Incorporating Web-Based Homework Problems in Engineering Dynamics

Ralph E. Flori, David B. Oglesby, Timothy A. Philpot, Nancy Hubing, Richard H. Hall, Vikas Yellamraju

University of Missouri-Rolla

Abstract

We are involved in a project funded by the Department of Education (FIPSE) which focuses on developing interactive software to improve the teaching and learning of engineering statics, dynamics, and mechanics of materials. This paper presents an overview of this project, discusses its objectives, and focuses on one particular aspect of the project—the use of web-based homework problems as assessment tools to evaluate student learning. The overall project includes creating, for all three engineering mechanics courses, the following web-based learning tools: (a) Animated theory modules, using Macromedia's Flash development software, which display basic theory and example problems in an engaging, clear, and concise way; (b) Conceptual quizzes to evaluate student understanding of the theory; (c) Web-based homework problems to assess students' quantitative skills; (d) Other media elements, including streaming video mini-lectures over key topics, and video of real mechanisms and examples. The paper will give examples of web-based homework used in dynamics, discuss aspects of creating and using these, and give some results of student feedback from using these problems.

I. Introduction: Mechanics Software Development Efforts at UM-Rolla

The faculty of the Basic Engineering Department at the University of Missouri-Rolla (UMR) have been involved in developing educational software for nearly a decade. The first project, BEST (Basic Engineering Software for Teaching) Dynamics, led by Dr. Ralph Flori, consisted of forty simulations of kinematics and kinetics problems that enabled learners to vary inputs to test and observe a wide variety of configurations and behavior (1). Dr. David Oglesby and Ed Carney created BEST Statics and On Call Instruction (OCI) for Statics, which were subsequently combined to create Statics On-Line, an interactive multimedia collection of problems and lessons which forms an integral part of the statics course currently taught at UMR (2). Dr. Tim Philpot, while at Murray State University, created MD-Solids, used to enhance teaching of Mechanics of Materials. Since joining the faculty at UMR in 1999, he has continued to expand and refine this work (3). Dr. Nancy Hubing has recently created, using Flash®, some very effective modules for teaching and learning topics in Statics. (4)

These UMR faculty members (Philpot, Oglesby, Hubing and Flori, plus Dr. Richard Hall as an assessment expert) are now collaborating on a three-year project funded by FIPSE for creating a web-based system for teaching and learning statics, dynamics, and mechanics of materials. For each course, the materials being developed will be comprised of four major components, displayed in Figure 1 below.

Multimedia Teaching Courseware. These products will be named BEST Statics, BEST Dynamics, and BEST Mechanics of Materials. (Collectively, the three multimedia products are referred to as the BEST Engineering Mechanics Suite.)

A quiz administration system termed **Concept Checkpoints.**

A homework administration system termed **Homework Manager**.

Active learning activities for each course termed **Hands-on Activities**.

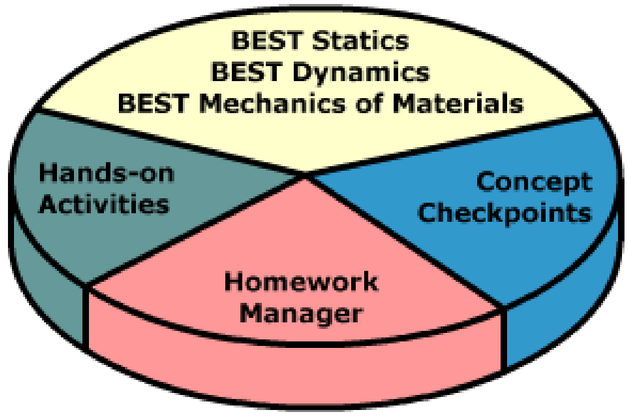


Figure 1: - Major Components of the New Teaching System

This project has just completed its first year of funding. The aim of the development effort is to create products that are easy-to-use, active and interactive, visually appealing, adaptable, transportable, universal, compelling, and state-of-the-art.

One key aspect of this new research is to study in-depth the optimal ways of incorporating these software packages into the total educational process. The engineering education landscape is littered with educational software packages that are not comprehensive. Typically these do not provide the extensive information, problem-solving support, and built-in quizzing and homework assessment that engineering students need. Incomplete software like this serve as add-on's to a class, requiring teachers to continue doing everything he/she is currently doing, plus assigning the software and trying to bring it into the class. This is why the use of software has not "caught on" to the degree that many thought it would.

