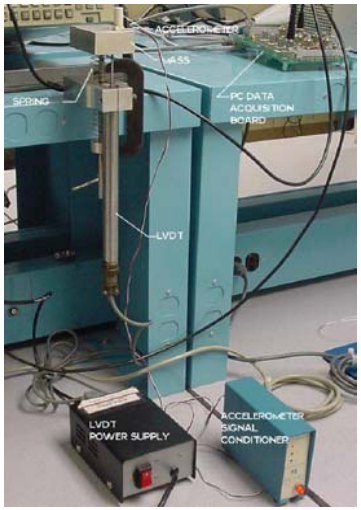
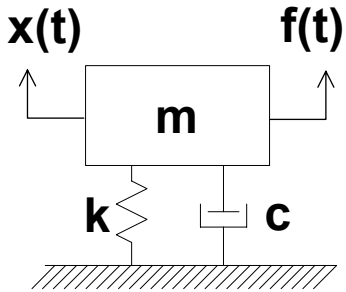
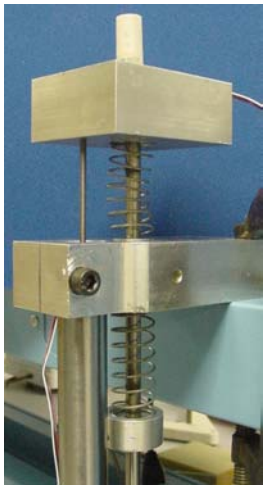
DYNamic SYStems

DYNAMIC SYSTEMS TEACHING ENHANCEMENT USING A LABORATORY BASED HANDS-ON PROJECT







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UMASS LOWELL

The Problem

DYNamic SYStems

Undergraduate course in Dynamic Systems requires many pre-requisite courses

Differential Equations
Mathematical Methods for Engineers
Dynamics
etc.

This is basic underlying material that is critical to the material covered in Dynamic Systems

The Problem

Material taught in those prerequisite courses is often considered irrelevant to the student.

Students do not see the practical application to firmly instill these basic STEM concepts (Science, Technology, Engineering, Mathematics) in their earlier courses

A traditional Dynamic Systems course, with traditional class lecture/homework/test scenario is destined to the same fate as these earlier courses, if taught in the same manner

The Problem

DYNamic SYStems

Student Comment:

Professor, why didn't you tell us that the material covered in other courses was going to be really important for the work we need to do in this Dynamic Systems course ?

Professor Thoughts:

Hmmmmm...

Student views material in a disjointed fashion

Professor clearly sees how pieces fit together

Dynamic Systems Course – New Variation

DYNamic SYStems

Course augmented with Project and Lab Work

Project requires analytical modeling
- *closed form differential equation*
- *Laplace solution*
- *MATLAB and Simulink models*

Laboratory work further reinforces material
- *1st order system measurement*
- *2nd order system measurement*

Formal reports which are peer reviewed

Analytical Modeling Project

Analytical Modeling Project

Develop closed form solutions for a 2nd order system using

- Ordinary Differential Equations
- Laplace Transformation Approach

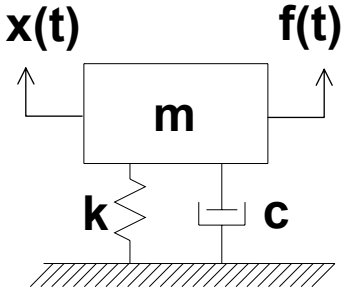
Develop computer simulation tools to confirm the closed form solution using

- MATLAB
- Simulink

Every student given a different 2nd order system

Social Security Number identifies M, C, K

Birth day & Birth month identifies initial conditions



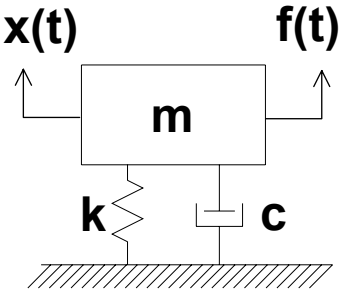
Social Security Number	*xxx*	*yy*	*zzzz*
System Characteristics	Mass	Damping	Stiffness
Birth month and birthday	***month***	***day***	
Initial displacement	month/10		
Initial velocity		day	

