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ABSTRACT

A computer-assisted instructional program used at the United States Naval Academy to provide students in introductory physics with practice in problem-solving is described. The author first discusses the rationale for using a time-shared, tutorial approach and presents the steps involved in building a tutorial problem drill. Following this, the matter of getting the tutorials onto the campus computer system is considered. A set of sample instructions for students is provided. Finally, the system's driver routine is briefly reviewed. (PB)

PHYSICS PROBLEM DRILL BY COMPUTER

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INTRODUCTION

One of the major problem areas encountered by students in an introductory college physics course is the difficulty in learning correct problem solving techniques. A great number of students become hopelessly mired in mediocrity due to a lack of proper training in this area. Even at the basic course level many problems present themselves which do not allow a quick and easy one-step solution. To become proficient in solving these more complex problems it is necessary for the average student to develop a clearly understood technique of problem solving which involves step-by-step procedures.

Perhaps the best method for teaching efficient problem solving is the tutorial approach. The drawback is that for truly tutorial instruction, the instructor-to-student ratio must be one-to-one, a situation which is seldom approached, even in advanced classes. In the more elementary level courses it is not even considered.

RATIONALE

The premise for the design of the material in this project is that through the means of material presented at a terminal, an instructor can effectively reach a much greater number of students than would ordinarily be possible through the usual extra-instruction techniques of individual tutoring for each student. The problem drills designed for this project follow the ancient tutorial method, where the purpose of asking a series of questions is not to expose the student's ignorance, but to carefully direct the student toward the correct answer. The student is allowed to select his own particular pathway to the final solution, but is always guided so that valuable time is not spent on excessive exploration of blind avenues, and yet not restricting him to only one correct path. It is realized that there are many different paths to the same solution, and although the problem drills usually present one specific approach, the student is also always learning a system of reasoning whereby he starts with the first bit of available knowledge and steadily builds a strong bridge of reason to the correct solution.

Because of the advances recently made in computer utility it is now more than ever possible to reach a large number of students with direct computer links. Advances in time-sharing have presented the educator with a ready and willing tool for greatly expanding both the instructor's capability and the student's knowledge. In a general introductory college physics course a large number of students generally do not receive any instruction other than what is given in the classroom. The problem drills are designed to

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present typical problems for solution, problems very much like those that would be used by an instructor if he were personally helping a student.

The teletype terminal for a time-shared computer can be used by as many students as there are terminals available at any given time. Thus, the instructor can prepare instructional material for student usage and be assured that all of his students are receiving direct access to the material. The extra benefits border on the psychological, but previous experience has shown that many students are much more willing to go to a rather impersonal terminal for extra instruction rather than go to their instructor and openly exhibit their lack of knowledge in a particular area.

In terms of the hours spent by each instructor per student, experience has shown that often as little as 15% of the students will avail themselves of the opportunities for extra instruction. Most students will first attempt to solve these difficulties themselves. If this is not successful, the next step is usually to go to a fellow student for aid. Generally, neither of these solutions is successful for the majority of students. The unwillingness on the part of the student to go to the instructor is due to many reasons, such as instructor availability, instructor-student relationship, or just a desire on the part of the student not to "rock the boat" by admitting his inability in certain areas of study. The impersonality of the terminal, coupled with its aura of being a new computer age symbol, make it more acceptable to the student than the instructor. The terminal is impersonal and the student does not have the feeling he is being watched over and constantly graded by the instructor. By proper programming techniques and the use of highly conversational languages the student can be made to feel quite at home with the terminal installation.

One additional motivational factor which has proved to be of some usefulness is the student feeling that this time-shared computer usage is putting him a little more in touch with the computer age. One of the severe problems in any elementary level science course is the fact that the material presented is generally hundreds of years old. With this in mind it is obvious that extra measures must be taken to bridge the time span between the material being presented and the technological usage of today. Direct access to a computer facility should help bridge this gap.