These software products we are developing will be comprehensive, covering virtually an entire course, delivering much of the content of the course (particularly the remedial, basic, and intermediate level content). We plan to use these to replace some classroom time. For example, a three credit hour class may meet only once or twice per week. Prior to class meetings, students will be assigned to complete certain lessons in the software each week. They will take on-line (web delivered) quizzes over these lessons to ensure their mastery of the concepts. Multiple retakes of the randomized quizzes (random quiz questions, each with random numbers) are permitted, and in fact, encouraged. Many students, when studying, will likely take the quiz first to discover what they don't know; then they will loop back for some study, and return to the quiz. The quizzes, when scored, will suggest the basis for the student's mistake and point the student to the appropriate theory section that must be understood to successfully complete the quiz. This quiz-theory-quiz-theory loop will probably be repeated several times by each student. The software will be organized to easily support multiple learning paths through the material.

The use of these learning materials will transform the relationship between the teacher and the learner. Teachers will be able to rely on the software to deliver virtually all of the remedial, basic, and intermediate level content of the course. During class meetings, therefore, the teachers will do what they do best. They will answer questions, ask questions of the students, and generally investigate topics involving "higher order" thinking skills not as easily supported by the software. Teachers will collect and grade less homework because the on-line quizzes will replace some of these. (There still will be traditional written hour exams and final exams comprising most of the students' grades to ensure that students are not relying on a friend's help with the on-line quizzes.)

We believe that this comprehensive, high quality software approach, plus hands-on activities, targeting the engineering service courses, is an educationally sound and practical approach that has a high degree of likelihood to become "systemic", that is, to be implemented elsewhere. There are many reasons for our optimism. Many engineering schools cannot totally restructure their curriculum. This wreaks havoc on transfer students and coop students, and casts faculty into new and unchartered roles. Our approach is aimed at significantly improving the learning outcomes in the core engineering courses. Developing these courses is resource-intensive, but once developed, it should be possible to offer these courses with no greater and perhaps less faculty commitment than traditional lecture-based courses. And the faculty time that is needed is spent interacting at a higher level, so faculty should feel that progress is being accomplished in their course. This approach, effecting a shift of responsibility of learning from the faculty member to the student, should appeal to the many engineering departments who have difficulty recruiting their best faculty members to teach the large enrollment, service courses.

II. On-Line Homework Problems in Dynamics

The focus of this paper is to give a progress report on developing and using a web-based homework system in a dynamics class. Performing some kind of assessment coupled with instruction is crucial to closing the loop of the instruction/learning cycle. As educators know well, students focus much more clearly when they know they will have a quiz or exam over the material. As instructors, we need feedback as to how our students are performing—what they know and don't know. Hand graded homework, quizzes and exams are the best way to obtain this information, but due to lack of time for making up and grading these, only a limited number can realistically be employed. On-line, web-delivered homework and quizzes seems to be an excellent vehicle for frequent and regular assessment of student knowledge and performance. It shouldn't replace hand-graded work, but it is a valuable additional tool. Other mechanics faculty, including Dr. Kurt Gramoll (5) and Dr. Ing-Chang Jong are also working on homework and quizzing tools.

The homework management system described here was originally created by Mr. Ed Carney and Dr. David Oglesby at UM-Rolla (2). They called it OCI, short for "On-Call Instruction." We are in the process of re-coding the CGI scripts, and we will shift to this new system when it is ready, but this older system was used here for the process of delivering the newly created dynamics problems and evaluating their use in the classroom.

During the fall 2001 semester, Drs. David Oglesby and Ralph Flori taught a two-credit hour engineering dynamics course at UM-Rolla, and incorporated on-line (OCI) homework problems as a small part of the class. Students handed in written homework (worth 10 percent of their overall grade), worked twelve on-line (OCI) problems (worth 5 percent total), took four exams (worth 15 percent each), and took a final exam (worth 25 percent of their overall grade). The classes were taught in a conventional, lecture format. Dr. Flori taught two sections of approximately thirty students each, and Dr. Oglesby taught one section of approximately 16 students.

