AC 2010-2124: UTILIZING INTERACTIVE WEB BASED DYNAMICS ANIMATION SOFTWARE IN ORDER TO OBTAIN GRAPHS OF PARAMETRIC STUDIES

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UTILIZING INTERACTIVE WEB BASED DYNAMICS ANIMATION SOFTWARE IN ORDER TO OBTAIN GRAPHS OF PARAMETRIC STUDIES

Animation software for an introductory *Dynamics* course has been developed, which will be an integral feature of the web-based learning system, WileyPLUS (John Wiley and Sons, Inc. New York). This interactive software is unique because each animation may be directly linked to a homework problem or case study and no programming is required of the user.

The software has been improved such that the user may download parametric studies of raw data in tab-delimited format. Graphs can then be automatically generated via a Microsoft EXCEL® (EXCEL) "macro", which is embedded in a single static EXCEL file. This EXCEL file must be downloaded only once and can be used to seamlessly graph and format parametric data that has been obtained via the animations program.

The focus of this paper is to illustrate and assess parametric studies that were created by the animation software. The software was used by students at Kettering University in order the increase their qualitative understanding of particle dynamics and rigid body kinematics. Student surveys and the results of student assignments suggest that the parametric studies enhanced the students' overall comprehension of dynamics.

1. Introduction

In typical *Dynamics* courses, most homework problems require the student to solve for a given variable at an instant in space and time. The professor typically assigns a set of homework problems and the students solve each problem by hand. The student knows that his or her calculations are correct by checking answers in the back of the book.

In reality, the subject of particle *Dynamics* is the study of motion and not the calculation of a particle's point at a particular instance in time. This differentiation is probably lost in the traditional classroom. A unique web-based animation program has been developed by the principal author of this paper, which has been explained in several previous publications[1,2,3,4,5,6]. A summary of comments and findings of the earlier publications are:

1) The primary purpose of the animation software is to help the student appreciate and understand *Dynamics* concepts more completely.
2) There is no software to install and there is absolutely no programming required of the user.
3) The animations can be played on virtually any computer; the Adobe Flash® Player is installed on 98.8% of internet-enabled desktops worldwide[7].
4) The software is extremely easy to use; the controls are similar to those of a DVD player.
5) Because the program is "hard-coded" in Adobe Flash ActionScript, there is an abundance of control in the advancement of the software package.
6) The cost and time of development is relatively low because all images may be duplicated directly from the textbook.

7) Although web based interactive animation software has been developed in the recent past by creating Java Applets or by writing computer programs in Adobe Flash ActionScript.[8,9,10,11,12,13,14,15], no comprehensive and interactive web-based animation software for educators has been developed on a mass scale (probably due to cost[16,17,18]).

A new feature has been added to the animation software; the user can now perform parametric studies of chosen variables via the animation. It is the author's opinion that parametric studies will help the student more fully comprehend the "time and space" nature of the subject of *Dynamics*.

In order to create the graphs of the parametric studies, raw data is created and downloaded via the animations program. Afterwards, an external program is used to automatically generate the formatted graphs.

Downloading the tab-delimited raw data is done via user interface that employs a combination of client-based Adobe Flash ActionScript and server-based PHP Hypertext Preprocessor *(*PHP) computer languages.

Several programs could have been used to graph and format the raw data (e.g. Matlab®, Mathcad®, Maple®, EXCEL, etc.). EXCEL was chosen because of its substantial popularity in the engineering field (based on the authors' experience). A Microsoft Visual Basic for Applications (VBA) macro was developed in EXCEL, which can be used to seamlessly create and format parametric graphs from the raw data; this EXCEL file will be referred to as the "EXCEL VBA" file in this paper.

2. Software Intent and Audience

It must be emphasized that the animation software and its features are not intended to eliminate the grading of homework for the professor. The primary objective of the software is to increase the engineering student's fundamental understanding of the subject of *Dynamics* via a user friendly, cost effective, and readily available web-based interface.

The principal audience is composed of educators who wish to enhance their students' overall comprehension of *Dynamics* via simulations.

3. Explanation of the Software

There are many categories of particle dynamics that are included as part of the main animation package; many homework and example problems are included in each category [5,6].

In this study, students were given assignments that cover two problem types: X-Y Kinematics and Crank/Slider Kinematics. The subject of crank/slider kinematics will be fully discussed in future publications, so it will only be discussed briefly here. Parametric studies of a problem involving X-Y kinematics will be the main focus of the paper.

A problem that was used in two sections of *Dynamics* at Kettering University during the fall term of 2009 will be used to explain the parametric study component of the software. (If the reader is interested in the functionality of the animation software, he or she may reference [1,2].)

Due to the suggestions of the principal author's former students, the page layout of the animation was recently changed from landscape to portrait mode (see[1,2,3,4,5,6] to view the landscape mode). The new and improved portrait version of the web page is shown in Figure 1.

3.1 Problem Statement and Setup (see Figure 1)

The problem background that was given to the students is, "A rocket is fired at an initial angle of 35º from the horizontal, with an initial elevation of 1300 meters. Once fired, it is influenced by the acceleration due to gravity in the Y-direction and wind drag causes an average (or constant) acceleration in the X-direction of -8.0 m/s^2".

3.1.1 Quantitative Problem (Briefly Described)

3.1.1.1 Quantitative Problem Statement

<u>Quantitative Analysis</u>: If the elevation of the target is 100 meters and it is 3500 meters away (horizontally), what initial velocity will result in a successful hit?