The suggested method for utilizing these drills is to have as many of them as possible available at all times. The students should be introduced to the problem drills early in the course of study and encouraged to go through each drill as that topic is reached. Assignments of particular drills might also be made for homework, but it is not suggested that the drills be substituted for homework problems on a large scale. The drills should also be kept available for review at the end of the course. One of the best possible configurations is to have all of the problem drills in a system library so that any user may access them at his convenience.

Since the basic strategy employed in these drills is a tutorial approach, each of the drills is presented in the same manner. The number of basic questions for each drill varies between two and seven. If a correct response is received to a basic question, the next basic question is posed until the entire drill is completed. If a wrong response is received to a basic question, remedial material is presented, often with additional questions.

Then the missed basic question is repeated. Because of the multiple choice type answers given, provisions are not made for repetition of the same answer. Once the student has successfully answered all of the basic questions, a simple tabulation of his performance is presented. In most cases, when a correct response is received additional reinforcing material is presented to help the student fully understand the principles underlying his response.

HOW TO BUILD A TUTORIAL PROBLEM DRILL

The method used to construct one of the problem drills follows the basic tutorial approach. First, a problem is selected that is typical of a class of exercises the student is expected to know how to solve. The problem is then broken down into several steps. As an example of this procedure the third drill will be used. The problem area is that of projectile motion. The particular problem selected consists of throwing a football from a height above the ground and determining when and where it will hit the ground. Some thought should go into problem selection, as those problems that can be easily broken down into separate phases are most easily approached in the tutorial manner. In this case the motion can be broken down into (1) the upward motion to the apex, (2) the motion back down to the starting point, and (3) the motion from the starting point down to the ground. Although phases (2) and (3) can be combined, it is useful to look at the state of several parameters at the intermediate position to give a clearer understanding of the total flight.

The problem is now broken down into several questions which are designed either to lead the student along toward the final answer, or to provide him with some interesting information along the way. In Problem 3 the major questions are:

(1) The total displacement in the Y-direction when the football hits the ground is:
(2) The total time in the air for the football is:
(3) The acceleration in the X-direction is:
(4) The displacement in the X-direction is always equal to:
(5) When the football hits the ground, what will be the displacement in the X-direction?
(6) The maximum range in the absence of air friction will be achieved if (A) equals:

Once the basic questions have been decided upon, the next step is to provide a connection between them when they are answered correctly. Sometimes this involves just a simple reinforcement of the previous answers, such as between basic questions (1) and (2):

> "Correct. The football ends up 19.6 M below the level of the cliff where it started."
> (Correct answer was -19.6 M)

Other times, if the question was more complex, a detailed explanation can be given to the student. For example, the response to basic question (2) is:

> "Correct. The football will rise for 1 second, then fall for 1 second returning to the level of the cliff, then continue to fall another 1.23 seconds until it hits the ground."

It is also possible to use the between question responses for introducing material that will be repeated in the following question. In responding to basic question (5), the word "range" is introduced, and then used in question (6)

Once all of these correct answer responses are completed, work begins on the incorrect responses. In actuality, one often calculates the actual wrong answers when developing the basic questions themselves, but it is best to complete the entire correct answer response package before working on responses to incorrect answers. This is suggested because the incorrect responses will eventually lead back to the basic questions and it is a good technique to include material in the correct responses which is later reinforced.

One of the major areas of difficulty in designing the problem drills is the problem of choosing wrong answers. This is an area that can be of great importance in the success of the drills. A wrong answer that is just picked at random can only lead to a very nebulous response when that answer is chosen, whereas a carefully chosen wrong answer can very clearly point out the pitfalls that occur in a particular problem area. This is especially true with numerical answers.

Looking at basic question (1), one obvious wrong answer is a displacement of 0, since the football does end up on the ground. Choosing this answer can then be responded to with a clear explanation of what zero displacement means: "In order to have zero displacement, the football must end up where it began." The other answer to basic question (1) is 10 M, a positive