The students were asked to work approximately three OCI problems between each of the four exams. The due dates of the OCI problems were set approximately a week after a topic was taught, to give students time to work their regular homework over the topic, to practice the OCI problem, and to ask questions about it before actually having to submit their answers. Each student had a unique account number and password. They logged onto the system (a secure server) either from home or on-campus, in order to view the current problem. The system allows them, and we encouraged them, to work a "guest" case of the problem. They then can compare their answers for the "guest" case to the given answers to determine if their procedure is correct. If not, they have time to talk to their teacher about the problem. Once they decide they have the right procedure, they then log on to get a unique set of numbers that are uniquely theirs. They have two chances to submit their answers to this case. Each problem has a different number of solution "boxes." The system compares their entries for each box with a database value. Each answer is either right or wrong. The student then is assigned a grade out of five, based on the number of correctly entered answers for that problem. For problems with one answer, they get either a zero or five. For problems with two answer blanks, they get zero, 2.5, or 5. Answers must be entered with accuracy within 0.3 percent of the correct answer. Signs must be correct. Students have two chances prior to the due date to get full credit for a problem. We found midnight on Thursdays to be a good due date; we also found that a consistent due date helped students remember it. For up to three days after the due, students can work the problem for half credit.

Students' grades on each problem are recorded into a gradebook. The students can view their own grades and total points, while the instructor can view the entire gradebook. If a student has special circumstances on a problem, and is able to present a believable case to the instructor, the instructor can log into the gradebook and change a grade, if necessary.

Figures 2 through 6, in the appendix of this paper, give examples of five out of the twelve problems assigned to students during the fall 2001 semester. These were created by R. Flori. Figure 2 is an idealized projectile problem involving a batter hitting a baseball down the right field line and striking a foul pole. Figure 3 is a four bar slider mechanism. Figure 4 is a fixed axis rotation problem. Figure 5 is a particle F=ma problem. Figure 6 is a particle work-energy problem involving work due to elevation change and due to energy stored in a spring. Each problem, due to the nature of the problem, involved a different number of answer blanks. For problems like this, special care is necessary to ensure that sign conventions are clear. If we ask for a vector quantity, provision must be made for students to enter magnitude and direction. Numbers must be large enough so that the differences between answers are seen in the first or second decimal place. Sometimes this involves using units of millimeters, for example, instead of meters, to get answers with larger numbers.

III. Results and Observations

In short, the students did not care for the extra work, but they performed better on the course exams than students have done in past semesters. A summary of their responses to a survey is included in Appendix B. They noted that the OCI problems took more time, they weren't sure the time was worth it, and they were not interested in other classes using these problems. Most of them always chose to work the guest case prior to working their problems, and they wanted more than two tries to get their problems correct. They found the system easy to access both on and off campus. They indicated that they primarily worked on their problems alone, with minimal help. (We don't mind them helping one another, as long as they are not simply copying from one another.) They appreciated their teacher's help with their problems.

From a faculty perspective, we found that students did noticeably better on exams. As a standard practice in every class, we focus our instruction to ensure students learn to work "standard" problems in the core topics. We use these standard problems in lectures and assign similar problems in their homework. Problems similar to these are often included on the exams. Students who have been in class and worked the homework thoughtfully usually do fairly well on these standard problems. This semester, we did all of this, just as usual, except that we also incorporated these standard, core problems in the OCI problems. We believe that the extra pressure of the OCI problems, working the guest case to ensure they know how to work the problem, getting extra help to correct their mistakes, then working their case, and having to commit to answers, all contributed to better overall knowledge of how to work these core problems. Consequently, students scored an average of approximately five percent higher on exams than they have done in the past on similar exams.

IV. Future Work

We plan to develop hundreds of OCI problems for both dynamics and mechanics of materials. (Dr. Oglesby has already created nearly two hundred statics problems.) We plan to continue to use these in our classes as an additional way to assess student work. We will add to these concept quizzes that focus more on theoretical concepts and short, one-step computational problems.