Differential Equation Approach

Students refresh their basic math skills

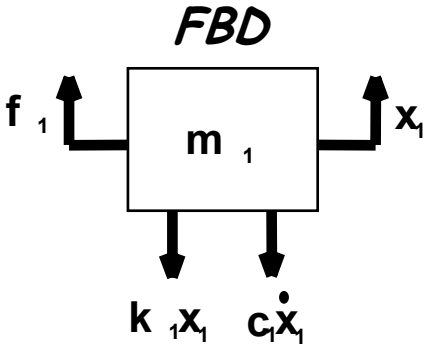
Homogenous equation is

$$m\ddot{x} + c\dot{x} + kx = 0$$



and assuming an exponential solution form gives

$$\left(ms^2 + cs + k\right)e^{st} = 0$$



Laplace Transform Approach

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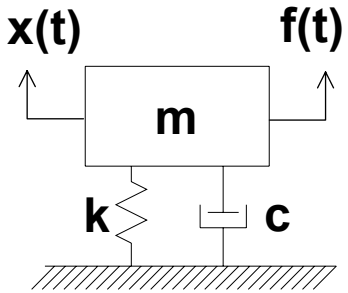
Students refresh their basic math skills

The second order differential equation is

$$m\ddot{x} + c\dot{x} + kx = f(t)$$



Laplace Transformation gives

$$(ms^2+cs+k)\quad x(s) \quad = \quad f(s) \quad + \quad (ms+c)x_0 \quad + \quad m\dot{x}_0$$

Characteristic Portion — ***Applied Force*** — ***Initial Displacement*** — ***Initial Velocity***

Block Diagram Form

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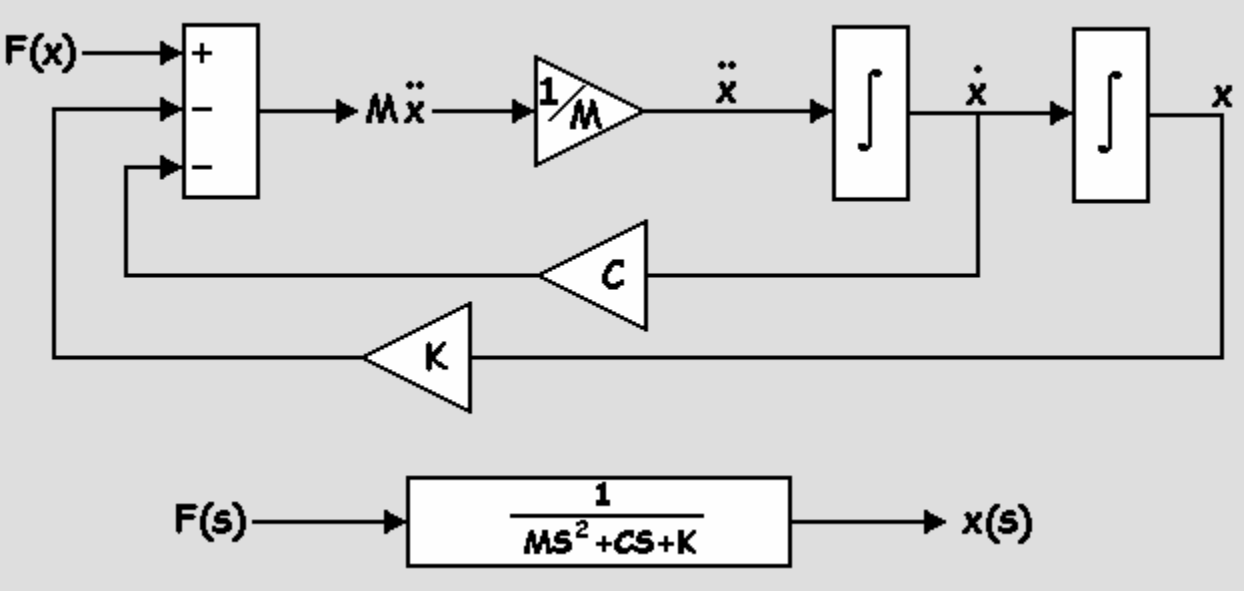
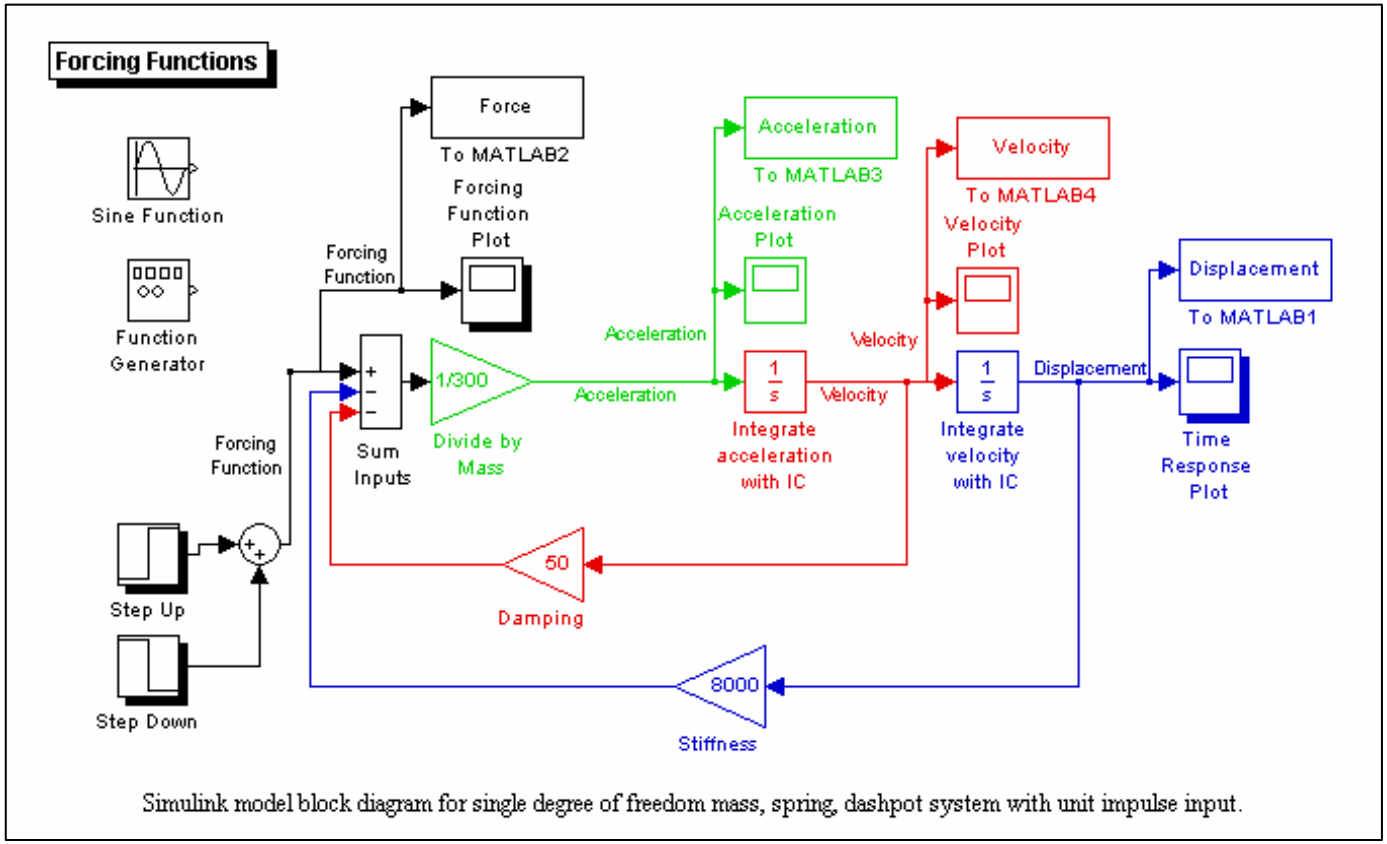
Students also develop new skills