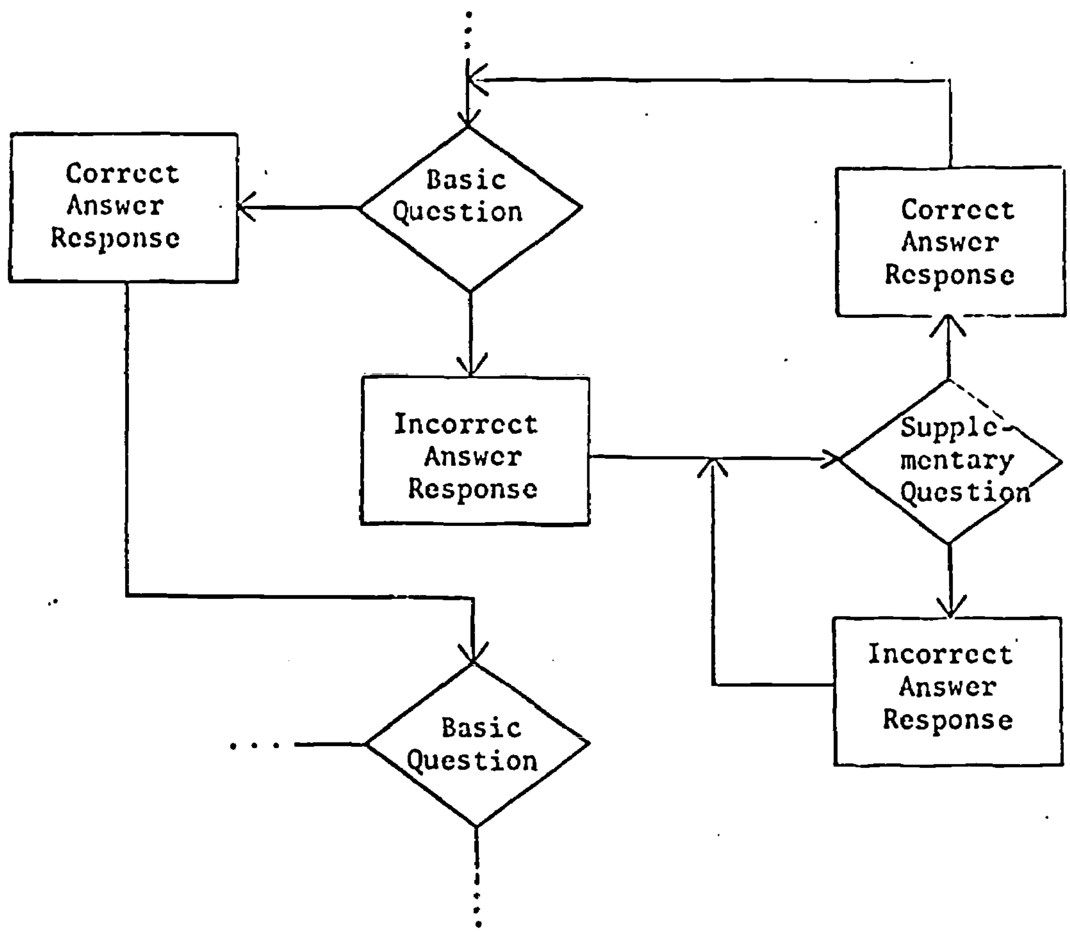

Figure 1

displacement, which, when chosen, is responded to with another explanation of the meaning of displacement.

In writing these incorrect answer responses, it is also possible to want to ask a further question to clarify some point. If this is done the entire scope of this secondary question should remain within the range of the original incorrect answer response. Figure 1 gives a flow chart for a typical problem drill. (A copy of the complete problem drill is available from the author.)

GETTING THE TUTORIALS ONTO YOUR SYSTEM

It is assumed that a rather wide range of experience will prevail among the persons interested in using these tutorial drills. In order for the drills to be used effectively, some sort of time-sharing system should be available. The most direct way of using the drills is by having each program stored so that it is accessible to all students. This can usually be done by using a special account number. Some systems may utilize a "public library" of programs that are available to all users, and this is another excellent way of making the programs accessible. Usage thus far at both the U. S. Naval Academy and Dartmouth College has allowed all of the drills to be available all of the time, but this requires a large amount of storage, as each program is approximately 1200 words long. If your system has some type of magnetic tape utility, this may be used to call out a particular drill. This method usually means the student must learn some special programming techniques, and that is often a factor to be considered. The access to the drills should be kept as simple as possible. In some cases, however, the only way all of the programs can be kept accessible is by using some non-standard device such as the magnetic tape. It should be remembered that the major goal is the learning of the material, and not mastery of some complex scheme of accessing it.

