humanizing aspect of CAI.

No student showed any evidence of concern regarding the fact that a human instructor was being replaced by a "machine".

Acceptance of CAI by the Faculty

CAI will only be an acceptable alternative to more traditional modes of instruction if it is accepted by the faculty of the Science Division as a whole. The college cannot be expected to fund a program which has only limited faculty acceptance. In order to acquaint the science faculty with the goals of this study and method of utilization of CAI they were given an opportunity to try the program for themselves and then asked for comments concerning its utilization. The general feeling was that the methods of CAI were acceptable but there was concern over the economics of this method of instruction. Part of this concern results from uncertainty over the continuing inclusion of a science requirement as part of the general education requirements. This is a topic still under discussion at Brevard Community College although it appears that at this time there will be no reduction in the science requirement for at least the next two years.

A second area of concern was the degree of administrative support that could be expected in terms of released time for faculty to prepare CAI programs. The faculty comments in general reflected not so much on CAI as an acceptable method of instruction but on the economics and politics of introducing this technique on a large scale. Most felt that a program such as the one under discussion could be very helpful in reducing the amount of class time spent on remedial work with individual students and would in turn free the instructor to pursue some of the course topics in greater depth.

Scheduling Problems

When this study was first proposed one of the major difficulties anticipated concerned scheduling of students to use the program. The Science department has access to only one teletype and this is used by four faculty members for a variety of purposes. Running the CAI program for 35 students would require fairly extensive use of the teletype over a short period of time if all students were to complete the program in time to join the remainder of the class for the next unit of study.

In order to achieve some idea of the time needed per student, the program was informally tested on students who would not be used in the study (primarily student assistants) and as a result of this, time blocks of 90 minutes were set up. A schedule of four 90 minute blocks were set up for each day and the students in the CAI group asked to sign up for one block of time. Additional times were arranged for completion of work not covered by the first 90 minute block. The other instructors were warned in advance that computer utilization would be somewhat limited for a two-week period and that any programs to be run would have to be handled in times other than the scheduled hours. It was found that after the other instructors had been familiarized with the goals of this study, fairly good cooperation was obtained as regards scheduling of computer time.

One immediate problem concerned system malfunctions. Occasionally a student would be cut off from the system by either computer or telephone line malfunction. This would necessitate rescheduling the student and adding coded statements to the program so that the computer would re-route the student to the appropriate place. This fortunately occurred in only a few cases since this tended to discourage and disturb the student when it did happen. A more common problem was that of the system being busy, with both WATS lines busy, and a resultant delay until the system could be accessed. None of these delays lasted for more than 15 minutes and necessitated only minor scheduling changes.

In general, a single teletype appeared to serve the purposes of this study where only a limited use of CAI is made. The facilities were taxed to the limit and any additional use of the system during this time period would have overloaded it and resulted in frayed nerves on the part of the faculty.

Economic Factors

An important consideration in a study of this nature is the cost to the college of CAI utilization. In a time when educational funding is highly uncertain in the State of Florida, CAI must be designed to be economically competitive with alternate forms of learning.

Table 5 gives a complete breakdown of the time-on-line for each phase of the program. Some time data was lost when

Table 5

Time On-Line For Each Part
of CAI Program
(All Times in Fractions of an Hour)

| Student Number | Exponents (Multip.) | Exponents (Division) | Exponents Quiz | Scientific Notat. #1 | Scientific Notat. #2 | Multip. Sc.Not. | Divis. Sc.Not. | Total Program |
|---|---|---|---|---|---|---|---|---|
| 1 | .242 | .051 | .114 | .168 | .186 | .158 | .168 | 1.087 |
| 2 | .087 | .041 | .116 | .119 | .142 | .195 | .325 | 1.025 |
| 3 | .107 | .045 | .164 | .124 | .098 | .137 | .244 | 0.919 |
| 4 | .076 | .051 | .117 | .130 | .100 | .164 | .191 | 0.829 |
| 5 | .088 | .047 | .102 | .123 | .130 | .164 | .157 | 0.787 |
| 6 | .078 | .031 | .132 | .122 | .100 | .162 | .161 | 0.786 |
| 7 | .071 | .030 | .071 | .122 | .096 | .214 | .177 | 0.781 |
| 8 | .080 | .047 | .065 | .117 | .095 | .107 | .140 | 0.651 |
| 9 | .075 | .030 | .081 | .129 | .095 | .094 | .085 | 0.589 |
| 10 | .094 | .030 | .078 | .120 | .098 | .156 | .480 | 1.056 |
| 11 | .135 | .091 | .101 | .163 | .127 | .347 | .471 | 1.422 |
| 12 | .114 | .069 | .159 | .203 | .148 | .229 | .312 | 1.234 |
| 13 | .080 | .059 | .190 | .226 | .284 | .668 | .521 | 2.028 |
| 14 | .079 | .030 | .109 | .129 | .116 | .198 | .383 | 1.044 |
| 15 | .100 | .050 | .131 | .138 | .097 | .150 | .219 | 0.885 |
| 16 | .121 | .037 | .096 | .140 | .116 | .161 | .253 | 0.924 |
| 17 | .070 | .036 | .071 | .125 | .100 | .087 | .158 | 0.647 |
| 18 | .098 | .033 | [illegible] | .127 | .103 | .126 | .257 | 0.841 |
| 19 | .122 | .057 | .13[illegible] | .156 | .135 | .378 | .453 | 1.431 |
| 20 | .079 | .080 | .230 | .172 | .138 | .271 | .414 | 1.384 |
| 21 | .114 | .122 | .210 | .204 | .130 | .234 | .401 | 1.415 |
| 22 | .074 | .033 | .087 | .145 | .116 | .165 | .224 | 0.844 |
| 23 | .075 | .057 | .099 | .134 | .112 | .216 | .209 | 0.902 |
| 24 | .094 | .073 | .254 | .160 | .122 | .225 | .268 | 1.196 |
| 25 | .076 | .036 | .142 | .158 | .117 | .127 | .261 | 0.917 |
| 26 | .074 | .030 | .071 | .127 | .097 | .122 | .125 | 0.646 |
| 27 | .076 | .039 | .146 | .119 | .104 | .154 | .243 | 0.881 |
| 28 | .147 | .066 | .083 | .227 | .127 | .404 | .942 | 1.996 |
| 29 | .091 | .057 | .138 | .124 | .105 | .213 | .339 | 1.067 |
| Mean | .097 | .050 | .124 | .293 | .122 | .208 | .296 | 1.042 |

the program was terminated due to telephone or computer problems. For this reason data appears for only 29 students. The average student time for the program was 1.042 hours with a standard deviation of .353 hr. The minimum time needed was .589 hours and the maximum time was 2.028 hours. Each running of the program utilized 36.6 cpu (central processor units) of actual computer time.

The costs of this program can be divided into two areas: Developmental costs and operational costs. The computer program was developed over a period of seven months and utilized approximately 600 man-hours of time in addition to about 100 hours of computer time. (The time referred to is terminal time as opposed to processor time.) These figures are somewhat high due to the fact that this was a first attempt on the part of the author of this study to produce a program of this nature and much of the time was spent in trying out different techniques of information presentation and testing.

To produce additional units of instruction would require only approximately 10% of the time mentioned above per unit. The developmental costs for the initial unit were $1200 for computer time and an estimated $3000 for salary. It should therefore be possible to develop future units for under $500 per unit.

Operational costs are based on two factors: actual terminal or on-line charges are $8.00 per hour, and processing time is $.03 per cpu. The CAI program takes 36.6cpu each time that it is accessed and the average student used 1.042 hours of terminal time as previously mentioned. The average cost per student is therefore $9.44 or a total of $330 for a group of 35 students. If the program is accessed more than once per student an additional cost of $1.10 per use must be added.

In addition to this there are program storage costs which were $11.00 for the month that the program was utilized. Teletype rental costs $65.00 per month and telephone charges are $15.00 per month. Finally, a student assistant is paid at the rate of $2.00 per hour. The total cost to run the program for a two week period was $453.95 or $12.97 per student. This can be expressed as $12.45 per hour of instruction. For purposes of comparison a private tutor of college level courses will usually receive $10.00 per hour. For a summary of these figures see Table 6.