The system can be modeled in block diagram form



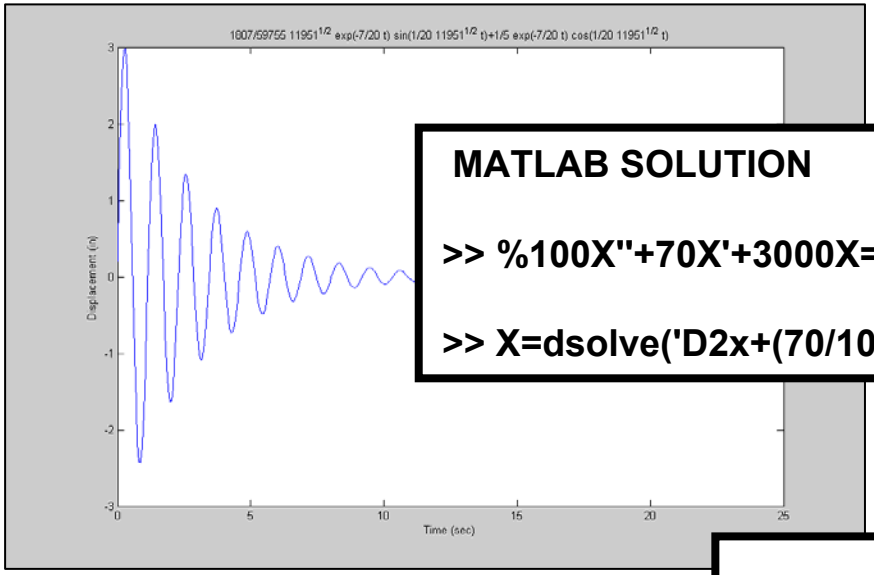
Simulink Model

The block diagram leads into Simulink



Simulink model block diagram for single degree of freedom mass, spring, dashpot system with unit impulse input.

