

## Interactive Multimedia for Engineering Dynamics

Kurt Gramoll  
Georgia Institute of Technology

Rob Abbanat  
Engineered Multimedia

### Abstract

This paper describes the development, implementation, and functionality of an interactive multimedia program designed to assist students in learning basic concepts in engineering dynamics. The program, currently called MED (Multimedia for Engineering Dynamics), covers the same material addressed in a typical, undergraduate dynamics book, and is designed to serve as a third source—in addition to lectures and textbooks—from which engineering students can learn about dynamics.

This program, which is example based, is comprised of 46 example problems, each of which illustrates a specific concept in dynamics. Each example is presented in four parts: Introduction, Theory, Solution, and Simulation. The first three parts, which incorporate graphics, audio components, animations, videos, and hypertext, introduce a problem to the user, present specific concepts in dynamics that are required to solve the problem, and apply the concepts to solve the problem. The fourth part allows the student to experiment with a computer generated simulation of the problem, which is implemented using a player version of Working Model® by Knowledge Revolution. Reference material for engineering dynamics is also accessible via interactive, on-line appendices.

MED will be commercially distributed on CD-ROM by Addison-Wesley Interactive (AWI). In order to make MED accessible to the widest variety of engineering students, the CD will be in a form that is compatible with both Windows and Macintosh platforms.

### Introduction

Over the last four to five years, an increase in the graphics capabilities of personal computers has led to a style of presentation that was not previously possible. With the advent of multimedia technologies, computers can convey—via objects such as pictures, sound, animations, videos, and simulations—concepts that are otherwise difficult to express [1]. Although the term ‘multimedia’ could be applied to many learning techniques (even books with text, graphs, pictures and equations are technically a ‘multi-media’) it is generally used today to identify computer based technologies that incorporate animations, videos, simulations, sound, graphics,

photos, and text, and provide nonlinear navigation and interactivity. Only recently, however, has the speed and memory capacity of computers been great enough to allow for the integration of different media into an interactive form.

The use of computers in education has traditionally followed one of two approaches: a) presentation of the theoretical and discursive aspects of knowledge, where students are provided with a database of information to explore as reference material, or b) provisions for experiential simulations of real-world situations [1]. Previous efforts to integrate multiple media into a computer based program have generally focused on the development of computer based simulations, which follows the latter approach mentioned above. Here, the emphasis is on experience. Learning by doing is a philosophy that has endured since the days when engineers were trained as apprentices, and experience was gained in laboratories and shops. With computer-based simulation, the media and delivery method has changed, but the approach is still the same.

One advantage of computer-based simulations is that they allow the student to experiment with a larger range of problems and situations, and they provide more immediate feedback. In addition, computer-based simulations are generally far more economical than laboratory or shop experience. However, hands on experience is still invaluable for a comprehensive education. Ideally, a student should be exposed to a combination of both mechanical and computer-based simulation.

Some early developments, such as those by Kraige, et al. [2], include effective dynamic simulations which allowed students to experiment with ‘what-if’ design scenarios. Other examples include the BEST program by Flori [3] at the University of Missouri at Rolla. This program presents an impressive set of simulations that cover the major topics addressed in a typical undergraduate dynamics course. Each problem provides the user with the ability to input new values for various parameters, and provides for some control over the form of the output, such as vector types. Other simulation programs have also been developed in university settings [4, 5]. Computer-based simulations are even finding their way into professional engineering. Simulation programs, such as Working Model by Knowledge Revolution [6], are common

in the work place to help speed up the design and manufacturing of mechanical systems.

Multimedia, however, is more than just simulations. A multimedia program for engineering may also include graphics, animations, videos, sound, equations and text. Here, the focus is on content; the computer uses these various components of multimedia to present the student with information on a particular topic in engineering. Unlike other sources of information, however, the computer enables the student to navigate through the material in a fashion that is both non-linear, and highly interactive. By "non-linear" it is meant that the student does not have to trudge through the material in a pre-defined path, but can easily move from one topic to another for cross-referencing or when new information is needed. Previous work in this area included the Pluto [7] and Athena [8] programs of the 1980's. They were impressive in quality of their content objects and the breadth of topics covered, but individual topics weren't covered in great depth, thus making it difficult to use in a specific engineering course. In addition, Pluto and Athena did not incorporate simulations.