Table 6

Summary of Cost Factors
For CAI Program

| | |
|---|---|
| Terminal time @ $8.00 per hour, 1.042 hours.......... | $8.34 |
| Central Processor Time @ $.03 per cpu, 36.6 cpu....... | $1.10 |
| Program Storage Costs @ $11.00 per month, 2 weeks.... | $0.31 |
| Teletype Rental @ $65.00 per month, 2 weeks........... | $0.93 |
| Telephone Rental @ $15.00 per month, 2 weeks......... | $0.21 |
| Student Assistant @ $2.00 per hour, 1.042 hour........ | $2.08 |
| Total.................. | $12.97 |

All figures in the right hand column above are cost per student based on a two week period of utilization of the CAI program

Chapter V

## SUMMARY AND IMPLICATIONS

The purpose of this study was to develop a method of computer-assisted mathematics review instruction which would be successful when utilized with physical science survey students having limited mathematical abilities and low motivation. In terms of the limited goal of meeting specific course objectives and teaching the students to use exponential notation the CAI program was successful. The highly structured, closely regulated format utilized by CAI programs can thus be successful in teaching basic mathematical concepts to students with this particular background. CAI has already been proven effective with students of high scholastic abilities and motivation.

In view of this finding a recommendation will be made to the math-science division that additional programs be written in areas of physical science that involve mathematical manipulation, specifically:

1. Use of the metric system
2. Newton's Second Law and forces
3. Energy and momentum

In addition, utilization of the program has shown the need to expand the present program in two areas. An introductory unit on the use of positive and negative numbers would be a useful review for most students. A unit on converting numbers to standard form should follow the units on writing numbers in exponential form. This latter topic was briefly discussed in the program but needs additional emphasis and student practice.

To improve analysis of student scores the program RECORDS will be modified to record the number of attempts on each problem by the student. In addition the grading system will be modified to reflect the number of attempts on a specific problem. One probable reason for the large difference in scores between the CAI and control groups may have been the fact that the CAI group was allowed two attempts per problem with no penalty for an initial wrong guess. This may have resulted in some students utilizing this factor as a means of eliminating one answer on the multiple choice quizzes.

A major result of this study was the verification of long-standing suspicions concerning the mathematical level at which many students at Brevard Community College enter the physical science survey course. It can now be assumed that a student who enrolls possessing no mathematical skills at all will only be frustrated, develop an even greater dislike for science and waste time that could be spent in strengthening his background in order to prepare him for college level work.

A recommendation will be made to the math-science division that a uniform diagnostic test be given to all physical science students during the first week of classes.

This test will cover the area of basic mathematical manipulations, specifically, multiplication, division, use of fractions, use of numbers in decimal form, and use of positive and negative numbers.

A cut-off score will be used to determine which students exhibit major mathematical deficiencies. It will be recommended that time be provided instructors to write remedial CAI programs covering the areas of math listed above and that these students work with the programs before proceding to the standard course work. This approach is highly preferable to reducing the mathematical level of the course for all students as has been suggested in the past by various elements of the academic community.

A second goal of this study was to analyze student acceptance of this method of instruction. There was concern that students might reject a mechanized instructor. Based on student responses following the use of the program these fears were groundless. It is possible that this particular group of students, living only a few miles from Cape Kennedy, have a higher level of acceptance of the results of technology due to their greater degree of exposure to some of the results of this technology. It may also be true that students today in general have so much contact with computers in almost every aspect of their lives that one more example of computer utilization does not particularly concern them. Quite possibly the nature of the course affected the degree of acceptance. This technique may be considered appropriate for a science or math course but might be resented if utilized in a humanities or behavioral science course.

This study has further analyzed the cost of such an instructional unit and shown that CAI is economically feasible when used in an adjunct role. The cost of using this technique for the entire course would be prohibitive. There is, however, no need to expand its use to an entire course. Different methods of instruction are applicable to different types of course objectives and rarely can all objectives be met by a single mode of instruction. Few courses can be successfully taught using only a lecture technique or only an open discussion technique to meet all objectives. Similarly, unless faced with a critical shortage of instructors, there is no need to use CAI as the exclusive method of instruction.

It was possible to utilize CAI for a single unit of instruction using the department's single teletype. This did put a strain on the facilities, however, and a recommendation will be made to either purchase or rent an additional teletype for purposes of CAI utilization. In view of student comments regarding the noise level it will be advisable to investigate the type of instrument using a thermal printer and see if the reduction in clarity of print with this method of printing is offset by the large reduction in noise level.

Another issue concerns acceptance of this technique by the faculty. The answer to whether or not the faculty will support the use of CAI in an adjunct role is inconclusive at this time. Many faculty are skeptical of the financial support that can be expected considering the crisis in funding for community colleges in the State of Florida and do not want to spend time developing techniques which will never be used. In addition many faculty would not be able to write their own programs and would need assistance in developing course material. Any utilization of CAI would require strong administrative support in the economic area and in providing release time for instructors to develop materials.

One facet of CAI that has interested the physical science instructors is the fact that more time for additional topics would be obtained if the instructor did not have to use class time for a review of math. If this material, along with the introduction to the metric system were handled via CAI, approximately two weeks of class lecture time would be saved and allow a more in-depth treatment of the other material.

This study has shown that CAI can be utilized as an adjunct to classroom instruction if its use is limited to eliminating deficiencies in a student's mathematical background. In addition, programs of this nature should be successful in any mathematically related topic requiring repetitive drill and practice. CAI should be treat as one of many alternate instructional devices available to the instructor.

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# APPENDIX A

## A Complete Listing of the Programs NOVAFIL and PHSFIL

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10 APPEND #2
20 FILES PHSFIL;RECØRDS
30  DELIMIT#1,(#)
40 PRINT"PLEASE TYPE YØUR NAME(LAST,CØMMA,FIRST) THEN**RETURN**"
50 INPUT N1$,N$
60 PRINT
65 PRINT #2,N1$;SPC(4);"START PRØGRAM...";DAT$;SPC(3);CLK$
67 IF N1$="HARLØW" THEN 2890
70 PRINT"LESSØN 1 IS AN INTRØDUCTIØN TØ THE USE ØF EXPØNENTS"
80 PRINT"LESSØN 2 CØNCERNS THE APPLICATIØN ØF EXPØNENTS"
90 PRINT"TØ THE USE ØF SCIENTIFIC NØTATIØN"
100 PRINT"WHICH LESSØN ARE YØU INTERESTED IN?"
110 PRINT"TYPE EITHER 1 ØR 2 AND THEN ***RETURN***  ";
120 INPUT K
130 IF K=2 THEN 1770
140 PRINT
150 PRINT
160 READ #1,A$
170 IF A$ = "MAIN PRØG" THEN 200
180  PRINT A$
190 GØ TØ 160
200 PRINT
210 PRINT
220 W=C0=0
230 PRINT"TYPE THE LETTER ØF THE CØRRECT ANSWER"
240 PRINT"AND THEN PRESS THE ***RETURN*** KEY"
250 PRINT
260 FØR I=1 TØ 5
270 T=1
280 READ B$
290 N=INT(15*RND(-1)+1)
300 M=INT(15*RND(-1)+1)
303 IF N=2 THEN 305
304 GØ TØ 310
305 IF M=2 THEN 290
310 X1=M+N\X2=M*N\X3=ABS(M-N)\X4=2*M+N
330 GØSUB 8000
340 PRINT USING 350,B$,N,B$,M,B$,A,B$,B,B$,C,B$,D
350:('↑##)*('↑##) =  A.  '↑###  B.  '↑###  C.  '↑###  D.  '↑###
360 PRINT"THE ANSWER IS ";
370 INPUT R$
380 IF R$="A" THEN 440
390 IF R$="B" THEN 450
400 IF R$="C" THEN 460
410 IF R$="D" THEN 470
420 PRINT"USE ØNLY THE LETTERS A,B,C,D FØR YØUR ANSWER...";
430 GØ TØ 360
```