Second Order System Solutions

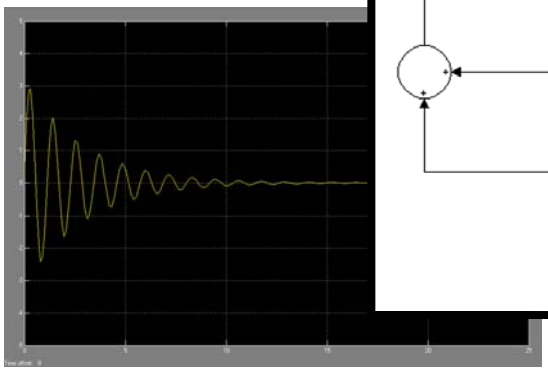


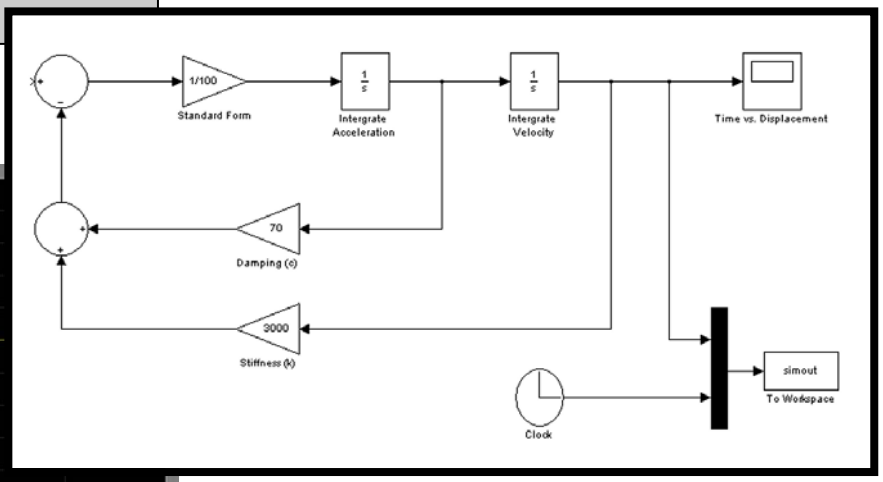
MATLAB SOLUTION

>> %100X''+70X'+3000X=f(t) where: X(0)=.2 X'(0)=18 f(t)=0

>> X=dsolve('D2x+(70/100)*Dx+(3000/100)*x=0','Dx(0)=18','x(0)=.2','t')

SIMULINK SOLUTION





Students can help each other

But ultimately every student has a different problem (different frequency, damping, etc)

Individual reports are written by each student describing all the analyses and models developed

Analytical Modeling Project

This first project is critical

It forces the students to refresh their basic mathematical tools necessary to solve these types of problems as well as learn new tools

It also guarantees that teamwork in the second project can be accomplished by all team members

Laboratory Based Projects

Lab Based Project

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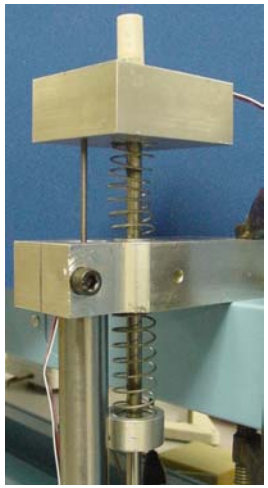
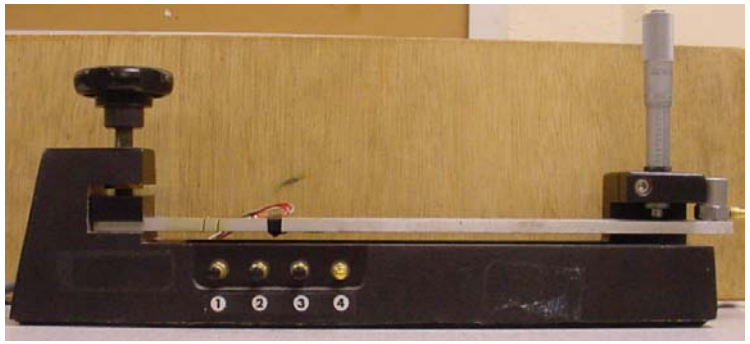
A simple mass, spring, dashpot system is evaluated