3.1.1.2 Quantitative Problem Setup and Verification

The student calculates V_0 by hand and enters it into the INPUT box of the animation. He or she runs the animation and validates that the correct answer is $V_0 \approx 306$ m/sec.

3.1.2 Qualitative Problem (Described in Detailed)

3.1.2.1 Qualitative Problem Statement (Relating to the Parametric Study)

<u>Qualitative Analysis</u>: Perform a parametric study by varying the initial velocity angle (ϕ_{V0}) from 10° to 80º in steps of 10º. Graph the default values as a function of time (X, Y, V_X, V_Y, A_X, A_Y). Print out each graph and perform the following analyses:

a) Analyze and explain the general trends of the series of curves in each graph.

b) Explain why the individual curves change as ϕ_{V0} changes in each graph.

Where:

X = Position in X-Direction (meters)
V_X = Velocity in X-Direction (m/sec)
A_X = Acceleration in X-Direction (m/s^2)

Y = Position in Y-Direction (meters)
V_Y = Velocity in Y-Direction (m/sec)
A_Y = Acceleration in Y-Direction (m/s^2)

Rocket Target Problem

A rocket is fired at an initial angle of 35 degrees from the horizontal, with an initial elevation of 1300 meters. Once fired, it is influenced by the acceleration due to gravity in the y-direction and wind drag causes an average acceleration in the x-direction of -8.0 m/s^2.

1) Quantitative Analysis: If the elevation of the target is 100 meters and it is 3500 meters away (horizontally), what initial velocity will result in a successful hit? (INPUT variable of the rocket: V_0).

2) Qualitative Analysis: Perform a parametric study by varying the initial velocity angle (ϕ_{V0}) from 10 deg to 80 deg in steps of 10 degrees. Graph the default values as a function of time (X, Y, V_X, V_Y, A_X, A_Y). Print out each graph and perform the following analyses:

a) Analyze and explain the general trends of the series of curves in each graph.

b) Explain why the individual curves change as ϕ_{V0} changes in each graph.

PROBLEM STATEMENT

Rocket Target Setup

1) Quantitative Analysis (WORTH 2 Points Extra Credit on Exam #1)

All of the INPUT variables have been passed in the animation, except for the initial velocity (V_0) of the rocket.

STEP 1: Calculate the required value of V_0 by hand and enter the value in the animation.

STEP 2: Run the animation and validate your calculations.

STEP 3: Print out the web page that verifies a HIT. (Landscape mode may yield better results on the printout, depending on your screen resolution.)

STEP 4: Hand in both the animation and the hand-calculations.

2) Qualitative Analysis (WORTH 8 Points Extra Credit on Exam #1)

While keeping the value of V_0 from the Quantitative Analysis (1, above), perform a parametric study by doing the following:

STEP 1: Click on the OUTPUT button of the rocket and choose PARAMETRIC STUDY. A popup labeled "PARAMETRIC STUDY" will appear.

STEP 2: Use the drop-down menu to choose phiv0 (φ_{V0}). Enter the values as indicated in the problem statement (i.e. STEP = 10 deg, FROM = 10 deg, TO = 80 deg) and click OK.

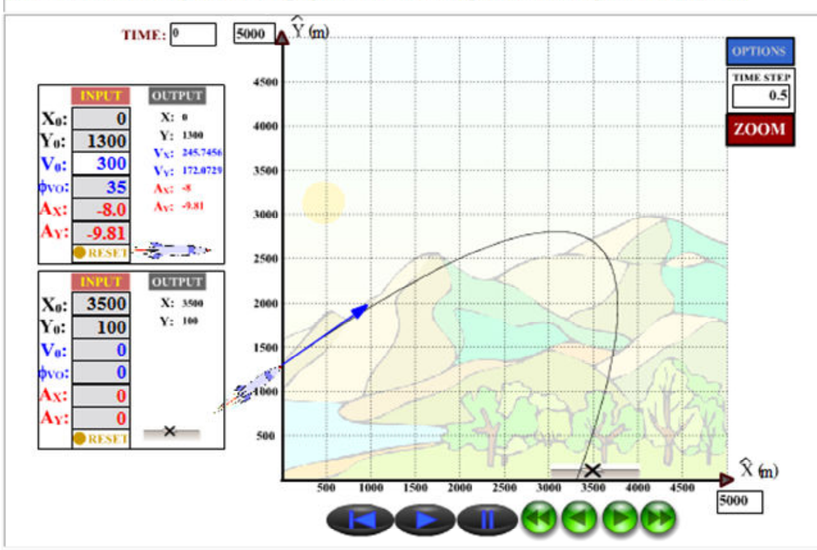
STEP 3: Another popup labeled "PARAMETRIC STUDY: CHOOSE VARIABLES TO DOWNLOAD" will then appear. Click OK to choose the default values.

STEP 4: A final popup box will appear, which is labeled "SELECT TIME RANGE AND PRECISION". Keep the default time steps and click OK again.

STEP 5: A new web page will appear with instructions on how to generate the graphs of parametric studies. It must be emphasized that you must download the programmed EXCEL file (template_graphing.xls) only once; this EXCEL file contains a Visual Basic for Applications (VBA) macro that can be used to automatically generate graphs for this study and any future studies.

STEP 6: Generate and print out the graphs and answer the questions of the problem statement.

PROBLEM SETUP



ANIMATION

Figure 1 Problem, Setup, and Animation Screen Shot (Improved Portrait Mode)

3.1.2.1 Qualitative Section Setup

Following is a brief description of how the student will create parametric graphs via the animations software. After the user enters the correct value V_0 = 306 m/sec into the INPUT area of the animation program, he or she follows the next steps (see Figure 1).