```
440 ØN R GØ TØ 480,500,510,520
450 ØN R GØ TØ 500,510,520,480
460 ØN R GØ TØ 510,520,480,500
470 ØN R GØ TØ 520,480,500,510
480 PRINT"CØRRECT"\CO=CO+1\GØ TØ 570
500 PRINT"NØ, YØU'RE MULTIPLYING THE EXPØNENTS"\GØ TØ 530
510 PRINT"NØ, WE DØN'T USE SUBTRACTIØN"\GØ TØ 530
520 PRINT"YØU'RE JUST GUESSING, REMEMBER THE RULE"\GØ TØ 530
530 IF T=2 THEN 550
540 T=T+1\GØ TØ 360
550 W=W+1\PRINT USING 560,B$,(M+N)
560:THE CØRRECT ANSWER IS   '**#
570 PRINT
580 NEXT I
590 PRINT#2,N1$;"   MULT.EXP. ";CO*20;"%";SPC(3);DAT$;SPC(3);CLK$
600 DATA V,W,X,Y,Z
610 IF W>2 THEN 630
620 GØ TØ 720
630 E=E+1
632 IF E=2 THEN 6000
635 PRINT"YØUR SCØRE WAS ";CO*20;"%, LETS REVIEW THE RULES"
640 CO=W=0\RESTØRE#1\RESTØRE
650 READ #1,A$
660 IF A$="*" THEN 680
670 GØ TØ 650
680 READ#1,A$
690 IF A$="MAIN PRØG" THEN 260
700 PRINT A$
710 GØ TØ 680
720  READ #1,A$
730 IF A$ ="MAIN PRØG" THEN 760
740 PRINT A$
750  GØ TØ 720
760 PRINT
770 W=CO=0
780 PRINT"TYPE THE LETTER ØF THE CØRRECT ANSWER"
790 PRINT"AND THEN PRESS THE RETURN KEY"
800 PRINT
810 FØR I=1 TØ 5
820 T=1
830 READ B$
840 N=INT(15*RND(-1))
850  M=INT(15*RND(-1)+1)
860 IF N>M THEN 880
870 GØ TØ 840
880 X1=N-M\X2=M-N\X3=N+M\X4=N*M
890 GØSUB 8000
900 PRINT USING 910,B$,N,B$,M,B$,A,B$,B,B$,C,B$,D
```

```
 910:('↑##)/('↑##) =  (A)  '↑###   (B)  '↑###   (C)  '↑###   (D)  '↑###
920 PRINT"THE ANSWER IS ";
930 INPUT R$
940 IF R$="A" THEN 990
950 IF R$="B" THEN 1000
960 IF R$="C" THEN 1010
970 IF R$="D" THEN 1020
980 PRINT"USE ØNLY THE LETTERS A,B,C,D FØR YØUR ANSWER..."\GØ TØ 920
990 ØN R GØ TØ 1030,1040,1050,1060
1000 ØN R GØ TØ 1040,1050,1060,1030
1010 ØN R GØ TØ 1050,1060,1030,1040
1020 ØN R GØ TØ 1060,1030,1040,1050
1030 PRINT"CØRRECT"\CO=CO+1\GØ TØ 1120
1040 PRINT"YØU'VE REVERSED NUMERATØR AND DENØMINATØR"\GØ TØ 1070
1050 PRINT" WRØNG RULE, WE'RE NØT MULTIPLYING"\GØ TØ 1070
1060 PRINT"DØN'T MULTIPLY THE EXPØNENTS"\GØ TØ 1070
1070 IF T=2 THEN 1090
1080 T=T+1\GØ TØ 920
1090 W=W+1\PRINT USING 1100,R$,(N-M)
1100:THE CØRRECT ANSWER IS  '↑##
1110 PRINT
1120 NEXT I
1130 DATA P,Q,R,S,T
1140 PRINT#2,N1$;"   DIV.EXP.   ";CO*20;"%";SPC(3);DAT$;SPC(3);CLK$
1150 IF W>2 THEN 1180
1160 GØ TØ 1270
1170 T=T+[illegible]
1180 E=E+[illegible]
1182 IF E[illegible] THEN 6000
1185 PRINT"YØUR SCØRE WAS ";CO*20;"%, WE NEED A REVIEW"
1190 CO=W=0\RESTØRE#1\RESTØRE
1200 READ #1,A$
1210 IF A$="**" THEN 1230
1220 GØ TØ 1200
1230 READ#1,A$
1240 IF A$="MAIN PRØG" THEN780
1250 PRINT A$
1260 GØ TØ 1230
1270   READ #1,A$
1280   IF A$="MAIN PRØG" THEN 1350
1290   PRINT A$
1300   GØ TØ 1270
1310   REM***THE FØLLØWING IS A QUIZ ØN THE USE ØF EXPØNENTS***
1320 PRINT"TYPE THE CØRRECT ANSWER THEN PRESS***RETURN***"
1330 PRINT"THE MINUS SIGN( - ) IS JUST ABØVE THE RETURN KEY"
1340 PRINT
1350 FØR I=1 TØ 10
1360 T=0
```

```
1370 X=INT(20*RND(-I)+1)
1380 Y=INT(20*RND(-I)+1)
1390 S(1)=INT(14*RND(-I)+65)
1400 S(0)=1
1410 CHANGE S TØ B$
1420 IF I>5 THEN 1460
1430 N=1
1440 C$="*"
1450 GØ TØ 1480
1460 N=-1
1470 C$="/"
1480 PRINT USING 1490,B$,X,C$,B$,Y,B$;
1490: ('↑##)'('↑##) = '↑
1500 INPUT R
1510 IF R=X+N*Y THEN 1560
1520 T=T+1
1530 IF T=2 THEN 1590
1540 PRINT"NØ,";R;"IS NØT CØRRECT...TRY AGAIN"
1550 GØ TØ 1500
1560 PRINT"CØRRECT"
1570 C1=C1+1
1580 GØ TØ 1620
1590 PRINT USING 1600,B$,X,C$,B$,Y,B$,X+N*Y
1600: THE CØRRECT ANSWER IS ('↑##)'('↑##) = '↑###  .
1610 W1=W1+1
1620 PRINT
1630 NEXT I
1640 PRINT#2,N1$;"    EXP.QUIZ ";C1*10;"%";SPC(3);DAT$;SPC(3);CLK$
1650 IF W1>5 THEN 1670
1660 GØ TØ 1710
1670 PRINT"YØUR SCØRE WAS ";C1*10;"%  STUDY THE INFØRMATIØN"
1680 PRINT"THAT I'VE GIVEN YØU TØDAY AND WE'LL TRY AGAIN LATER"
1690 PRINT" SEE YØU THEN ";N$
1700 STØP
1710 PRINT
1720 PRINT"YØU HAVE NØW CØMPLETED THE LESSØN ØN THE USE ØF EXPØNENTS"
1730 PRINT"DØ YØU WISH TØ PRØCEED TØ LESSØN 2 WHICH IS AN INTRØDUCTIØN"
1740 PRINT"TØ THE USE ØF SCIENTIFIC NØTATIØN";
1750 INPUT R$
1760 IF R$="NØ" THEN 1765
1763 GØ TØ 1770
1765 STØP
1767 PRINT
1768 PRINT
1770 READ #1,A$
1780 IF A$ = "SCI-NØT" THEN 1800
1790 GØ TØ 1770
1800 READ #1,A$
```

```
1810 IF A$="MAIN PRØG" THEN 1840
1820 PRINT A$
1830 GØ TØ 1800
1840 PRINT"TYPE THE LETTER ØF THE CØRRECT ANSWER AND THEN"
1850 PRINT"PRESS THE RETURN KEY"
1860 PRINT
1870 FØR I=1 TØ 10
1880 S=T=0
1890 FØR J=1 TØ 6
1900 Y(J)=INT(9*RND(-1)+1)
1910 S=S+Y(J)*10↑(J-1)
1920 NEXT J
1930 P=INT(4*RND(-1)+1)
1940 X=INT(S*10↑(-P)+.5)
1950 Q=(P-5)
1960 U=X*10↑Q
1970 X1=-Q\X2=1-Q\X3=-1-Q\X4=4-Q
1980 GØSUB 8000
1990 PRINT USING 2000,X,U,A,U,B,U,C,U,D
2000:###### =   (A) #.##*10↑#   (B) #.##*10↑#   (C) #.##*10↑#   (D) #.##*10↑#

2010 PRINT"THE ANSWER IS ";
2020 INPUT R$
2030 IF R$="A" THEN 2080
2040 IF R$="B" THEN 2090
2050 IF R$="CB@TN 2100
2060 IF R$="D" THEN 2110
2070 PRINT"USE ØNLY THE LETTERS A,B,C,D FØR YØUR ANSWER...";\GØ TØ 2010
2080 ØN R GØ TØ 2130,2140,2150,2160
2090 ØN R GØ TØ 2140,2150,2160,2130
2100 ØN R GØTØ 2150,2160,2130,2140
2110 ØN R GØ TØ 2160,2130,2140,2150
2120 PRINT
2130 PRINT"CØRRECT"\C6=C6+1\GØ TØ 2220
2140 PRINT"NØ, YØUR PØWER ØF 10 IS TØØ LARGE"\GØ TØ 2170
2150 PRINT"NØ, YØUR PØWER ØF TEN IS TØØ SMALL"\GØ TØ 2170
2160 PRINT"THINK ABØUT THE CØRRECT PRØCEDURE"\GØ TØ 2170
2170 IF T=1 THEN 2190
2180 T=T+1\GØ TØ 2010
2190 W6=W6+1\PRINT USING 2200,U,-Q
2200:THE CØRRECT ANSWER IS  #.##*10↑#
2210 PRINT
2220 NEXT I
2230 PRINT#2,N1$;"    SCI.NØT1 ";C6*10;"%";SPC(3);DAT$;SPC(3);CLK$
2240 IF W6>5 THEN 2260
2250 GØ TØ 2370
2260 E=E+1
2262 IF E=2 THEN 6000
2265 PRINT"YØUR SCØRE WAS ";C6*10;"%,LETS REVIEW THIS MATERIAL"
```