Up until now, the two uses for computers in education as described above have remained essentially separate [1]. The result is that students sometimes learn theory they can't transfer to real situations, or have experiences that they can't explain or generalize. With MED, the focus has been to integrate computer-based simulations with graphics, audio components, animations, videos, and hypertext, into a self-contained program that will assist students taking a first-year undergraduate dynamics course. The goal: to embody the theoretical and discursive aspects of dynamics with experiential simulations in the same program. The result for the students will (hopefully) be a more efficient learning process and a deeper understanding of dynamics.

With many applications in the field of education, multimedia programs are particularly well suited for implementation in engineering education. Many topics in engineering are abstract and difficult to visualize, such as work and energy. Others are difficult to visualize due to the nature of the dynamics involved, such as the kinematics of rigid bodies. Concepts are usually taught by developing abstract mathematical models and fundamental physical principles, and then employing them to solve practical problems. Connecting abstract models with practical situations and presenting time as an independent variable are troublesome facets in the engineering curriculum, especially at the introductory level. Multimedia, with the ability to integrate motion into the presentation, is ideal for addressing the difficult topics in dynamics such as kinetics of particles (force, acceleration, work, energy, impulse, and momentum), the kinematics of rigid bodies in two and three dimensions, and vibrations.

### **Multimedia for Engineering Dynamics (MED) Program**

MED is intended to serve as a supplement to textbooks and lectures for students taking a first-year undergraduate dynamics course. It is *in no way* intended to

replace the textbook or lectures. The program, designed for distribution on CD-ROM, is self contained and fully integrated so that students have full control to navigate through the content and explore the simulations. Because the text and graphics are designed for use by an individual with a personal computer, the program is not intended to function as an in-class lecture aid for the professor, although it could be used in that manner.

The program is composed of 46 problems, each illustrating a specific concept in dynamics. The examples are grouped according to topic in a fashion that is similar to that of a typical dynamics textbook. In addition, there are four on-line, interactive appendices that contain important reference material. The program embodies a user-friendly interface with two levels. The first level (see Fig. 1) contains the Main Menu which lists all the topics and appendices, as well as the examples and concepts covered in each topic. The topics and appendices include:

- |  |                                   |
|--|-----------------------------------|
| 1. Particle:                             | General Motion                    |
| 2.                                       | Force and Acceleration            |
| 3.                                       | Energy Methods                    |
| 4.                                       | Momentum and Impulse              |
| 5. Rigid Body:                           | General Motion                    |
| 6.                                       | Force and Acceleration            |
| 7.                                       | Energy Methods                    |
| 8.                                       | Momentum and Impulse              |
| 9. Three Dimensional Motion a Rigid Body |                                   |
| 10. Vibrations                           |                                   |
| Appendix A:                              | Basic Equations in Dynamics       |
| Appendix B:                              | Section Properties / Inertia      |
| Appendix C:                              | Units and Conversion Factors      |
| Appendix D:                              | Fundamental Topics of Mathematics |

The program covers all the major topics in a typical dynamics textbook, but it does not cover every topic in every book. To assist the user, the menu bars at the top of the screen can be used to cross reference any one of the six most popular dynamics books to the examples and concepts that are addressed in the program. For instance, if *Vector Mechanics for Engineers* by Beer and Johnson is the book that is used in the course, the student can choose 'Beer and Johnson' in the 'Book' menu, and the 'Section' (or chapter) pull down menu will be organized for that particular book. This enables the students to access the content in MED in a manner that is consistent with whatever book that they may be using.

After choosing a particular topic, a second menu appears which lists the problems and concepts that are illustrated under that topic (Fig. 2). From here, the student can select any of the individual problems, which invokes the introductory screen of that problem. The introductory screen presents a detailed problem related to engineering, and the student is challenged to solve the problem.

### **Presentation of a Typical Problem**

Each problem is designed to illustrate one particular concept, but the problem is examined in detail and all theory required to solve the problem, as well as the solution itself, is presented. Each problem is split into four areas: Introduction, Theory, Solution, and Simulation. Once the user has left the menu areas, the interface provides navigation buttons which allow the student to access each of the four areas at any time.