<u>STEP 1</u>: The student clicks on the OUTPUT button of the rocket and chooses PARAMETRIC STUDY (Figure 2).

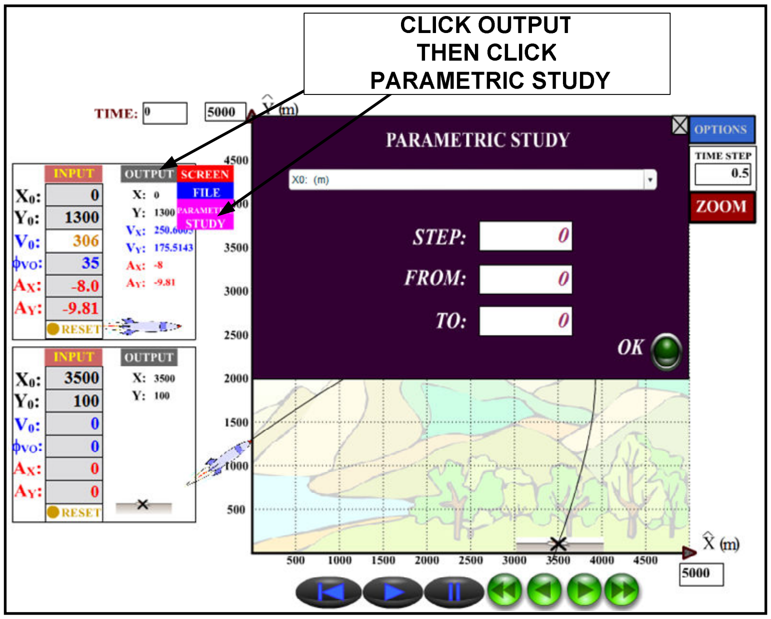


Figure 2 Parametric Study: **<u>STEP 1</u>**

<u>STEP 2</u>: The student uses the drop-down menu to choose phiv0 (ϕ_{V0}). He or she then enters the values required by the problem statement into the corresponding text boxes (i.e. STEP = 10º, FROM = 10°, TO = 80º) and clicks OK (Figure 3).

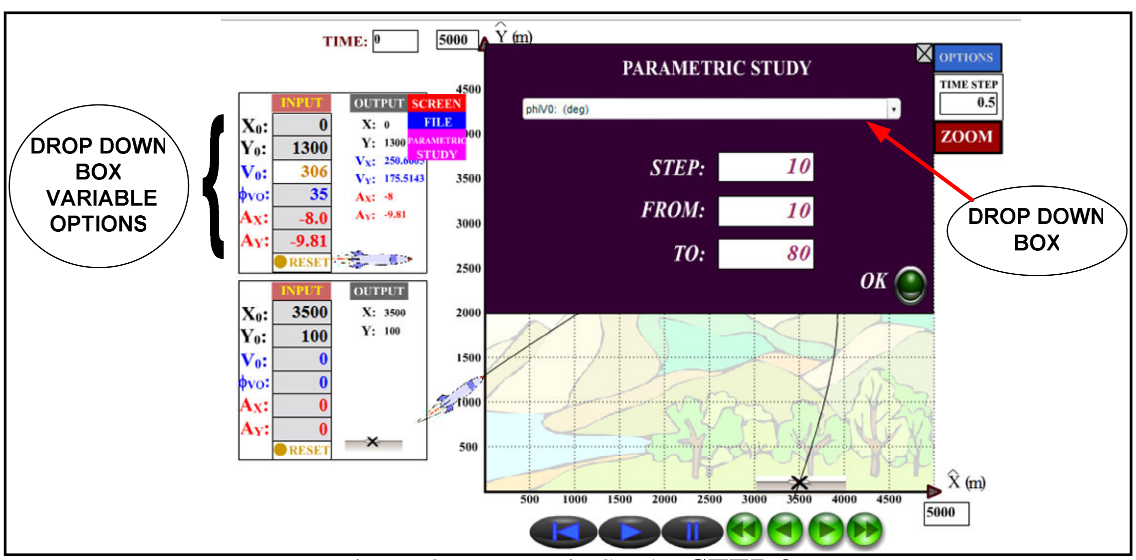


Figure 3 Parametric Study: **<u>STEP 2</u>**

STEP 3: Another popup labeled "PARAMETRIC STUDY: CHOOSE VARIABLES TO DOWNLOAD" will then appear (Figure 4). The student clicks DOWNLOAD VARIABLES to choose the default values of X, Y, V_X, V_Y, A_X, and A_Y (see section 3.1.2.1, above).