```
2270 C6=W6=0\RESTØRE#1
2280 READ#1,A$
2290 IF A$="***" THEN 2310
2300 GØ TØ 2280
2310 READ#1,A$
2320 IF A$="MAIN PRØG" THEN 2350
2330 PRINT A$
2340 GØ TØ 2310
2350 PRINT
2360 GØ TØ 1840
2370 READ #1,A$
2380 IF A$="MAIN PRØG" THEN 2410
2390 PRINT A$
2400 GØ TØ 2370
2410 PRINT"TYPE THE LETTER ØF THE CØRRECT ANSWER AND THEN"
2420 PRINT"PRESS THE RETURN KEY"
2430 PRINT
2440 FØR I=1 TØ 10
2445 S=T=0
2450 FØR J=1 TØ 3
2460 Y(J)=INT(9*RND(-1)+1)
2470 S=S+Y(J)*10↑(J-1)
2480 NEXT J
2490 P=INT(5*RND(-1)+3)
2500 X=S*10↑(-P)
2510 Q=P-2
2520 U=X*10↑Q
2530 X1=-Q\X2=-Q+1\X3=-Q-1\X4=5-Q
2540 GØSUB 8000
2550 PRINT USING 2570,X,U,A,U,B
2560 PRINT USING 2580,U,C,U,D
2570: .######## =      (A)    #.###*10↑##      (B)    #.###*10↑##
2580:                  (C)    #.###*10↑##      (D)    #.###*10↑##
2590 PRINT"THE ANSWER IS ";
2600 INPUT R$
2610 IF R$="A" THEN 2660
2620 IF R$="B" THEN 2670
2630 IF R$="C" THEN 2680
2640 IF R$="D" THEN 2690
2650 PRINT"USE ØNLY THE LETTERS A,B,C,D FØR YØUR ANSWER...";\GØ TØ 2590
2660 ØN R GØ TØ 2692,2694,2696,2698
2670 ØN R GØ TØ 2694,2696,2698,2692
2680 ØN R GØ TØ 2696,2698,2692,2694
2690 ØN R GØ TØ 2698,2692,2694,2696
2692 PRINT"CØRRECT"\C2=C2+1\GØ TØ 2740
2694 PRINT"NØ, YØUR EXPØNENT IS TØØ LARGE"\GØ TØ 2700
2696 PRINT"NØ, YØUR EXPØNENT IS TØØ SMALL"\GØ TØ 2700
2698 PRINT"YØUR ANSWER IS WAY ØFF,CØUNT THE PLACES"\GØ TØ 2700
```

```
2700 IF T=1 THEN 2720
2710 T=T+1\GØ TØ 2590
2720 W2=W2+1\PRINT USING 2730,U,-Q
2730:THE CØRRECT ANSWER IS  #.##*10↑##
2740 PRINT
2750 NEXT I
2760 PRINT#2,N1$;"    SCI.NØT2 ";C2*10;"%";SPC(3);DAT$;SPC(3);CLK$
2770 IF W2>5 THEN 2790
2780 GØ TØ 2890
2790 E=E+1
2792 IF E=2 THEN 6000
2795 PRINT"YØUR SCØRE WAS ";C2*10;"%, A SHØRT REVIEW IS NEEDED"
2800 C2=W2=0\RESTØRE#1
2810 READ #1,A$
2820 IF A$="****" THEN 2840
2830 GØ TØ 2810
2840 READ#1,A$
2850 IF A$="MAIN PRØG" THEN 2880
2860 PRINT A$
2870 GØ TØ 2840
2880 GØ TØ 2410
2890 READ #1,A$
2900 IF A$="SCI-MULT" THEN 2920
2910 GØ TØ 2890
2920 READ #1,A$
2930 IF A$="MAIN PRØG" THEN 3030
2940 PRINT A$
2950 GØ TØ 2920
3030 PRINT
3040 PRINT"TYPE THE LETTER ØF THE CØRRECT ANSWER AND THEN"
3050 PRINT"TYPE RETURN, REMEMBER TØ EXPRESS ALL ANSWERS IN"
3060 PRINT"STANDARD FØRM"
3070 PRINT
3080 PRINT
3090 FØR I=1 TØ 10
3100 T=0
3110 A=INT(9*RND(-1)+1)
3120 B=INT(9*RND(-1)+1)
3130 P=INT(18*RND(-1)-9)
3140 Q=INT(18*RND(-1)-9)
3150 A1=A*B
3160 IF A1>=10 THEN 3190
3170 P1=P+Q
3180 GØ TØ 3210
3190 A1=A*B/10
3200 P1=P+Q+1
3210 A2=A1*10
3220 P2=P1-1
```

```
3230 R=INT(4*RND(-1)+1)
3240 ØN R GØ TØ 3250,3260,3270,3280
3250 R1=A1\R2=P1\S1=A2\S2=P2\T1=A1\T2=P2\U1=A2\U2=P1\GØ TØ 3290
3260 R1=A2\R2=P2\S1=A1\S2=P2\T1=A2\T2=P1\U1=A1\U2=P1\GØ TØ 3290
3270 R1=A1\R2=P2\S1=A2\S2=P1\T1=A1\T2=P1\U1=A2\U2=P2\GØ TØ 3290
3280 R1=A2\R2=P1\S1=A1\S2=P1\T1=A2\T2=P2\U1=A1\U2=P2\GØ TØ 3290
3290 PRINT USING 3300,A,P,B,Q,R1,R2,S1,S2
3295 PRINT USING 3310,T1,T2,U1,U2
3300:(#*10↑##)*(#*10↑##) =    (A)  ##.##*10↑###     (B)  ##.##*10↑###
3310:                         (C)  ##.##*10↑###     (D)  ##.##*10↑###
3320 PRINT"THE ANSWER IS ";
3330 INPUT R$
3340 IF R$="A" THEN 3400
3350 IF R$="B" THEN 3410
3360 IF R$="C" THEN 3420
3370 IF R$="D" THEN 3430
3380 PRINT"USE ØNLY THE LETTERS A,B,C,D FØR YØUR ANSWER....";
3390 GØ TØ 3320
3400 ØN R GØ TØ 3440,3450,3460,3470
3410 ØN R GØ TØ 3450,3460,3470,3440
3420 ØN R GØ TØ 3460,3470,3440,3450
3430 ØN R GØ TØ 3470,3440,3450,3460
3440 PRINT"CØRRECT"\C3=C3+1\GØ TØ 3520
3450 PRINT"THIS ANSWER IS NØT IN STANDARD FØRM"\GØ TØ 3480
3460 PRINT"THE NUMBER ";A1;" IS CØRRECT BUT PØWER IS WRØNG"\GØ TØ 3480
3470 PRINT"THE PØWER ";P1;" IS CØRRECT BUT THE NUMBER IS WRØNG"\GØTØ3480
3480 IF T=1 THEN 3500
3490 T=T+1\GØ TØ 3320
3500 W3=W3+1\PRINT USING 3510,A1,P1
3510: THE CØRRECT ANSWER IS  #.##*10↑###
3520 PRINT
3530 NEXT I
3540 PRINT#2,N1$;"   SCI.MULT.";C3*10;"%";SPC(3);DAT$;SPC(3);CLK$
3550 IF W>5 THEN 3570
3560 GØ TØ 3700
3570 E=E+1
3572 IF E=2 THEN 6000
3575 PRINT"YØUR SCØRE WAS ";C3*10;"%  LETS REVIEW THE RULES"
3580 C3=W3=0\RESTØRE#1
3590 READ#1,A$
3600 IF A$="SCI-MULT" THEN 3620
3610 GØ TØ 3590
3620 READ#1,A$
3630 IF A$="MAIN PRØG" THEN 3660
3640 PRINT A$
3650 GØ TØ 3620
3660 GØ TØ 3040
3700 READ#1,A$
```