Each of the first three areas (Introduction, Theory, Solution) makes extensive use of animations, sound, videos, graphics, text, and equations to present the material. The fourth area is a fully interactive simulation of the problem that is presented in the first three areas. At any time, the student can invoke the simulation for an experiential representation of the problem. It should be noted that the student is *not* required to make choices or answer questions before moving from one area to another. MED is not intended to serve as a tutorial where the progress of the student is monitored or controlled. Figures 3-7 and 8-10 show sample screens from two problems

### Introduction

Having selected a particular problem and concept from the menu area (Fig. 2), MED moves to the introductory screen for that problem (Fig. 3). Here, the problem is stated, the student is asked to solve the problem, and a strategy, which involves the particular concept to be illustrated by that problem, is suggested. In order to make the problems more captivating and substantial, they are generally realistic, and the student is encouraged to approach the problem as if he or she really had to solve it. For example, Problem 4.2, 'The Porsche Car Jump', begins with a stunt man driving a Porsche off a barge onto a dock, only to find that the barge moves *backward* away from the dock as the Porsche accelerates *forward* towards the edge of the barge. The stunt man wants to know why this is happening, and the student is required to find the minimum speed at which the Porsche must leave the barge in order for it to land on the dock. The concept of Conservation of Linear Momentum is suggested for the theoretical approach to the solution. The specific details of the problem (mass of the Porsche, length of the barge, etc.) are presented, and an animation is available to help the student visualize the problem. The Introduction area generally occupies no more than one screen.

### Theory

After the problem is introduced, the user then can review the theory needed to solve the problem. In the Theory area, a specific concept in dynamics is presented in sufficient detail to solve the problem. For 'The Porsche-Barge Jump' problem, the Theory area (Fig. 4) illustrates the concept of Conservation of Linear Momentum with derivations and equations, supported by animations. The Theory area generally ranges from one to three screens, and makes extensive use of animation and sound to help provide an intuitive understanding of difficult concepts. The scope of the theory is complete, but the presentation is generally not as detailed as that found in a textbook. Emphasis is placed on presenting the theory in a concise and easy to use form so that the student can quickly grasp its application to the problem.

### Solution

The Solution area (Fig. 5-6) applies the material presented in the Theory area to the problem presented in the Introduction area. Each part of the solution process is illustrated and key facets are animated to help the student better understand the application of the theory. The solution area generally ranges from 1 to 3 screens in length.

### Simulation

At anytime during the problem, the student can invoke a simulation of the problem. A Working Model file, specifically designed to simulate the problem as closely as possible, provides the opportunity for students to modify

parameters, such as mass, velocity, friction, etc. In order to isolate the behavior that exemplifies the concept that is being illustrated in that particular problem, the student is generally only allowed to modify one or two parameters. A Working Model Player is included with the program so that the student does not need to purchase a copy of Working Model to play the simulation. However, if a complete version of Working Model is available, the file could be opened and further modified.

## **Appendixes**

In addition to the problems, four appendixes are available at any time, as listed above. Appendix A reviews all major equations used in an introductory dynamics course. There are pop-up explanations and/or derivations for most of the equations. Appendix B is an electronic handbook/reference tool that assists the student in calculating the moment of inertia of common objects and cross sections. The user can also input his or her own values for cross section dimensions, and the program will calculate the moment of inertia about specific coordinate axes. Appendix C lists all the basic units used in both the SI and US systems, as well as conversion factors. Appendix D gives a listing of the major mathematical equations that could be useful for solving problems in dynamics.

## **Development Process**

Previous multimedia programs [9-11] have been developed by the students and faculty of the Aerospace Multimedia Lab at the Georgia Institute of Technology. However, due to the complexity and size of the dynamics curriculum, the production of MED required the resources of a commercial publishing company. Other programs were externally funded through National Science Foundation or EduTech of Georgia Tech. Those programs effectively demonstrated the potential of multimedia from a research point of view, but they lacked the professional touch found in commercial multimedia programs. It quickly became apparent that multimedia products that were developed internally at Georgia Tech were difficult to organize and refine to the standards of commercial multimedia products. In addition to high attrition rates, graduate students could only devote a portion of their attention to the project. Graduate students excel with creative tasks, and tend to avoid 'busy work'. For this reason, graduate students working in the Aerospace Multimedia Lab are granted the freedom to explore and experiment with new technologies, but it is difficult to impose development guidelines in this environment. As a result, some impressive multimedia products have been produced at the Aerospace Multimedia Lab, but they lack the depth and elegance of a commercial product.