References

1. Flori, R.E., Koen, M.A., Oglesby, D.B., “Basic Engineering Software for Teaching (“BEST”) Dynamics”, *ASEE Journal of Engineering Education*, 1996: p. 61-67.
2. Oglesby, D.B, Carney, E.R., Prissovsky, M., Crites, D., “Statics On-Line: A Project Review”, *Proceedings of the ASEE Annual Conference*, Seattle, WA, June 1998.
3. Philpot, T. A., “MDSolids: Software to Bridge the Gap Between Lectures and Homework in Mechanics of Materials”, *International Journal of Engineering Education*, Vol. 16, No. 5, 2000.
4. Hubing, N., Oglesby, D.B., “Animating Statics: Flash in the Classroom”, *American Society for Engineering Education Midwest Section Conference*, Manhattan, Kansas, March 2001.
5. Gramoll, K. and Sun, Q., “Internet-Based Distributed Collaborative Environment for Engineering Education and Design”, *Proceedings of the ASEE Annual Conference*, Albuquerque, NM, June 2001.
6. Jong, I-C. and Muyshondt, A., “Interactive Web-Based Tests with Immediate Auto-Feedback via E-mail to the Instructor: Software and Illustration”, *Proceedings of the ASEE Annual Conference*, Albuquerque, NM, June 2001..

Acknowledgement

This work was supported in part by a grant from the United States Department of Education Fund for the Improvement of Post-Secondary Education (FIPSE #P116B000100).

Appendix A: Example Dynamics On-Line Problems, Fall 2001

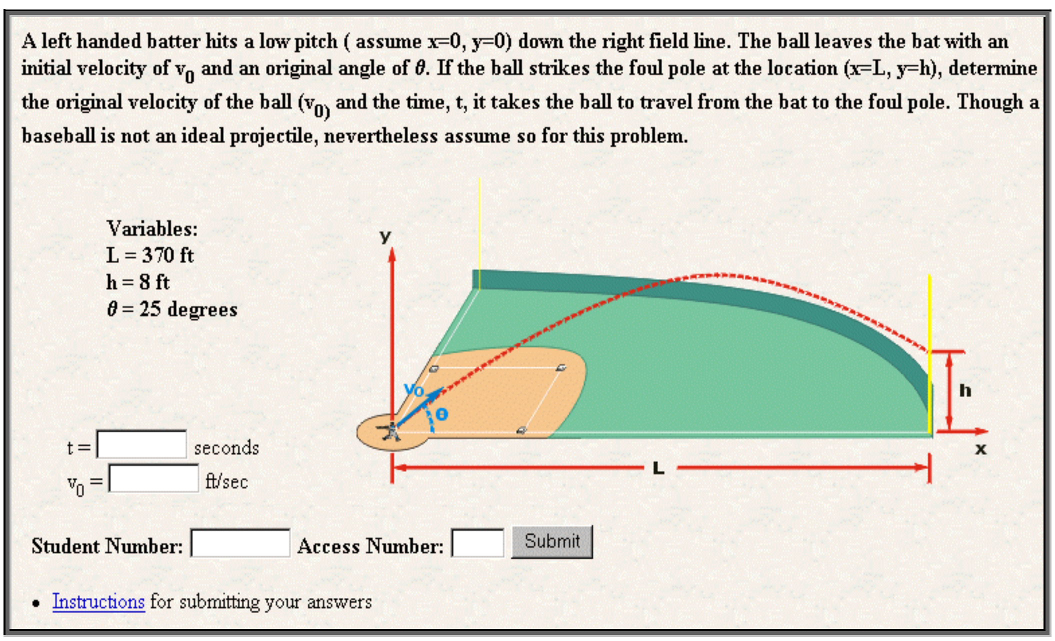
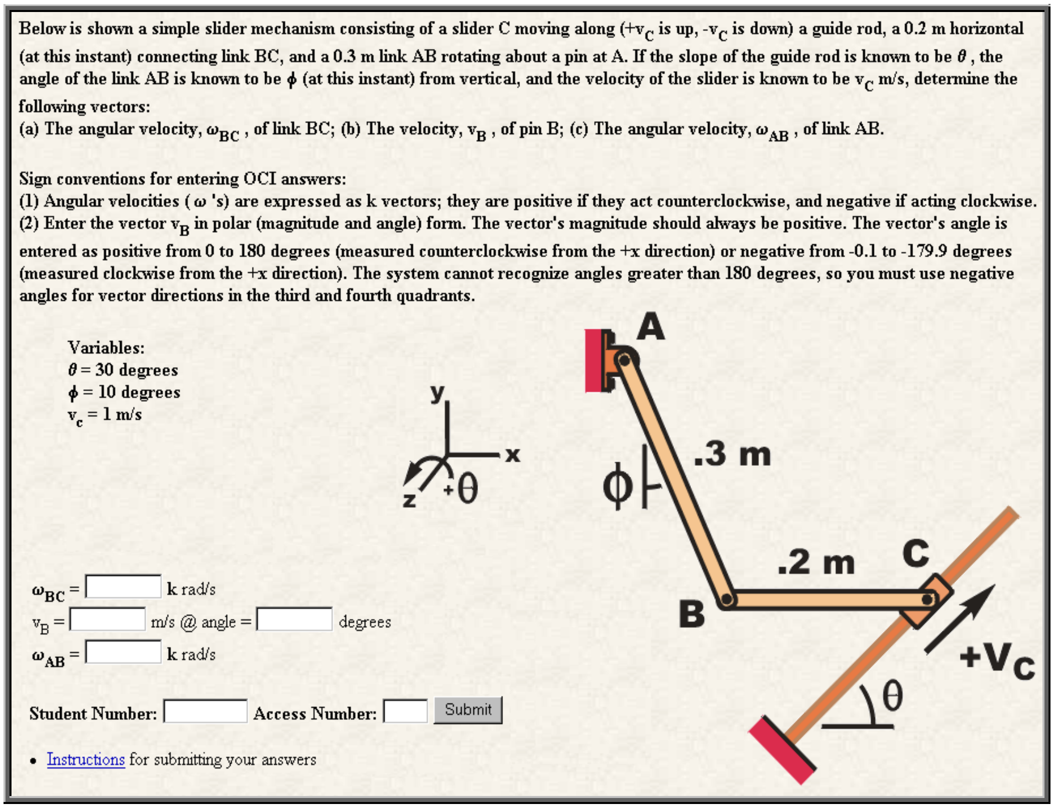