```
3710 IF A$="MAIN PROG" THEN 3740
3720 PRINTA$
3730 GO TO 3700
3740 PRINT"TYPE THE LETTER OF THE CORRECT ANSWER AND THEN"
3750 PRINT"TYPE RETURN, ' REMEMBER THAT ALL ANSWER SHOULD"
3760 PRINT"BE IN STANDARD FORM"
3765 PRINT
3770 FOR I=1 TO 10
3780 T=0
3790 B=INT(9*RND(-I)+1)
3800 A=B*INT(9*RND(-I)+1)
3810 P=INT(18*RND(-I)-9)
3820 Q=INT(18*RND(-I)-9)
3822 IF Q=-1 THEN 3820
3830 IF A>=10 THEN 3850
3840 GO TO 3870
3850 A=A/10
3870 A1=A/B*10
3872 IF A1>=10 THEN 3880
3874 P1=P-Q-1
3876 GO TO 3890
3880 A1=A1/10
3882 P1=P-Q
3890 A2=A1/10
3900 P2=P1+1
3910 A3=A*B/10
3920 P3=P+Q+1
3930 A4=A1
3940 P4=P3
3950 R=INT(4*RND(-1)+1)
3960 ON R GO TO 3970,3980,3990,4000
3970 R1=A1\R2=P1\S1=A2\S2=P2\T1=A3\T2=P3\U1=A4\U2=P4\GO TO 4010
3980 R1=A2\R2=P2\S1=A3\S2=P3\T1=A4\T2=P4\U1=A1\U2=P1\GO TO 4010
3990 R1=A3\R2=P3\S1=A4\S2=P4\T1=A1\T2=P1\U1=A2\U2=P2\GO TO 4010
4000 R1=A4\R2=P4\S1=A1\S2=P1\T1=A2\T2=P2\U1=A3\U2=P3\GO TO 4010
4010 PRINT USING 4030,A,P,B,Q,R1,R2,S1,S2
4020 PRINT USING 4040,T1,T2,U1,U2
4030:(#.##10↑##)/(#.##10↑##) =   (A)   ##.#*10↑###     (B)   ##.#*10↑###
4040:                            (C)   ##.#*10↑###     (D)   ##.#*10↑###
4050 PRINT"THE ANSWER IS ";
4060 INPUT R$
4070 IF R$="A" THEN 4220
4080 IF R$="B" THEN 4230
4090 IF R$="C" THEN 4240
4100 IF R$="D" THEN 4250
4200 PRINT"USE ONLY THE LETTERS A,B,C,D FOR YOUR ANSWER...";
4210 GO TO 4050
4220 ON R GO TO 4260,4270,4280,4290
```

```
4230 ØN R GØ TØ 4270,4280,4290,4260
4240 ØN R GØ TØ 4280,4290,4260,4270
4250 ØN R GØ TØ 4290,4260,4270,4280
4260 PRINT"CØRRECT"\C4=C4+1\GØ TØ 4340
4270 PRINT"YØUR CHØICE ØF ANSWER IS NØT IN STANDARD FØRM"\GØ TØ 4300
4280 PRINT"YØU'VE MULTIPLIED, NØT DIVIDED"\ GØ TØ 4300
4290 PRINT"THE NUMBER IS ØK, BUT YØUR EXPØNENT IS WRØNG"\GØ TØ 4300
4300 IF T=1 THEN 4320
4310 T=T+1\GØ TØ 4050
4320 W4=W4+1\PRINT USING 4330,A1,P1
4330:THE CØRRECT ANSWER IS  #.#*10↑###
4340 PRINT
4350 NEXT I
4360 PRINT#2,N1$;"   SCI.DIV.";C4*10;"%";SPC(3);DAT$;SPC(3);CLK$
4370 IF W>5 THEN 4500
4400 GØ TØ 5000
4500 E=E+1
4502 IF E=2 THEN 6000
4505 PRINT"YØUR SCØRE WAS ";C4*10;"%, LETS REVIEW THE RULES"
4510 C4=W4=0\RESTØRE#1
4520 READ#1,A$
4530 IF A$="THEREFØRE THE PRØCEDURE FØLLØWED IS TØ:" THEN 4550
4540 GØ TØ 4520
4550 READ#1,A$
4560 IFA$="MAIN PRØG" THEN 4590
4570 PRINT A$
4590 GØ TØ 3740
5000 PRINT "YØU HAVE CØMPLETED THE LESSØN ØN THE USE ØF"
5010 PRINT "EXPØNENTIAL NØTATIØN"
5020 STØP
5999 STØP
6000 PRINT"YØU APPEAR TØ BE HAVING DIFFICULTY WITH THIS MATERIAL"
6010 PRINT"LETS STØP FØR NØW AND SHØW YØUR WØRK TØ YØUR INSTRUCTØR"
6020 PRINT"I'LL SEE YØU LATER ";N$
6030 STØP
7980 STØP
8000 R=INT(4*RND(-1)+1)
8010 ØN R GØ TØ 8020,8030,8040,8050
8020 A=X1\B=X2\C=X3\D=X4\GØ TØ 8060
8030 A=X2\B=X3\C=X4\D=X1\GØ TØ 8060
8040 A=X3\B=X4\C=X1\D=X2\GØ TØ 8060
8050 A=X4\B=X1\C=X2\D=X3\GØ TØ 8060
8060 RETURN
9999 END
```

```
100 EXPØNENTIAL NØTATIØN(SØMETIMES CALLED SCIENTIFIC NØTATIØN) IS#
110 A METHØD ØF EXPRESSING ANY NUMBER, NØ MATTER HØW LARGE ØR SMALL#
120 IT IS, IN A CØMPACT SHØRTHAND FØRM.#
130 " "#
140 IT IS NECESSARY TØ USE THIS NØTATIØN IN ØRDER TØ SIMPLIFY ØUR#
150 WØRK IN THE PHYSICAL SCIENCE CØURSE.#
160 BEFØRE WE START, LET US BRIEFLY REVIEW SØME BASIC FACTS ABØUT#
170 EXPØNENTS:#
180 " "#
190 "      N                                              4"#
200 "      A  = (A*A*A*...*A)  N-TIMES; FØR EXAMPLE: A   = A*A*A*A"#
210 " "#
220 TØ SIMPLIFY ØUR WRITING EXPØNENTS ØN THE TELETYPE WE WRITE:#
230 " "#
240 "      N"#
250 "      A  = A↑N  WE USE THE ARRØW FØR EXPØNENTIATIØN"#
260 " "#
295 "*"#
300 IF WE WISH TØ MULTIPLY TWØ NUMBERS WRITTEN IN EXPØNENTIAL#
310 FØRM THEY MUST HAVE THE SAME BASE: FØR EXAMPLE; IF "A" REPRESENTS#
320 ANY NUMBER,(SUCH AS 1,3,6,2.45,5.67 ETC.), AND "N" AND "M"#
330 REPRESENT ANY ARBITRARY PØWER, THEN#
340 " "#
345                   (A↑N)*(A↑M) = A↑(N+M)    FØR EXAMPLE:#
350 " "#
360     (3↑5)*(3↑2) = 3↑7    (X↑6)*(X↑4)=X↑10    (W↑3)*(W↑9)=W↑12#
370 YØU WILL NØTICE THAT WE CAN EITHER WØRK WITH SPECIFIC NUMBERS#
380 (SUCH AS "3") ØR WITH SYMBØLS REPRESENTING ANY NUMBER#
390 (SUCH AS "X" ØR "W"). THE RULES ARE THE SAME IN EITHER CASE#
400 " "#
405 NØW LETS TRY SØME PRØBLEMS. EACH TIME THAT YØU ARE ASKED FØR AN#
410 ANSWER*** (1). FIRST TYPE THE ANSWER... THEN,#
420 "          (2). PRESS THE KEY MARKED ***RETURN***."#
430 MAIN PRØG#
435 "**"#
440 THE RULES FØR DIVISIØN, USING NUMBERS WRITTEN IN EXPØNENTIAL FØRM,#
450 ARE VERY SIMILAR TØ THØSE FØR MULTIPLICATIØN.#
460 " "#
470 " (A↑N)/(A↑M) = A↑(N-M) (NØTE THE SYMBØL (/) FØR DIVISIØN)"#
480 " "#
490 FØR EXAMPLE: (3↑5)/(3↑2) =3↑3    (X↑9)/(X↑4) = X↑5
500 NØW TRY SØME PRØBLEMS#
510 " "#
```