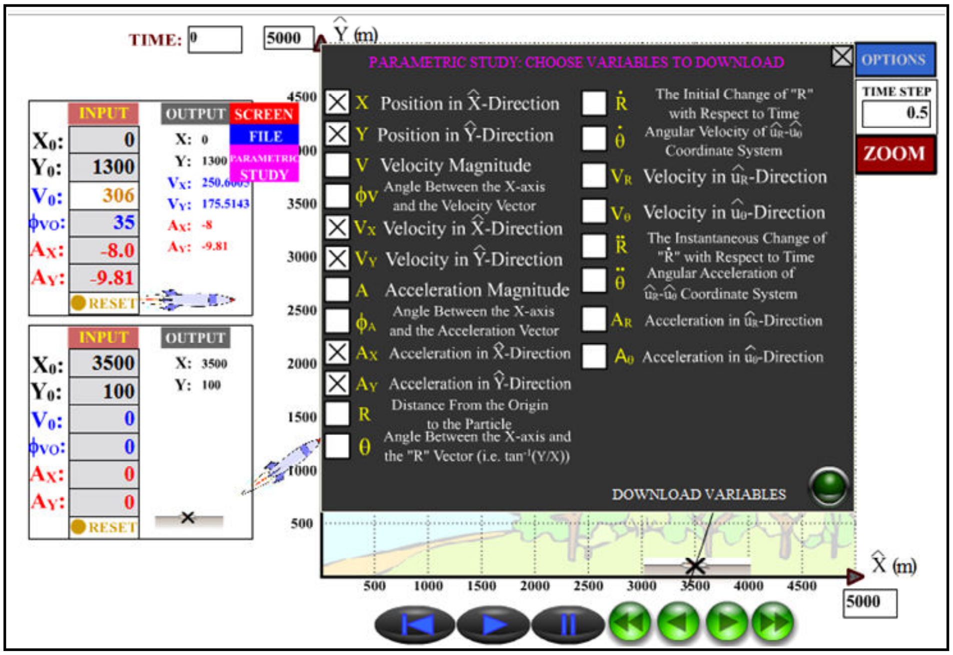


Figure 4 Parametric Study: **STEP 3**

STEP 4: A final popup box then appears, which is labeled "SELECT TIME RANGE AND PRECISION". The student keeps the default time steps and clicks DOWNLOAD.

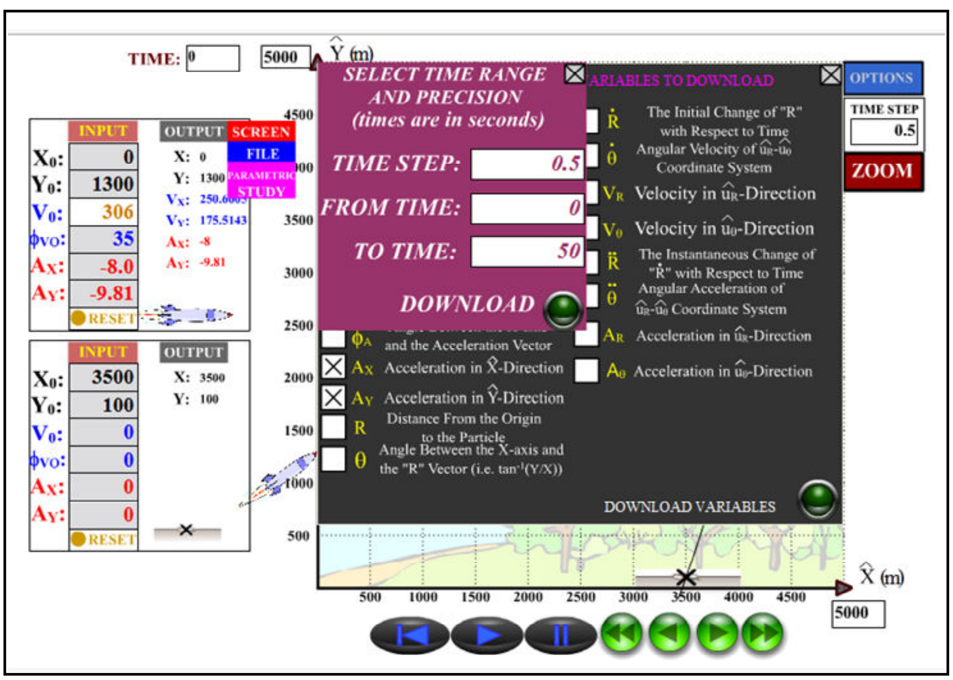


Figure 5 Parametric Study: **STEP 4**

STEP 5 A new web page appears with instructions on how to generate the graphs of parametric studies. The student needs to download the programmed EXCEL© VBA file (template_graphing.xls) only once.

STEP 6 Once both the EXCEL© VBA file and the raw EXCEL© data are downloaded, the graphs of the parametric studies may be created.

4. Parametric Graph Generation

In order to create the graphs, the student opens up the EXCEL© VBA file, which contains a single large button. He or she clicks on the button and then chooses the EXCEL© file that was previously downloaded, which contains the raw data. Graphs are then automatically created and formatted. They are then embedded in the raw EXCEL© data file as separate "sheets" of graphs.

For the purposes of this paper, only the parametric graphs of the Y-components of the rocket kinematics are considered (Figures 6-8).