Probably the best idea for getting the drills onto any given computer system is to make a visit to the computer center and talk with the personnel there. Usually there will be one person designated as faculty liaison or, if not, the applications programming staff can usually help out. The main idea is to make the student's job as easy as possible. Avoid complicated processes that are prone to interruptions when not carried out exactly.

SAMPLE INSTRUCTIONS FOR STUDENTS

The following is an example of an instruction sheet that could be used in getting students familiarized with running the tutorial drills. This set of instructions assumes the students have in their possession a copy of the student workbook. The tutorials have been given program names "HELP01", "HELP02", ..., "HELP50".

* * * * * * * * * * * * * * *

A set of fifty computer assisted drills is part of the material that is available in Physics 100, "General Engineering Physics". These drills may be performed by the student on the University's Time Shared Computer System. You have been provided with a student workbook which contains material relating to each of the fifty drills. You should read the material in the workbook prior to attempting any drill. Be sure to bring your student workbook with you to the computer terminal as you will need to refer to the figures in the workbook during the drill.

Computer terminals are available throughout the University and the drills may be accessed from any terminal. There is a special terminal room located at the Computer Center in Ham Hall with twenty terminals. The University Time Shared Computer Service is available from 6 a.m. to 2 a.m., seven days a week.

Once you are seated at a terminal, you should follow the instructions posted on the terminal for getting a connection to the computer. The following example will show how to complete the process of accessing a particular drill. User responses are underlined.

```
FROST UNIVERSITY TIME SHARING
21 DEC 1972--21 USERS PRESENTLY ON LINE
8:14 AM

USER NUMBER--PHY22
PASSWORD--DRILLS
NEW OR OLD--OLD
OLD FILE NAME--HELP16
READY

RUN

HELP16        8:15        21 DEC 72
TYPE YOUR NAME--BILL
WELCOME, BILL, TO AN INTERESTING...
```

From this point on you will be asked several questions relating to the figure shown in the particular problem you have chosen. Problem 1 is program name HELP01, Problem 2 is program name HELP02, and so on through program HELP50.

For each question you will be given three possible answers. You should pick one of the three and then type 1, 2, or 3 followed by a carriage return. The program will then evaluate your response and continue with the drill. You should try to figure out each answer and not guess.

EXPLANATIONS OF RECORD KEEPING TECHNIQUES

There are several options that can be implemented when using the Physics Tutorial Drills. Among these are various methods of recording student responses, including the responses to various questions and elapsed response time.

In order to accomplish the job of keeping records it is necessary that the computer system being used have the capability of using external files between programs. Most systems offering BASIC have this capability. The following example will show how Problem 3 can be easily modified to include very simple record keeping. The statement

```
10 FILE #1:"RECORDS"
```

must be added at the beginning of the program and the file "RECORDS" must be saved. It is best if "RECORDS" has only append permission so that information cannot be altered once written.

The normal sequence of code for a question is as follows:

```
270 PRINT "(1) The total displacement in the Y-direction when the"
280 PRINT "football hits the ground is:"
290 PRINT "(1) 10 M        (2)  0        (3)  -19.6 M"
300 INPUT Z
310 ON Z GO TO 820,890,320
320 LET R=R+1
330 PRINT "CORRECT..."
```

In this case lines 820 and 890 are the beginning of responses to incorrect answers (1) and (2). If the statement

```
305 PRINT #1:3,1,Z
```

is inserted, then a record is kept in file "RECORDS" of the response to each question. After several uses of the tutorial drills the file "RECORDS" could be listed, giving something like this:

```
RECORDS          6 SEP 72         8:15

3                1                2
3                2                3
2                1                1
2                1                3
1                1                1
3                2                2
1                1                1
2                1                1
.                .                .
.                .                .
.                .                .
```

The first column is the drill number, the second column is the question within the drill, and the third column is the response to the question.