Figure 2: Baseball (Idealized Projectile) Problem, Particle Kinematics



Below is shown a simple slider mechanism consisting of a slider C moving along (+v_C is up, -v_C is down) a guide rod, a 0.2 m horizontal (at this instant) connecting link BC, and a 0.3 m link AB rotating about a pin at A. If the slope of the guide rod is known to be θ , the angle of the link AB is known to be ϕ (at this instant) from vertical, and the velocity of the slider is known to be v_C m/s, determine the following vectors:
(a) The angular velocity, ω_{BC} , of link BC; (b) The velocity, v_B , of pin B; (c) The angular velocity, ω_{AB} , of link AB.

Sign conventions for entering OCI answers:
(1) Angular velocities (ω 's) are expressed as k vectors; they are positive if they act counterclockwise, and negative if acting clockwise.
(2) Enter the vector v_B in polar (magnitude and angle) form. The vector's magnitude should always be positive. The vector's angle is entered as positive from 0 to 180 degrees (measured counterclockwise from the +x direction) or negative from -0.1 to -179.9 degrees (measured clockwise from the +x direction). The system cannot recognize angles greater than 180 degrees, so you must use negative angles for vector directions in the third and fourth quadrants.

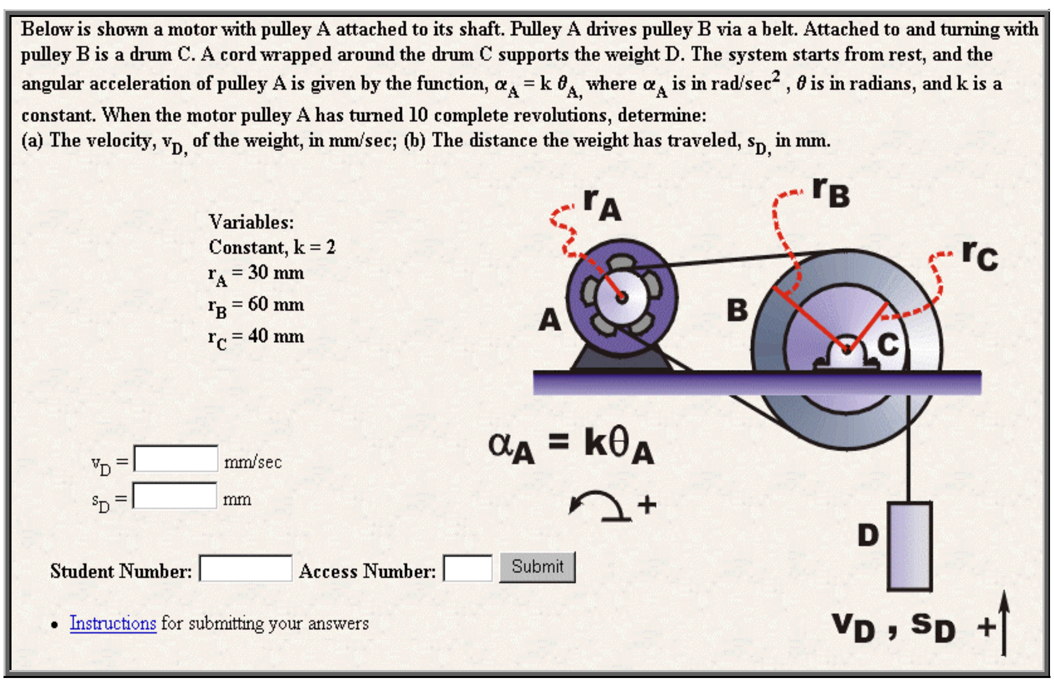
Variables:
θ = 30 degrees
ϕ = 10 degrees
v_c = 1 m/s

ω_{BC} = [ ] k rad/s
v_B = [ ] m/s @ angle = [ ] degrees
ω_{AB} = [ ] k rad/s

Student Number: [ ] Access Number: [ ] Submit

- Instructions for submitting your answers

Figure 3: Four Bar Slider Problem, Rigid Body Kinematics



Below is shown a motor with pulley A attached to its shaft. Pulley A drives pulley B via a belt. Attached to and turning with pulley B is a drum C. A cord wrapped around the drum C supports the weight D. The system starts from rest, and the angular acceleration of pulley A is given by the function, $\alpha_A = k\,\theta_A$, where α_A is in rad/sec^2 , θ is in radians, and k is a constant. When the motor pulley A has turned 10 complete revolutions, determine:
(a) The velocity, v_D, of the weight, in mm/sec; (b) The distance the weight has traveled, s_D, in mm.

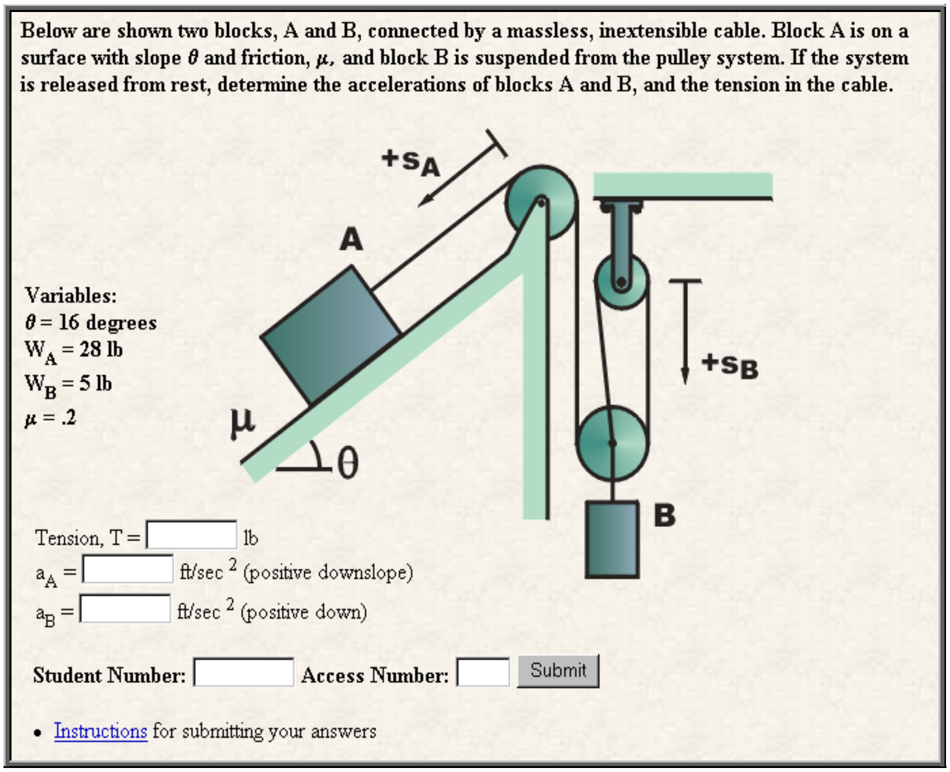
Variables:
Constant, k = 2
r_A = 30 mm
r_B = 60 mm
r_C = 40 mm