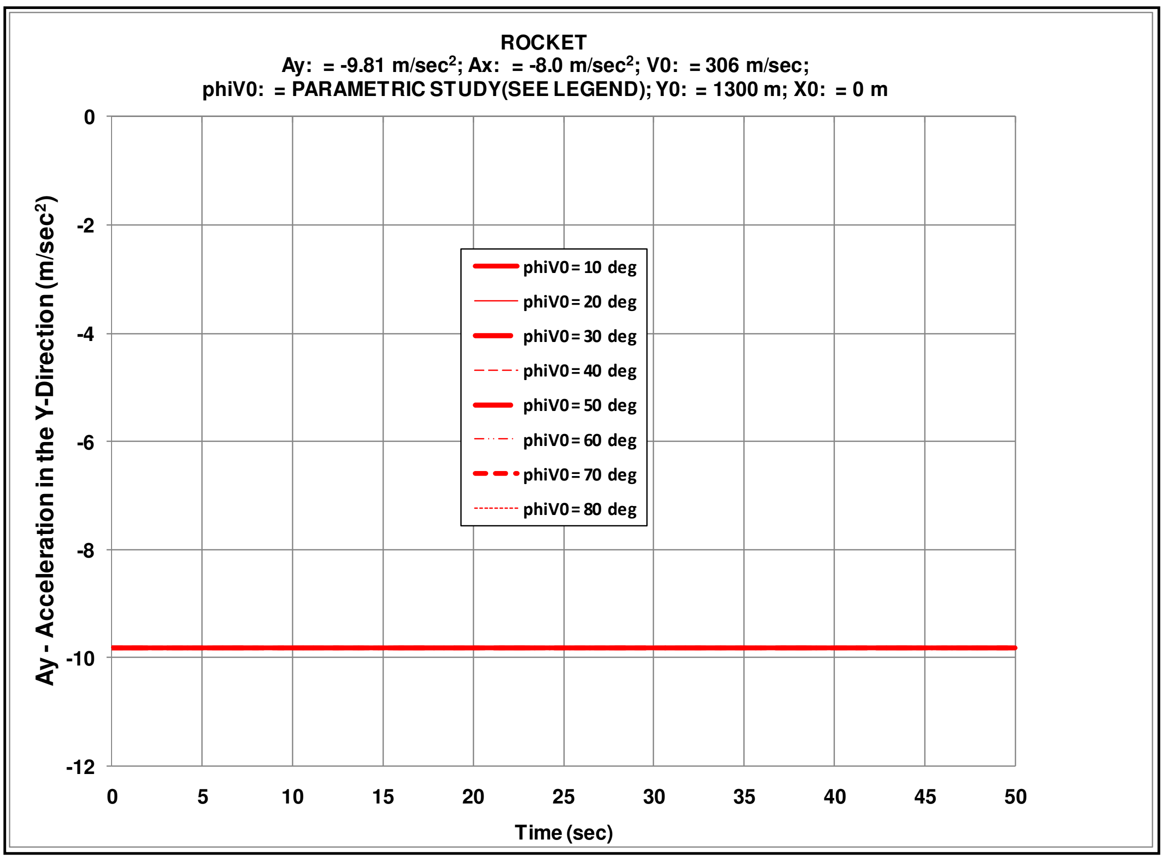


Figure 6 **Ay(t):** Parametric Study of the Initial Velocity Angle (ϕ_{V0}) From 10º to 80º

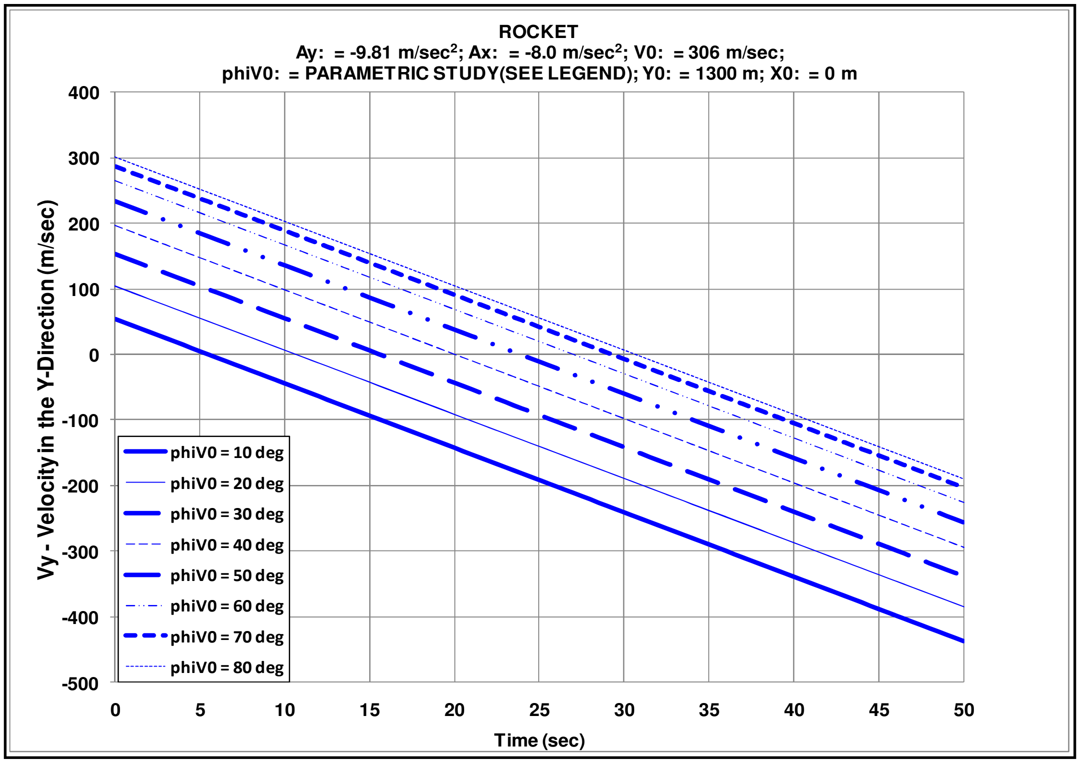


Figure 7 **Vy(t):** Parametric Study of the Initial Velocity Angle (ϕ_{V0}) From 10º to 80º