This project was funded by Addison-Wesley Interactive for the main purpose of developing a high quality multimedia program that could be used at any university. Because this project was funded by AWI from its initial concept through completion, AWI had the ability to help guide the development. This developmental model differs from that of the traditional publishing contract, where only small advances on royalties are provided (if any). A

commercial-level multimedia product requires large up-front funding for equipment, software and labor. Unlike book authors who do not incur substantial direct costs, multimedia authors cannot be expected to pay these costs directly.

### **Delivery of Program**

The program is stored and delivered on a single CD-ROM that is compatible with any basic Macintosh or Windows environment without any special accessories (other than a double speed CD-ROM player). The program is too massive (approximately 500 megabytes) for distribution on traditional floppy disks. This method of delivery has a number of advantages: the storage capacity is sufficiently large, production and distribution is economical, and unauthorized reproduction is prohibitively costly. The major disadvantage is that the data transfer rate of CD-ROM can be slow. However, a well designed CD can circumvent most speed barriers. Furthermore, CD-ROM technology is continuously progressing. With quad speed CD drives already widely available, the problem is rapidly diminishing.

### **Testing and Classroom Use**

In the development of MED, it became apparent that periodic testing of the program would be needed in addition to the classroom use testing. Initially, MED underwent testing for both functionality and proof of concept. In recent months, MED was also reviewed by two professional beta-testers who examined the program for functionality. In essence, their job was to identify "bugs" in the software.

In the fall of 1994, several focus-groups consisting of both professors and students were organized and conducted by Addison-Wesley Interactive. Here, the proof of concept was tested, including areas such as the usability of the interface and the usefulness of the MED when integrated into a curriculum. The results of these focus-groups were overwhelmingly positive (surpassing our expectations). Some professors went so far as to indicate that they would require MED for their dynamics class. Students said that they would purchase the program voluntarily. They also provided numerous suggestions to improve the program for students' learning. Focus groups are limited in the scope of information that they can provide. To get a more complete analysis of the usefulness of MED when integrated into a curriculum, it is necessary to perform controlled experiments in a classroom setting.

The second testing phase used MED in an actual classroom setting. During the 1995 Spring quarter at Georgia Tech, the MED program was integrated into one of the basic Dynamics course that is required of all engineering students. The course was taught by the author who introduced MED as additional learning tool for the students. MED was not designed to replace the book or lectures, but to provide an extra learning resource. The students were told to use the program outside of the classroom. MED was not designed to be a lecture tool and thus not used during lectures. To encourage the students to use the program, they were told that test questions could come from the MED program. At the time of writing, the quarter still had not been complete, and

thus the final results are not known at this time if MED actually contributed educating the students more efficiently. The final results of the classroom testing will be presented at the conference which will include a survey and the test results. However, initial response to the program has been good. The students have enjoyed using the program and have mentioned that they seem to have a better understanding of the physical concepts of Dynamics. It is planned to compare the student test scores with other Dynamic courses that have been taught by the same instructor.

### **Summary**

Multimedia has potential to play an increasingly important role in education, especially engineering education. The goal of the MED project is the implementation of recent multimedia technologies in the field of dynamics. The final product of this project is a self-contained, multimedia program that assists college students who are taking a first-year course in dynamics. The program is self contained and covers all the major concepts and topics addressed in a typical dynamics textbook. With MED we hope to provide students with a more efficient means of understanding dynamics.

### **Acknowledgments**

The authors would like to acknowledge Denise Descoteaux and Doug Stein of Addison-Wesley Interactive for their assistance and support in the development of this product.