v_D = [ ] mm/sec
s_D = [ ] mm

Student Number: [ ] Access Number: [ ] Submit

- Instructions for submitting your answers

Figure 4: Fixed Axis Rotation Problem, Rigid Body Kinematics


Below are shown two blocks, A and B, connected by a massless, inextensible cable. Block A is on a surface with slope θ and friction, μ, and block B is suspended from the pulley system. If the system is released from rest, determine the accelerations of blocks A and B, and the tension in the cable.

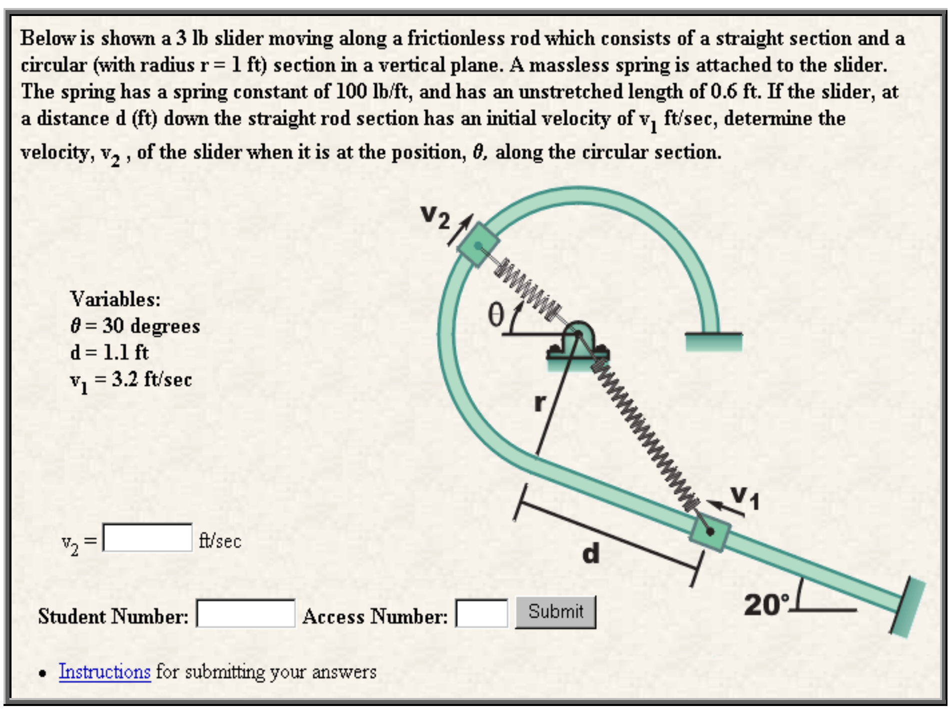
Variables:
θ = 16 degrees
W_A = 28 lb
W_B = 5 lb
μ = .2

Tension, T = [ ] lb
a_A = [ ] ft/sec ^{2} (positive downslope)
a_B = [ ] ft/sec ^{2} (positive down)

Student Number: [ ] Access Number: [ ] Submit

- Instructions for submitting your answers

Figure 5: Two Blocks Problem, Particle Equations of Motion


Below is shown a 3 lb slider moving along a frictionless rod which consists of a straight section and a circular (with radius r = 1 ft) section in a vertical plane. A massless spring is attached to the slider. The spring has a spring constant of 100 lb/ft, and has an unstretched length of 0.6 ft. If the slider, at a distance d (ft) down the straight rod section has an initial velocity of v_1 ft/sec, determine the velocity, v_2 , of the slider when it is at the position, θ, along the circular section.