If the record keeping method is to be used for only the primary questions, the simple question number is all that is necessary to record. However, if the response to secondary questions are also to be recorded, then some more complex numbering scheme can be devised for the question numbers, such as

30	#3 primary
31	#3 first secondary
32	#3 second secondary

Another item that is often desired for analysis is the response time of the student to a question. This can be determined and recorded in BASIC systems that offer the CLK$ string function. CLK$ returns as a value the time of day in the form 15:22:06, meaning 6 seconds past 3:22 PM. By checking the time both after the question is posed and after the answer is entered, the time difference can be calculated and recorded in the "RECORDS" file. To do this it is necessary to utilize the CHANGE statement. You should consult your version of BASIC to see if your system can accept both CLK$ and CHANGE. Using these two statements the following program segment will calculate the two times T1 and T2 and record the difference in the record keeping file, along with the responses.

```
                .
                .
                .
290 PRINT "(1)  10 M        (2)  0         (3)  -19.6M"
291 LET = CLK$
292 CHANGE C$ TO C
293 LET T1 = (C(8)-48) + (C(7)-48)*10 + (C(5)-48)*60 + (C(4)-48)*600
300 INPUT Z
301 LET C$ = CLK$
302 CHANGE C$ TO C
303 LET T2 = (C(8)-48) + (C(7)-48)*10 + (C(5)-48)*60 + (C(4)-48)*600
304 PRINT #1:  MOD(T2-T1),3600),
306 PRINT #1:  3,1,Z
310 ON Z GO TO 820,890,320
                .
                .
                .
```

Each time a question is set in the program these lines would have to be inserted. If your BASIC system offers multiple line function definitions, the coding could be simplified by putting the following function at the beginning of the program:

```
20 DEF FNT(A$)
30 CHANGE A$ TO A
40 LET FNT = (A(8)-48) + (A(7)-48)*10 + (A(5)-48)*60 + (A(4)-48)*600
50 FNEND
```

With this included the coding for each question becomes:

```
                .
                .
                .
290 PRINT "(1)  10 M        (2)  0         (3)  -19.6 M"
291 LET C$ = CLK$
293 LET T1 = FNT(C$)
300 INPUT Z
301 LET C$ = CLK$
303 LET T2 = FNT(C$)
304 PRINT #1: MOD(T2-T1),3600),
306 PRINT #1: 3,1,Z
310 ON Z GO TO 820,890,320
                .
                .
                .
```

Further record keeping can be devised as needed by the individual user. If the computer system being used offers each user a unique user number and also offers public library files, then the file "RECORDS" should be a public file, so that it is accessible to all user numbers. This normally means the file declaration becomes

```
10 FILE #1:  "RECORDS***"
```

The computer center personnel are normally responsible for creation of public library files, so they should be contacted if this method is to be used.

Another option that is often desired but much harder to implement is variable answers. In the basic version of the programs, if a student were to run a particular drill for a second time he would see exactly the same questions and possible answers as the first time he ran the drill. A listing of Problem Drill 3 with an option for variable answers can be obtained from the author.

THE DRIVER ROUTINE

A system has been designed to allow for automatic creation of tutorial drills which are then run by the students using a single driver program. Because of the fact that data files occupy less storage space than programs this is a more efficient method for maintaining large numbers of drills on a computer system at the same time. The driver routine consists of two programs. The first program, "MAKEFILE", and the second program, "DRIVER", are available from the author.

Another advantage of the driver approach is the simplification of the creation of new and original drills. By simply following the basic tutorial approach as outlined in Figure 1, the teacher can create drills for any subject desired. The material presented in the student workbook can generally be given as an introduction to each drill. If any diagrams are needed they must be provided separately.

SUMMARY

The attempt has been made to give the student, in an introductory physics course, an opportunity to gain practice in problem solving by means of a set of tutorial problem drills. The material has been presented with the idea of making it available to as large a number of students as possible. Important consideration has been given to the design of answer sequences and expected responses. A method has been presented which will allow simple record keeping to be done and techniques have been shown to allow for variable answers and utilization of a driver approach.