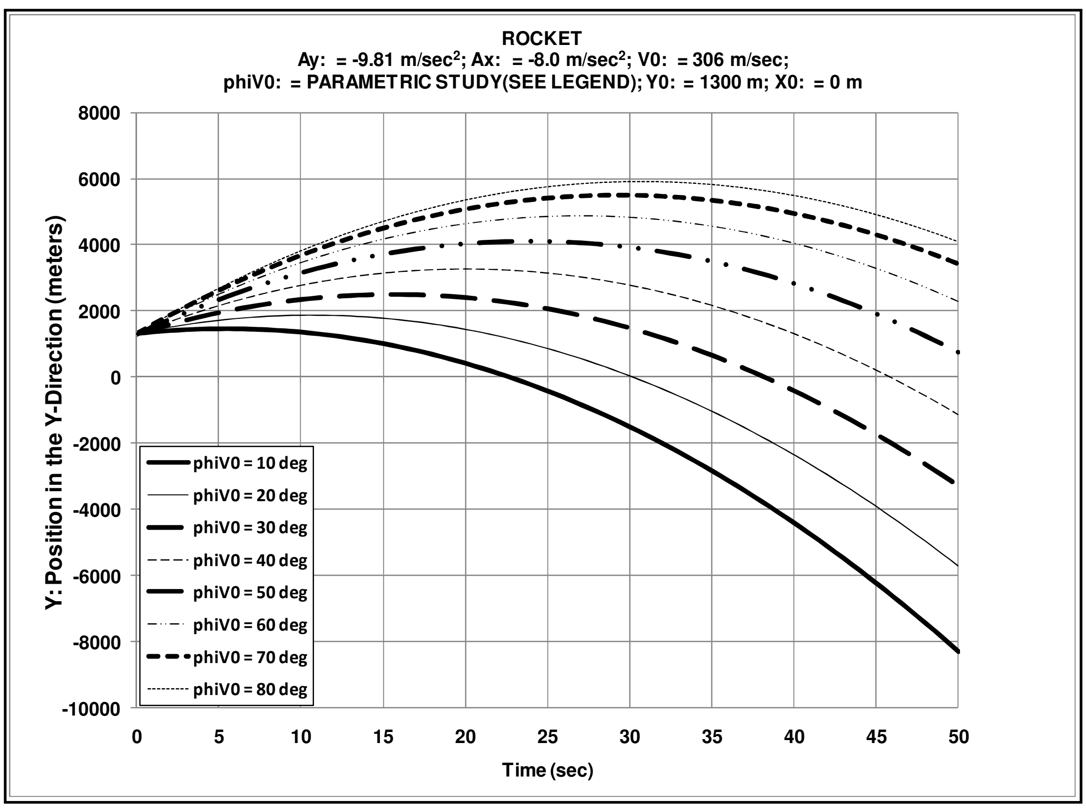


Figure 8 **Y(t):** Parametric Study of the Initial Velocity Angle (ϕ_{V0}) From 10º to 80º

5. Results of the Students' Work

Students were asked two questions regarding the series of graphs (see section 3). The questions were open ended, which required the students to evaluate the curves by both intuition and the use of kinematic principles. A target level of a 70% student success rate is considered satisfactory.

5.1 Qualitative Analysis: Question a)

The students were asked, "Analyze and explain the general trends of the series of curves in each graph". The percentage of correct answers for acceleration, velocity, and position are shown in Figure 9.

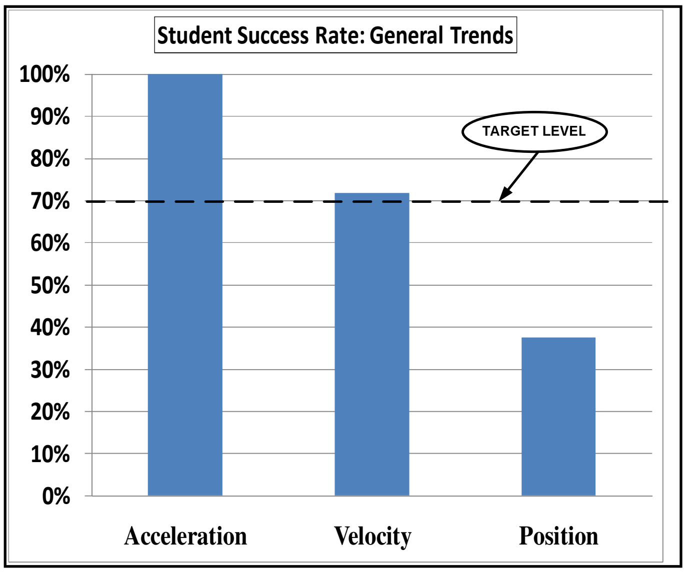


Figure 9 Student Success Rate: General Trends

5.1.1 Acceleration

The correct answer should be (paraphrasing), "The horizontal line is a result of the acceleration being constant". All students answered this question correctly. This was expected because the problem itself states that acceleration is constant.

5.1.2 Velocity

The correct answer should be (paraphrasing), "The velocity decreases linearly with respect to time because the acceleration is constant and negative". Approximately 73% of the students answered this question correctly. This is acceptable; the target level of 70% was reached.

5.1.3 Position

The correct answer should consist of two parts: 1) "The rocket's position reaches a maximum when the velocity becomes zero" and 2) "The curve is parabolic due to a constant acceleration".

Not a single student addressed part 1. This might be because the problem statement was too vague. In future assignments, the problem statement will be made clearer; minima and maxima should be taken into account in their analyses. Because of this, a student's answer was considered to be correct if part 2 was included in his or her answer.

Approximately 37% of the students answered this question correctly, which is much lower than the target level of 70%. In future assignments, the students will be told to reference closed form kinematic equations of a particle with constant acceleration, which clearly reveal a parabolic relationship between position and time.

5.2 Qualitative Analysis: Question b)

The students were asked, "Explain why the individual curves change as ϕ_{V0} changes in each graph". The percentage of correct answers for acceleration, velocity, and position are shown in Figure 10.