```
520 MAIN PRØG#
600  WE CAN USE ØUR RULE FØR DIVISIØN TØ DEFINE THE MEANING#
610  ØF A "ZERØ" PØWER ØR EXPØNENT#
615 "   (X↑N)/(X↑N) = X↑(N-N) = X↑0"#
620 " "#
640  BUT  (X↑N)/(X↑N) = 1  SINCE ANY QUANTITY DIVIDED BY ITSELF#
650  EQUALS UNITY.  THEREFØRE; NØ MATTER WHAT THE VALUE ØF X IS#
660 " "#
670 "                          X↑0 = 1"#
680 " "#
690  SUPPØSE WE WERE GIVEN THE PRØBLEM:  (X↑5)/(X↑8) =?#
700  USING ØUR RULE FØR DIVISIØN THE ANSWER SHØULD BE#
710 " "#
720 "         (X↑5)/(X↑8) = X↑(5-8) = X↑(-3) = X↑-3"#
730 " "#
740  BUT WHAT IS MEANT BY X↑-3???#
750  LETS WØRK IT ØUT THE LØNG WAY#
760 " "#
770  (X↑5)/(X↑8) = (X*X*X*X*X)/(X*X*X*X*X*X*X*X) = 1/(X*X*X)#
780 " "#
790 THIS ANSWER CAN ALSØ BE WRITTEN AS:  1/X↑3 AND WE NØW SEE#
800 THAT X↑-3 IS JUST A CØNVENIENT WAY ØF WRITING 1/X↑3#
810 IN GENERAL:#
820 " "#
830 "      1/X↑N = X↑-N   (AND)  1/X↑-N = X↑N"#
840 " "#
850  REMEMBER THAT WHEN WRITING X↑-N WITHØUT THE TELETYPE IT WILL#
860  LØØK LIKE:#
870 "            -N"#
880 "    X↑-N = X"#
882 " "#
884 (THE NEGATIVE SIGN IS THE KEY ABØVE THE *RETURN* KEY#
886 ØN THE TELETYPE)#
888 " "#
890 " "#
900  NØW LETS CØMBINE ALL ØF ØUR RULES AND TRY SØME PRØBLEMS#
910 " "#
920  MAIN PRØG#
950 SCI-NØT#
1000 NØW THAT WE UNDERSTAND THE USE ØF EXPØNENTS LET US SEE#
1010 THE WAY IN WHICH WE CAN USE THEM TØ EXPRESS ANY NUMBER#
1020 IN A SHØRTHAND FØRM USING PØWERS ØF TEN#
1030 " "#
1040 FØR EXAMPLE*   THE NUMBER  3600  CAN BE WRITTEN AS THE PRØDUCT#
1050 ØF 3.6 AND 1,000.#
1060" "#
1070 "                  3600 = 3.6*1000"#
1080 " "#
```

```
1090 (AGAIN NØTE THE USE ØF THE SYMBØL * FØR MULTIPLICATIØN)#
1100 BUT WE CAN ALSØ WRITE THE NUMBER 1000 AS 10*10*10 ØR 10↑3#
1110 " "#
1120 THEREFØRE WE CAN WRITE:   3600 = 3.6*10↑3#
1130 " "#
1140 (IF WE WERE NØT USING A TELETYPE WE WØULD WRITE THIS AS)#
1150 "                          3"#
1160 "                    3.6*10"#
1170 " "#
1180 WE CALL THIS NØTATIØN "SCIENTIFIC" ØR "EXPØNENTIAL" NØTATIØN#
1190 IT CØNSISTS ØF WRITING ANY NUMBER AS A PRØDUCT ØF TWØ QUANTITIES#
1200 "     (1). A NUMBER BETWEEN 1 AND  0,  AND"#
1210 "     (2). TEN RAISED TØ SØME PØWER."#
1220 WE USE THE FACT THAT THE PØWER TØ WHICH WE RAISE 10 IS#
1230 EASILY INDICATED BY THE NUMBER ØF ZERØES FØLLØWING THE 1.#
1240 10↑0 = 1         ØNE#
1250 10↑1 = 10        TEN#
1260 10↑2 = 100       ØNE HUNDRED#
1270 10↑3 = 1000      ØNE THØUSAND#
1280 10↑4 = 10,000    TEN THØUSAND#
1290 10↑5 = 100,000 ØNE HUNDRED THØUSAND#
1300 10↑6 = 1,000,000 ØNE MILLIØN...ETC.#
1310 " "#
1315 "***"#
1320 THEREFØRE: TØ CØNVERT A NUMBER TØ SCIENTIFIC NØTATIØN:#
1330 (1). MØVE THE DECIMAL PØINT TØ THE LEFT UNTIL ØNLY ØNE#
1340 "      DIGIT REMAINS LEFT ØF THE DECIMAL PØINT"#
1350 (2). CØUNT THE NUMBER ØF PLACES THAT YØU HAVE MØVED  THE#
1360 "      DECIMAL PØINT AND THAT NUMBER IS THE PØWER ØF TEN NEEDED."#
1370 " "#
1380 FØR EXAMPLE: LETS USE THE NUMBER 79500.  NØTE THAT I HAVE#
1390 WRITTEN IN THE DECIMAL PØINT AT THE END ØF THE NUMBER#
1410 EVEN THØUGH THIS IS AN INTEGER AND IT IS UNDERSTØØD THAT#
1412 A DECIMAL PØINT APPEARS AFTER THE LAST DIGIT.#
1420 " "#
1430 MØVE THE DECIMAL PØINT 4 PLACES TØ THE LEFT#
1440 "              7 9500."#
1450 "               ↑<---↑"#
1460 NØW WE HAVE 7.9500, ØR SIMPLY, 7.95. BUT THIS NUMBER IS SMALLER#
1470 THAN THE ØRIGINAL BY 10,000 ØR 10↑4. TØ PRESERVE THE ØRIGINAL#
1480 NUMBER WE MUST THEREFØRE MULTIPLY 7.95 BY 10↑4#
1490 " "#
1500 THEREFØRE:   79500  =  7.95*10↑4#
1510 SØME ØTHER EXAMPLES:                  421 = 4.21*10↑2#
1520 "                      7308 = 7.308*10↑3"#
1530 "                         19,666,000 = 1.97*10↑7"#
1540 NØW LETS PRACTICE CØNVERTING SØME NUMBERS TØ THIS FØRM#
1550 " "#
```

```
1560 MAIN PRØG#
1600 BEFØRE WE TRY ANY ADDITIØNAL PRACTICE PRØBLEMS#
1610 LETS SEE HØW WE HANDLE NUMBERS LESS THAN 1.0 IN VALUE#
1620 THE PRØCEDURE WE USE IS AS FØLLØWS:#
1630 " "#
1640 "      .00265  =  2.65/1000  =  2.65/10↑3  =  2.65*10↑-3"#
1650 " "#
1660 ANØTHER WAY ØF THINKING ABØUT THIS PRØCESS IS:#
1680 " "#
1690 "      .00265  =  2.65*(1/1000) = 2.65*(.001) = 2.65*10↑-3"#
1700 " "#
1710 NØTE THAT:#
1720   10↑0 = 1.0#
1730   10↑-1 = .1          =  1/10#
1740   10↑-2 = .01         =  1/100#
1750   10↑-3 = .001        =  1/1000#
1760   10↑-4 = .0001       =  1/10000#
1770   10↑-5 = .00001      =  1/100000#
1780   10↑-6 = .000001     =  1/1000000   ETC.#
1790 " "#
1800 THEREFØRE THE PRØCEDURE FØLLØWED IS TØ:#
1810 (1). MØVE THE DECIMAL PØINT TØ THE RIGHT UNTIL ØNLY#
1820 "     ØNE DIGIT IS TØ THE LEFT ØF THE DECIMAL PØINT"#
1830 (2). THE NUMBER ØF PLACES THAT THE DECIMAL PØINT MØVED#
1840 "     DETERMINES THE NEGATIVE PØWER ØF TEN"#
1850 EXAMPLE:   .0006973#
1860 "MØVE THE DECIMAL PØINT 4 PLACES TØ THE RIGHT:     .0006 973"#
1870 "                                                   ↑--->↑"#
1880 WE NØW HAVE 0006.973 ØR SIMPLY 6.973#
1890 THIS NUMBER IS LARGER THAN THE ØRIGINAL NUMBER BY 4 PØWERS ØF TEN#
1900 TØ RETAIN ØUR ØRIGINAL VALUE WE MUST THEREFØRE MULTIPLY 6.973#
1910 BY SØME NUMBER WHICH WILL MAKE IT 4 PØWERS ØF TEN SMALLER#
1920 ØR, IN ØTHER WØRDS, BY 10↑-4.
1930 THEREFØRE:#
1940 "                .0006793  =  6.793*10↑-4"#
1950 " "#
1960 SØME ØTHER EXAMPLES:   .0521 = 5.21*10↑-2    .00223 = 2.23*10↑-3#
1970 "   .0000708 = 7.08*10↑-5    .629 = 6.29*10↑-1"#
1980 " "#
1990 ØK, LETS TRY SØME CØNVERSIØNS TØ EXPØNENTIAL NØTATIØN#
2000 USING NUMBERS SMALLER THAN UNITY(1.0).#
2005 " "#
2010 MAIN PRØG#
2050 SCI-MULT#
2100 THE USE ØF EXPØNENTIAL NØTATIØN MAKES MULTIPLICATIØN#
2110 AND DIVISIØN ØF LARGE ØR SMALL NUMBERS EXTREMELY EASY#
2120 WITH NØ CØNFUSIØN AS TØ THE LØCATIØN ØF THE DECIMAL PØINT#
2130 THE GENERAL RULE FØR MULTIPLICATIØN IS:#
2140 " "#
```