### **Reference**

1. Abbanat, R.F. "Multimedia in Engineering: Review and Analysis of the Georgia Tech Aerospace Engineering Multimedia Lab," Masters' Special Project Report, Aerospace Eng., Georgia Institute of Technology, 1994.
2. Kraige, L.G., P.R. Gagnon, and T. Lin, "Motion Simulation Software for Personal Computer Use in Undergraduate Mechanics Courses," ASEE 1985 Conf. Proc. pp. 1569-1574.
3. Cutchins, M.A. and J.E. Cochran, "Dynamic Windows," 6th Annual TBBEC Conf. Proc., Gatlinburg, TN, Nov, 1994.
4. Flori, Ralph, Mary A. Koen, and D.B. Oglesby, "Classroom Experiences with "Best" Dynamics ("Basic Engineering Software for Teaching" Dynamics ASEE 1994 Conf. Proc., Edmonton, Canada, June, pp. 959-968.
5. Gramoll, K.C., "Interactive Beam Analysis Program for Engineering Education," Computer Applications in Engineering Education, Vol 1, No. 6, 1994.
6. Working Model, Knowledge Revolution, San Meida, CA.
7. Bitzer, D.L., "The PLATO Project at the University of Illinois," *Engineering Education*, 77(3), pp. 175-180.
8. Hodges, Matthew and Rusel Sasnett, *Multimedia Computing, Case Studies from the MIT Project Athena*, Addison-Wesley, Reading, MA, 1990.
9. Yusuf, I., K. Slater and K.C. Gramoll, "Using 'GT Vibrations' in System Dynamics and Vibrations

Courses," ASEE 1994 Conf. Proc., Edmonton, Canada, June, pp. 952-958.

10. Yusuf, I., K. Slater and K.C. Gramoll, "Case Based Multimedia in Engineering Education," ASEE 1995 Conf. Proc., Anaheim, CA June.
11. Gramoll, K.C., "Multimedia Based Education for Engineering Design," 1994 ASME Design Theory and Methodology Conf., Minneapolis, MN, Sept. 1994.



Fig. 1. Basic Topic Menu.

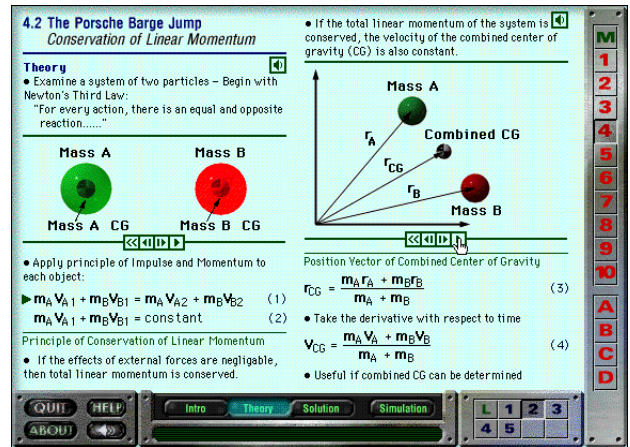


Fig. 4. Typical Theory Segment.

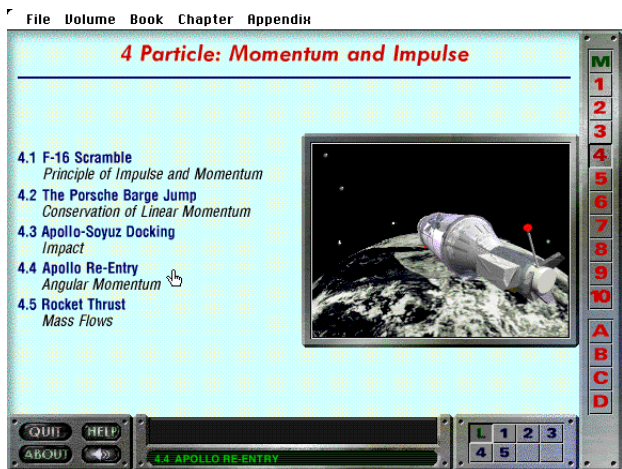


Fig. 2. Section Menu

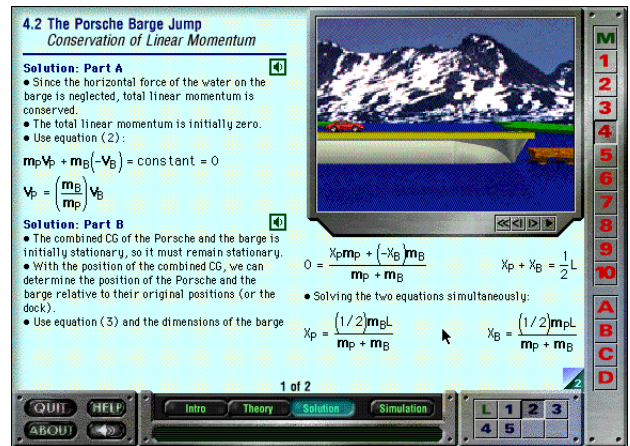


Fig. 5. Typical Solution Segment, Screen 1/2.