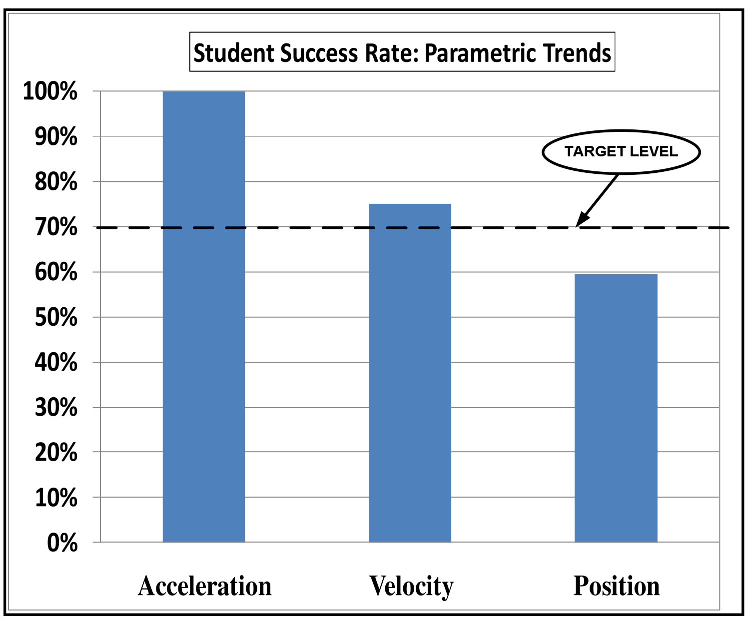


Figure 10 Student Success Rate: Parametric Trends

5.2.1 Acceleration

The correct answer should be (paraphrasing), "The curves do not change because the constant acceleration is not affected by the initial velocity angle". All students answered this question correctly. This was expected because the problem itself states that acceleration is constant.

5.2.2 Velocity

The correct answer is (paraphrasing), "A higher initial velocity angle ϕ_{V0} results in a higher initial velocity in the Y-direction. The lines are parallel because their slopes are the constant acceleration in the Y-direction".

Approximately 74% of the students answered this question correctly. This is considered acceptable; the target level of 70% was reached.

5.2.3 Position

Similar to the answer of the velocity, the correct answer is (paraphrasing), "A higher initial velocity angle ϕ_{V0} results in a higher initial velocity in the Y-direction, because the Y-component of the initial velocity vector increases with an increase in the initial velocity angle".

Approximately 59% of the students answered this question correctly; this is lower than the target level of 70%. Most of the incorrect answers only described the behavior and provided no analysis. It will be stressed in the future that students must explain <u>why</u> the trends occur, not just <u>what</u> occurred.

6. Student Surveys

The animation software was used in two sections of *Dynamics* at Kettering University (Flint, MI) during the fall term of 2009. A total of 29 students were surveyed at the end of the term regarding the effectiveness of the software. The students surveyed were assured that their answers would remain anonymous.

6.1 Survey Results: Effectiveness of the Parametric Studies

As explained in section 3, the students used the software to perform parametric studies of two problem types: X-Y Kinematics and Crank-Slider Kinematics. The survey results are shown in Figures 11 and 12.

Approximately 86% of students agree that their understanding of particle kinematics was increased by using the software and about 3% disagree, while approximately 73% of the students feel that their understanding of crank/slider kinematics was increased by using the software and roughly 12% disagree.

A majority of the students think that the software is effective in both cases. However, the students' increase in understanding of the particle kinematics was perceived to be significantly greater than their increase in understanding of the crank/slider kinematics.

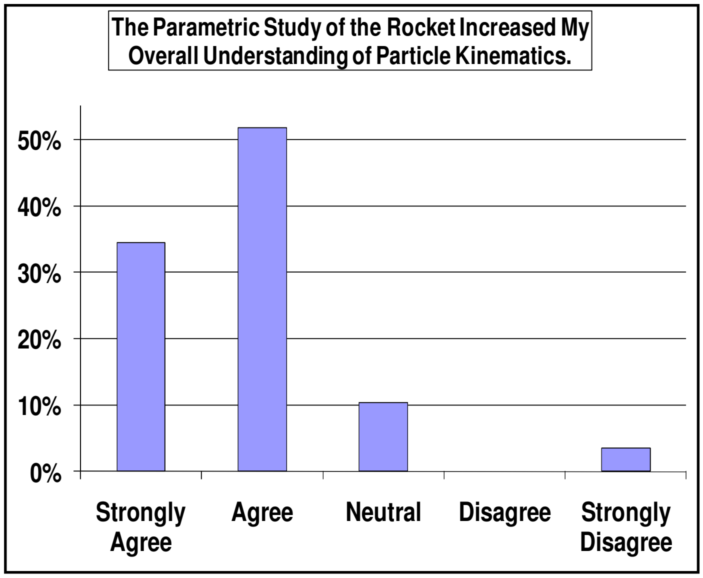


Figure 11 Students' Understanding of Particle Kinematics
Was Increased by the Parametric Studies