```
2150 "       (A*10↑N)*(B*10↑M) = (A*B)*10↑(N+M)"#
2160 " "#
2170 WHERE A AND B REPRESENT ANY PØSITIVE ØR NEGATIVE NUMBER#
2180 AND...N,M REPRESENT ANY PØSITIVE ØR NEGATIVE INTEGER PØWERS#
2190 " "#
2200 FØR EXAMPLE:  (3*10↑5)*(4*10↑3) = 12*10↑8 = 1.2*10↑9#
2210 " "#
2220 THE LAST STEP CØNSISTED ØF REWRITING THE NUMBER IN "STANDARD FØRM"#
2230 WE ARE ACTUALLY WØRKING THE PRØBLEM:#
2240 300,000 X 4,000  =  1,2000,000   BUT, IN A SHØRTHAND FØRM#
2250 " "#
2260 SUPPØSE WE HAVE:    .0007 * 12,000,000 = ?#
2270 REWRITE THIS AS:#
2280 "           (7*10↑-4)*(1.2*10↑7) = 8.4*10↑(-4+7) = 8.4*10↑3"#
2290 SIMPLE, ISN'T IT?  NØW TRY THESE:
2300 " "#
2301 MAIN PRØG#
2350 DIVISIØN ØF NUMBERS USING EXPØNENTIAL NØTATIØN IS JUST#
2360 AS EASY AS MULTIPLICATIØN.  THE GENERAL RULE IS:#
2370 " "#
2380 "       (A*10↑N)/(B*10↑M) = (A/B)*10↑(N-M)"#
2390 " "#
2400 FØR EXAMPLE:      (6*10↑5)/(3*10↑2) = (6/3)*10↑(5-2) = 3*10↑3#
2410 ALSØ LØØK AT THESE EXAMPLES CAREFULLY:
2420 " "#
2430 (6*10↑4)/(2*10↑9) = 3*10↑(4-9) = 3*10↑-5#
2440 " "#
2450 (8.4*10↑-7)/(2*10↑6) = 4.2*10↑(-7-(6)) = 4.2*10↑(-7-6) = 4.2*10↑-13#