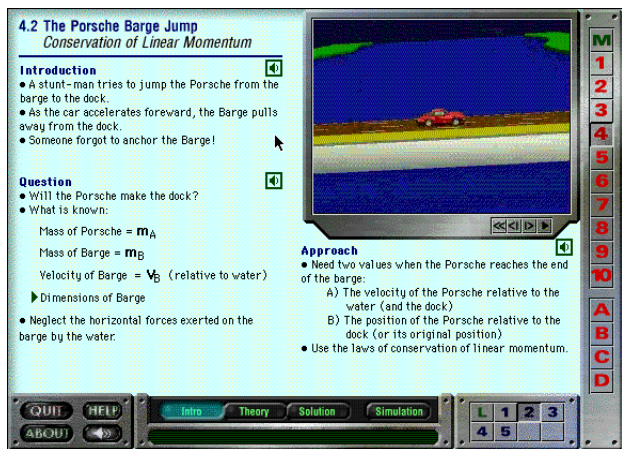


Fig. 3. Typical Introduction Segment.

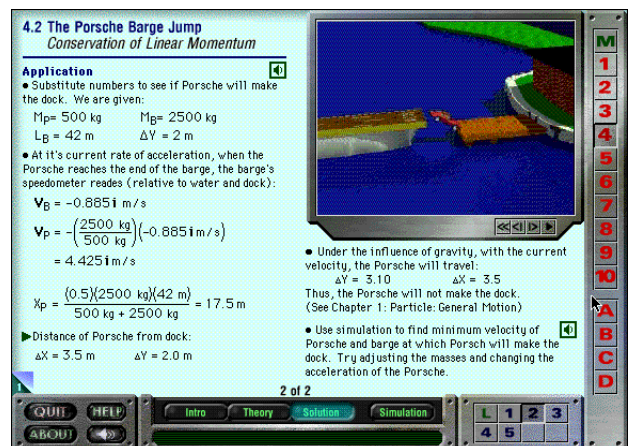


Fig. 6. Typical Solution Segment, Screen 2/2.

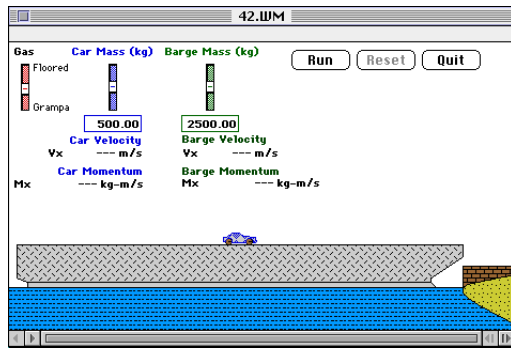


Fig. 7. Working Model Simulation Window.