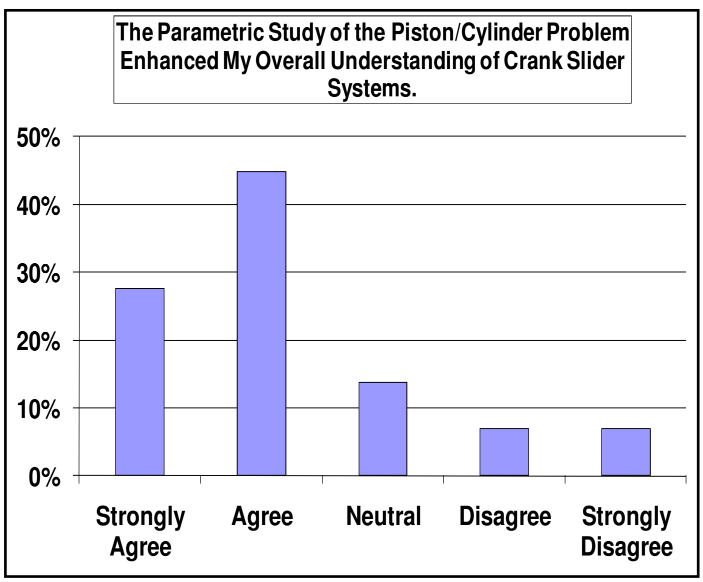


Figure 12 Students' Understanding of the Crank/Slider
Systems Was Increased by the Parametric Studies

This difference is probably due to the variation in complexity of the two problem types. Crank/slider kinematics is quite more complicated than particle kinematics. It is the authors' opinion that parametric studies can only improve the students understanding of the basic material. If the student does not understand the material beforehand, he or she will not appreciate any parametric trends of the data.

6.2 Survey Results: Ease of Use of the Software to Create Parametric Studies

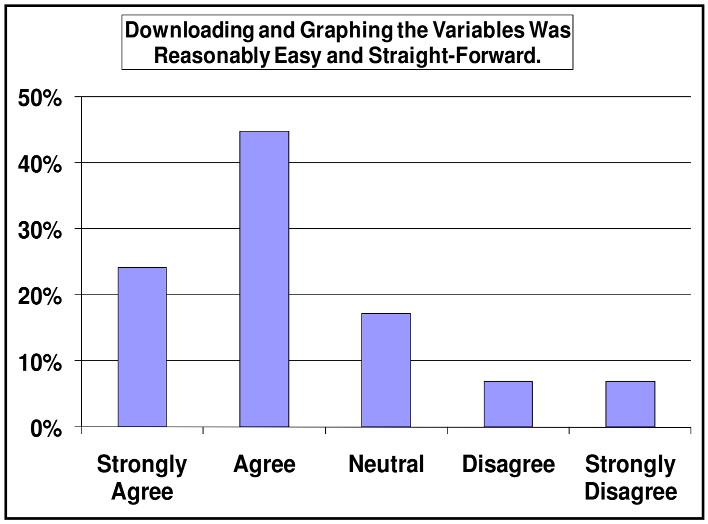


Figure 13 Downloading and Graphing was Easy and Straight-Forward

An essential advantage of the animation software is its ease of use. In previous studies, over 95% of students found that the animation software is easy to use[1,2,3,4,5,6]. Accordingly, the process of creating parametric studies has been held to a high criterion. The target level of software ease is 85%.

Approximately 69% of the students agree that the downloading and graphing of the variables is straightforward, while about 11% do not agree (Figure 13). The 69% figure is below the target level of 85% and will be addressed. Some of the areas of improvement of the software have been stated by the students. They are:

"…Excel doesn't explain how to enable macros very well, so maybe you can take the initiative to do that in simple terms…"

"The only place I had problems was with the excel graphs. After downloading the graphing template, getting the graphs to appear was not easy for me. Keep in mind that I probaly [sic] have below average computer skills. Excel is like black magic to me, never could figure it out."

In order to increase the ease of generating parametric studies, videos will be embedded in the animations website that will show step-by-step instructions on how to create the graphs. This will be done via Adobe Captivate© software, which dynamically captures screen activity and may be played on the Adobe Flash© player.

6.3 Survey Results: General Opinions

It is the author's opinion that animations and related features are useful teaching tools that will be used more frequently in the classroom. Questions were asked of the students in order to validate this opinion. The results of this survey were in agreement with those found in previous publications[1,2,3,4,5,6].

1) Virtually all students surveyed are visual learners.
2) The vast majority of students believe the animations enhance the student's overall understanding of *Dynamics* principles.
3) Students believe that linking a homework problem or case study to an animation is effective.
4) Students recommend the animation program to instructors who teach *Dynamics*.

7. Additional Software Features

The animation program has the following additional features available, some of which have been explained in previous papers:

1) Sound effects can be incorporated into the program.
2) The problem statement can contain pseudo-random variables, which are seamlessly passed into the animation[3,4].
3) The user can add or subtract various OUTPUT variables, as desired[1,2].

8. Conclusions

1) Parametric studies are now available as part of the animation program, which will be an integral part of the WileyPLUS platform (John Wiley and Sons, Inc.).
2) Students were successful in explaining the acceleration and velocity of a particle. However, they did not meet the targeted expectation of explaining the particle's position as a function of time. Corrective action for future assignments has been identified in this paper and will be implemented in upcoming coursework.
3) Most students' understanding of particle and crank/slider kinematics was enhanced by generating the parametric studies and analyzing them.
4) The process of downloading and graphing of the parametric studies is reasonably straightforward, but the software will be enhanced with additional instructional aides in order to make the procedure more clear-cut.

9. Future Considerations

1) Studies will be conducted with peer institutions and/or separate groups of students that objectively measure the student's performance with and without the use of the software.
2) At the request of a Kettering University student, a "legend" key will be added to the blank area just to the right of the animation (under the "ZOOM" button). This legend will give the user quick hints regarding the software functionality.
3) "Hints" will be added to the problem statement. These hints will be intended to help the student solve the problem. The professor will have the ability to limit the access to these hints, if desired.

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