2460 " "#
2470 (8*10↑6)/(4*10↑-3) = 2*10↑(6-(-3)) = 2*10↑(6+3) = 2*10↑9#
2480 " "#
2490 ØK, LET'S SEE HØW WELL WE CAN DØ WITH SØME NEW PRØBLEMS#
2500 MAIN PRØG#
```

APPENDIX B

Unit II of Physical Science Survey I

All students were provided with this material. This was the only source of textual material for the Control Group.

The textual material in this unit dealing with topics other than exponential notation has been deleted.

Personalized Instructional Unit Number II

Instructor: Joel F. Sherman

Brevard Community College

Course Title: Physical Science Survey, PHS101

Topic: Scientific Notation, Metric System, Vectors

Target Group: College Parallel, non-science majors.

Approximate Working Time: 4 hours

Rationale: In any attempt to discuss our environment the range of numbers that we come into contact with extends from the microscopic to the macroscopic. We examine an electron with a mass of .000000000000000000000000000000[illegible] kilograms and work with the distance from the sun to Pluto which is approximately 3,550,000,000 miles. Two factors which greatly simplify our work are the metric system and scientific notation. This unit will provide the student with the necessary tools to handle numbers of any magnitude and introduce him to a system of measurement which is used by the majority of countries in the world. We will also introduce the concept of a vector which is necessary to comprehend some of the basic principles of mechanics which follow this unit.

Upon satisfactory completion of this unit of study the student will show the ability to:

1. Perform simple algebraic manipulation, in particular, those needed to solve a linear equation for one of its variables.

2. Express any number, whether greater or less than unity, in exponential notation. Take a number in exponential notation and express it in decimal notation.

3. Perform the operations of multiplication and division using numbers expressed in exponential notation.

4. Define any of the following units in terms of the meter; kilometer (km), centimeter (cm), millimeter (mm), micrometer (μm) and nanometer (nm).

5. Define the terms vector and scalar and use the definitions to distinguish between the concepts of velocity and speed.

6. Distinguish between scalar addition and vector addition. Be able to add two velocities using the graphical method of vector addition.

Large Group. We will have a class discussion concerning the metric system and scientific (exponential notation). We will also discuss vectors and vector diagrams. The film "powers of ten" will be shown. The purpose of this film is to explore the complete range of numbers used by the scientist. We begin by focusing on a man on the beach in Miami. We move away from him, increasing our distance, by a power of ten, each ten seconds, until $10^{24}$ meters has been reached. We then move back until we finally focus on a carbon atom in the man's hand. Why do some changes in position seem to occur rapidly and others very slowly?

Small Group. Discuss with others the advantages and disadvantages of using the metric system in this country. What major changes would this result in, in your own daily activities? Describe the dimensions of common objects, including your own height, in metric units.

Individual. Carefully work the examples given in the mathematics refresher in your text on pages 893-904. Check your answers with the answers given at the end of the exercises. If you have any difficulty with the material then work through the examples given on the following pages. If not then you are ready to proceed to unit III.

## Positive and negative numbers

We will be working with numbers which are both greater than or less than zero. A few simple rules will enable us to handle these numbers with ease.

Addition. If the numbers have the same sign then simply add them and the answer has the same sign as both of the original numbers.

examples: (+4) + (+6) = + 10        (-7) + (-5) = -12

If the signs differ then take the difference between the two numbers and keep the sign of the larger one.

examples: (+3) = (-6) = +2 , (+6) + (-9) = -3 , (-14) + (18) = 4

(note that 18 and +18 mean the same thing. If a sign is missing the number is positive.)

Multiplication. Multiply the two numbers together ignoring the signs. If the numbers had the same sign then the result is positive. If they had different signs then the result is negative.

examples: (5) x (-6) = -30 , (6) x (7) = 42, (-8) x (-9) = +72 = 72

(note that 5 x 6 and (5) x (6) and (5)(6) all mean the same thing. We very often simply omit the multiplication sign).

Division. Same rule as multiplication regarding signs. (-6)/2 = -3 (-8)/(-4) = 2 etc. note that we use a (/) to denote division. 8/4 means $\frac{8}{4}$ .

Note that subtraction combines the above rules:

(6) - (-3) = (6) + (3) = 9

the two negative signs combine to produce a positive (+) sign.

Think of it as: (6) + (-1)(-3)

Now go back to the math refresher in your text and rework the problems involving positive and negative numbers.

The notation $a^n$ simply means the number a multiplied by itself n times.

examples: $2^5 = 2 \times 2 \times 2 \times 2 \times 2 = 32$, $4^3 = 4 \times 4 \times 4 - 64$

This is a useful shorthand notation. To multiply numbers written in this form: $2^5 \times 2^3 = (2 \times 2 \times 2 \times 2 \times 2) \times (2 \times 2 \times 2) =$

$$2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 = 2^8$$

You can see that the general rule is: $a^n \times a^m = a^{m+n}$. Note that both numbers must have the same base. (in this case a). $2^5 \times 3^7$ cannot be evaluated this way.

example: $(3^2)4 = (3^2)\times(3^2)\times(3^2)\times(3^2) = (3 \times 3)\times(3\times3)\times(3\times3)\times(3\times3)$
$= 3\times3\times3\times3\times3\times3\times3\times3 = 3^8$ therefore $(3^2)^4 = 3^8$

The general rule in this case is: $(a^n)^m = a^{n\times m}$

In division a similar case occurs:

example: $\frac{3^6}{3^4} = \frac{\not 3 \times \not 3 \times \not 3 \times \not 3 \times 3 \times 3}{\not 3 \times \not 3 \times \not 3 \times \not 3} = 3 \times 3$

therefore: $\frac{3^6}{3^4} = 3^2$ In general: $\frac{a^n}{a^m} = a^{n-m}$

Examples: $\frac{7^9}{7^6} = 7^3$ $\frac{4^{12}}{4^8} = 4^4$ $\frac{3^5}{3^9} = 3^{-4}$ ??????

In our last example what do we mean by $3^{-4}$? Lets work it out.

$$\frac{3^5}{3^9} = \frac{3\times3\times3\times3\times3}{3\times3\times3\times3\times3\times3\times3\times3\times3} = \frac{1}{3\times3\times3\times3} = \frac{1}{3^4} = 3^{-4}$$

Therefore when we move a number, raised to a power, from the denominator to the numerator, the sign of the power changes. In general $\frac{1}{a^n} = a^{-n}$

We can now define $a^0$. $\frac{a^n}{a^n} = a^{n-n} = a^0$ but anything divided by itself is equal to unity (one). Therefore, any number raised to the zero power = 1.

Numbers greater than one.

Let us use the number 5280 as an example. We can write 5280 as 5.28x1000. But 1000 = 10 x 10 x 10 or $10^3$. Therefore 5280 = 5.28 x $10^3$. This is the notation we wish to use for all numbers. The result will be a number between one and ten multiplied by a power of ten. As a reminder:

$10^0 = 1$

$10^1 = 10$

$10^2 = 100$

$10^3 = 1,000$

$10^4 = 10,000$

$10^5 = 100,000$

$10^6 = 1,000,000$ etc.

Note that instead of going through the process of writing 5280 = 5.28 x 1000 = 5.28 x $10^3$.

We can simply count the number of places that the decimal point is moved to the left and this number of places gives us the exponent for our power of ten.

examples: 3,600,000,000 = 3.6 x $10^9$ 472,000 = 4.72 x $10^5$

To convert a number back to decimal notation simply move the decimal point to the right a number of places as determined by the power of 10.

examples: 4.68 x $10^5$ we can move the decimal point two places to the right and reduce the power of ten by 2. 4.68 x $10^5$ = 468.x$10^3$ to completely get rid of the power of 10 we must move the decimal point three more places to the right by adding three zeroes. 468,000. (Even though we usually omit the decimal point at the end of a number it still is there and this is our starting point when we begin to move it.)

Now try some of the examples in your math-review.

Numbers less than one.

The number .00067 can be written as $6.7 \times .0001 = 6.7 \times \frac{1}{10,000}$

$= 6.7 \times \frac{1}{10^4} = 6.7 \times 10^{-4}$. This is the final form we are trying to arrive at.

We are using the fact that:

$1/10 = .1 = 10^{-1}$

$1/100 = .01 = 10^{-2}$

$1/1000 = .001 = 10^{3}$

$1/10,000 = .0001 = 10^{-4}$ etc.

Again, we do not have to work this long conversion process, but can simply count places that we move the decimal. Move the decimal to the <u>right</u> until you are left with a number between 1 and 10 and the number of places moved becomes the <u>negative</u> power of 10.

examples: $.0000879 = 8.79 \times 10^{-5}$ $\quad .00167 = 1.67 \times 10^{-3}$

To convert back to decimal notation: move the decimal point to the <u>left</u> a number of places indicated by the power of ten.

example: $5.27 \times 10^{-4} = .527 \times 10^{-3} = .0527 \times 10^{-2} = .00527 \times 10^{-1}$
$= .000527$

Now work the appropriate examples in your math review.

<u>Multiplication and division of numbers in exponential notation.</u>

<u>Multiplication</u>: General Rule $(A \times 10^n) \times (B \times 10^m) = (A \times B) \times 10^{m = n}$

Examples: $(3 \times 10^5) \times (4 \times 10^6) = 12 \times 10^{5 + 6} = 12 \times 10^{11}$

$= \underline{1.2 \times 10^{12}}$

$(4 \times 10^{-2}) \times (2 \times 10^7) = 8 \times 10^{-2+7} = \underline{8 \times 10^5}$

$(9 \times 10^{-3}) \times (3 \times 10^{-5}) = 27 \times 10^{-3+(-5)} = 27 \times 10^{-3-5} = 27 \times 10^{-8}$

$= \underline{2.7 \times 10^{-7}}$

<u>Division:</u> General Rule: $(A \times 10^{n})/(B \times 10^{m}) = (A/B) \times 10^{n-m}$

examples: $(9 \times 10^{6})/(3 \times 10^{2}) = (9/3) \times 10^{6-2} = 3 \times 10^{4}$

$(8 \times 10^{5}/(4 \times 10^{7}) = (8/4) \times 10^{5-7} = 2 \times 10^{-2}$

$(7 \times 10^{-4}/(2 \times 10^{3}) = 3.5 \times 10^{-4-3} = 3.5 \times 10^{-7}$

$(8 \times 10^{6}/(2 \times 10^{-6}) = 4 \times 10^{6-(-6)} = 4 \times 10^{6+6} = 4 \times 10^{12}$

$(9 \times 10^{55})/(4 \times 10^{-7}) = 2.25 \times 10^{-5-(-7)} = 2.25 \times 10^{2} = 225$

Use these examples as a guide and work the appropriate examples in your math review.

<u>METRIC SYSTEM</u>

The system of measurement has had a very haphazard history and often, units of measurement were extremely imprecise. Units were based on dimensions of the human body [illegible] cubit is the distance from your elbow to middle finger tip) a[illegible]ten depended on the physical size of the ruling monarch in England or France. The <u>meter</u> was defined by Napolean as one tentmillionth the distance from the pole to the equator along a line drawn along the Earth's surface through the city of Paris. This is now standardized by a system using wavelengths of light. The exact procedure will be studied in a later unit. The meter is a unit of <u>length</u>.

Any system of units is based on basic quantities. These are quantities which cannot be defined in terms of simplier units. These quantities are length, mass and time. All other units are combinations and are called <u>derived</u> quantities. We will use two major systems of units in our work. One is a <u>metric</u> system (based on powers of ten). The other is the British system. The basic units in these systems are as follows:

| | LENGTH | MASS | TIME |
|---|---|---|---|
| METRIC (MKS) | METER | KILOGRAM | SECOND |
| BRITISH | FOOT | SLUG | SECOND |

(note: MKS stands for meter, kilogram, second and is one of several metric systems).

APPENDIX C

Math Diagnostic Exam

# Math Diagnostic Quiz

Part I. If $y = 7$ and $z = 3$ then find the value of x.

1. $x = z - y =$
2. $x = 3y + 4z =$
3. $x = y^2 - z^2 =$
4. $x = yz^3 =$
5. $x = (y - z)(z + y) =$
6. $x = \frac{2}{y} + \frac{4}{z} =$

Part II. Express the following numbers in standard exponential notation.

1. 3500 =
2. 435000 =
3. 72080 =
4. .0987 =
5. .0000645 =
6. .00000706 =

Part III. Carry out the following mathematical operations and express your answer in standard exponential notation.

1. $(3 \times 10^6) \times (2 \times 10^4) =$
2. $(2.4 \times 10^3) \times (5 \times 10^6) =$
3. $(8 \times 10^3) \times (4 \times 10^{-4}) =$
4. $(6 \times 10^{-5}) \times (3 \times 10^{-7}) =$
5. $(8 \times 10^6) / (2 \times 10^2) =$
6. $(7 \times 10^9) / (3 \times 10^{11}) =$
7. $(6 \times 10^4) / (2 \times 10^{-4}) =$
8. $(9 \times 10^{-5}) / (3 \times 10^{-8}) =$

Part IV. Carry out the indicated operations and write your answer in the space provided.

1. $A^5 \times A^4 =$
2. $A^6 \times A^{-2} =$
3. $B^{-3} \times B^{-7} =$
4. $Y^6/Y^2 =$
5. $W^4/W^9 =$
6. $X^3/X^8 =$