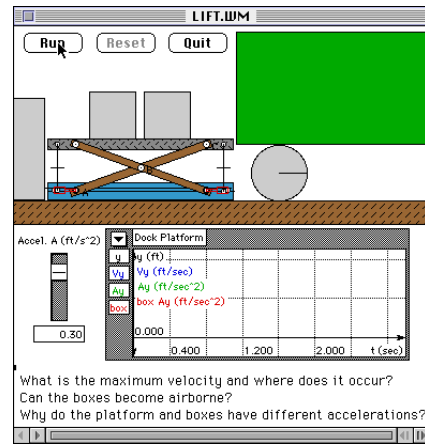


Fig. 10. Working Model Simulation

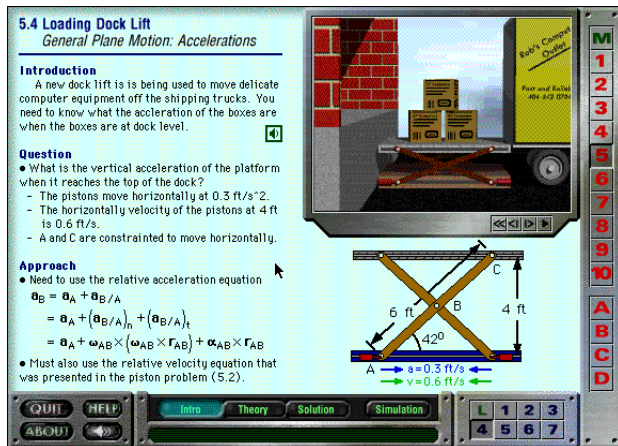


Fig. 8. Introduction to Dock Lift

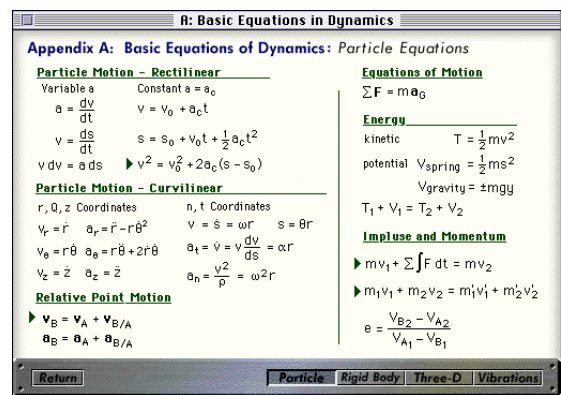


Fig. 11. Appendix A, Equations.

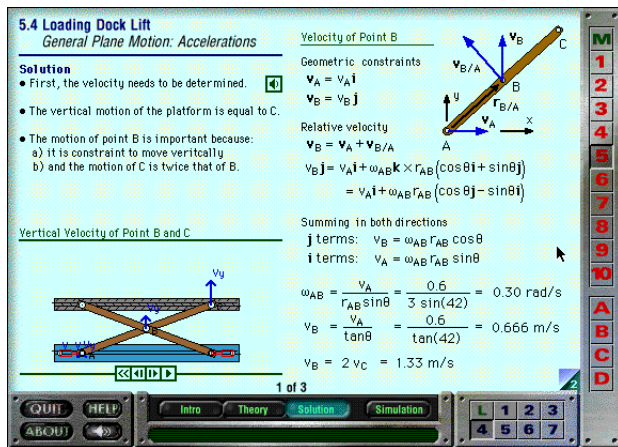


Fig. 9. Solution to Dock Lift

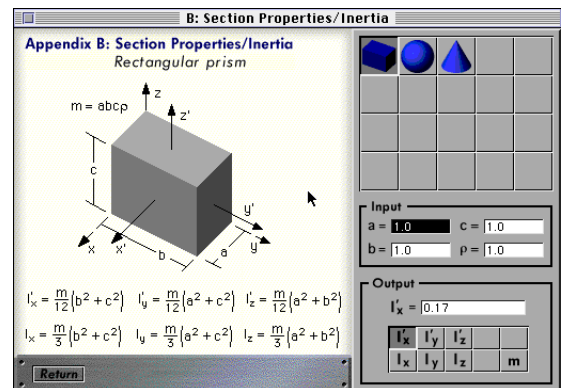


Fig. 12. Appendix B, Properties.

## **KURT GRAMOLL**

Dr. Kurt Gramoll is currently an Assistant Professor in the School of Aerospace Engineering at Georgia Institute of Technology. He graduated from the University of Utah with a BS in Civil and a MS in Mechanical Engineering. Later, after working at Thiokol, Inc., he received his Ph.D. in Engineering Science at Virginia Tech in 1988. Since then he has taught at Memphis State University and worked at the Japanese National Institute for Space and Astronautical Science. His technical research work involves filament winding of composite structures and fluid-structure interaction. He is also heavily involved educational research, particularly in the development and use of multimedia programs in engineering.

## **ROB ABBANAT**

Rob Abbanat graduated from Boston College in 1992 with a BS in physics and a minor in computer science. In 1994 he earned an MS in aerospace engineering from Georgia Tech. While studying at Georgia Tech, Mr. Abbanat held a position as a graduate research assistant in the Aerospace Engineering Multimedia Lab, where he researched the application of multimedia technologies in the field of engineering education. He is now developing multimedia products for engineering at a professional level.