Variables:
θ = 30 degrees
d = 1.1 ft
v_1 = 3.2 ft/sec

v_2 = [ ] ft/sec

Student Number: [ ] Access Number: [ ] Submit

- Instructions for submitting your answers

Figure 6: Particle Work Energy Problem

Appendix B: Survey Results from Use of Dynamics On-Line Homework Problems

BE 150 (Dynamics) End of Term OCI Survey
(Overall Results, 71 Students)
Fall 2001

We have assigned you twelve OCI problems (on the web) in dynamics this semester. This survey attempts to assess your reaction to and experiences with working these problems. On the questions with the numbers, **circle the appropriate number, based on the following scale:**

1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree.

	Avg Response	Questions
1.	**3.52**	Working OCI problems takes more time than regular homework problems.
2.	**3.38**	Working OCI problems takes too much time for their benefit.
3.	**3.11**	Working OCI problems helped me learn the material better.
4.	**2.93**	Working OCI problems helped me learn better the kinds of problems which were used in the OCI problems.
5.	**4.24**	I regularly worked the guest case to be sure I was working the problem correctly.
6.	**3.59**	Having two tries to work my case was sufficient.
7.	**3.52**	I would like three instead of two tries to work my OCI case.
8.	**4.01**	I regularly worked my OCI problems by myself.
9.	**2.32**	I regularly got help from a friend in working my OCI problems.
10.	**4.18**	The OCI system was easy to access on campus.
11.	**4.24**	The OCI system was easy to access off of campus.
12.	**4.10**	My teacher was helpful with how to work the problems.
13.	**2.28**	I would like more classes to use OCI type problems.
14.	**2.87**	My overall impression of the educational value of using the OCI problems (5 is highest, and 1 is lowest).

15. Please write any other general comments you have on educational and usage aspects of the OCI problems. Thank you.

Biographical Information

RALPH E. FLORI
Dr. Ralph E. Flori was educated as a petroleum engineer (UM-Rolla PhD '87). Now an associate professor in the Basic Engineering dept. at the University of Missouri-Rolla, he teaches dynamics, statics, mechanics of materials and a freshman engineering design course, and is actively involved in developing educational software for teaching engineering mechanics courses. He has earned thirteen awards for outstanding teaching and faculty excellence.

DAVID B. OGLESBY
David B. Oglesby is a Professor of Basic Engineering and a Research Associate for the Instructional Software Development Center at the University of Missouri-Rolla. Dr. Oglesby received a B. S. degree in Civil Engineering from the Virginia Military Institute in 1963, and M. S. and D Sc. degrees in Applied Mechanics from the University of Virginia in 1965 and 1969, respectively. He is actively involved in developing software for teaching statics.

TIMOTHY A. PHILPOT
Timothy A. Philpot is an Assistant Professor in the Basic Engineering Department at the University of Missouri – Rolla. He completed his PhD degree at Purdue University in 1992, the M.Engr.degree at Cornell University in 1980, and the B.S. at the University of Kentucky in 1979, all in Civil Engineering. Dr. Philpot teaches Mechanics of Materials and is the PI of the US Department of Education grant that supported this work.

NANCY HUBING
Dr. Hubing is an Associate Professor in the Basic Engineering Dept. at the University of Missouri-Rolla. Prior to joining the BE department in August 2000, she was on the faculty of the Electrical and Computer Engineering Dept. at UMR from 1989 to 1999, and taught high school physics 1999-00. She completed her Ph.D. in ECE at NC State University in 1989. Dr. Hubing enjoys research involving educational methods and technology in the classroom.

RICHARD H. HALL
Richard H. Hall, Associate Professor of Psychology at UMR, will be moving to UMR's new Information Science and Technology program in the fall of 2002. He received his BS degree in Psychology from the University of North Texas, and PhD degree in Experimental Psychology from Texas Christian University. He is the director of UMR's Media Design and Assessment Laboratory, and his research focuses on Web Design and Usability Assessment.

YELLAMRAJU VIKAS
Yellamraju Vikas is a Software Support Analyst at UMR. He works in designing, developing and implementation of online education tools. He has M.S in I.E from University of Oklahoma and B.Tech. in Mech Engg from Nagarjuna University, India. He also has 3 years professional experience in Polyester/Nylon Monofilament Yarn plant in India. His present work involves research on multimedia and online learning technology for engineering applications.