- *single degree of freedom system*
- *cantilever beam system*

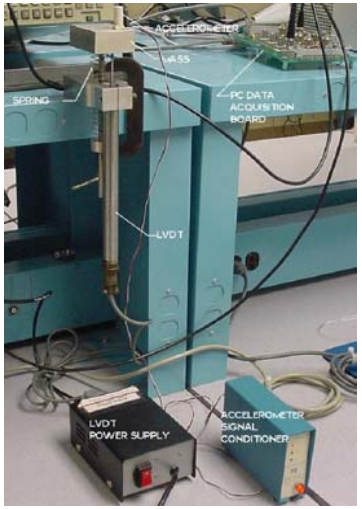


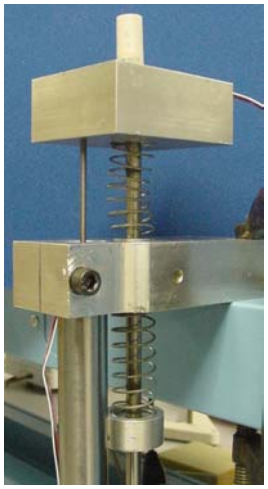


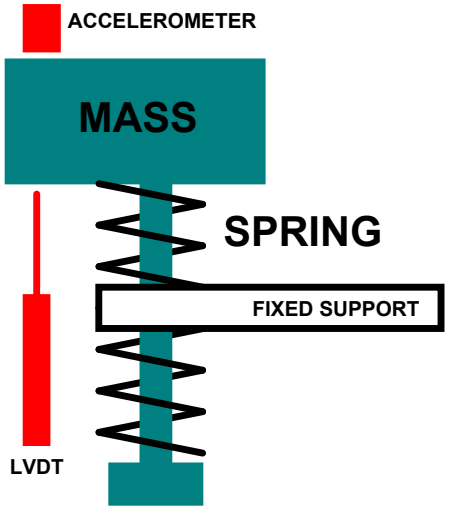
Students work in teams of 3-4 on this project

Lab Based Project – SDOF System

A single degree of freedom mass, spring, dashpot system



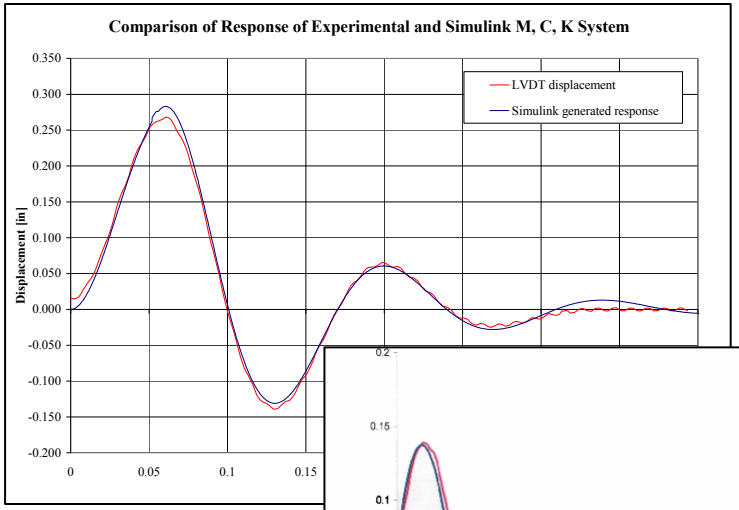


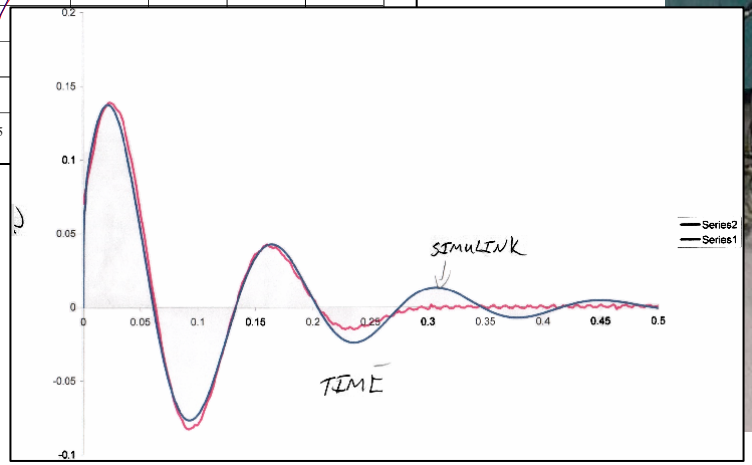


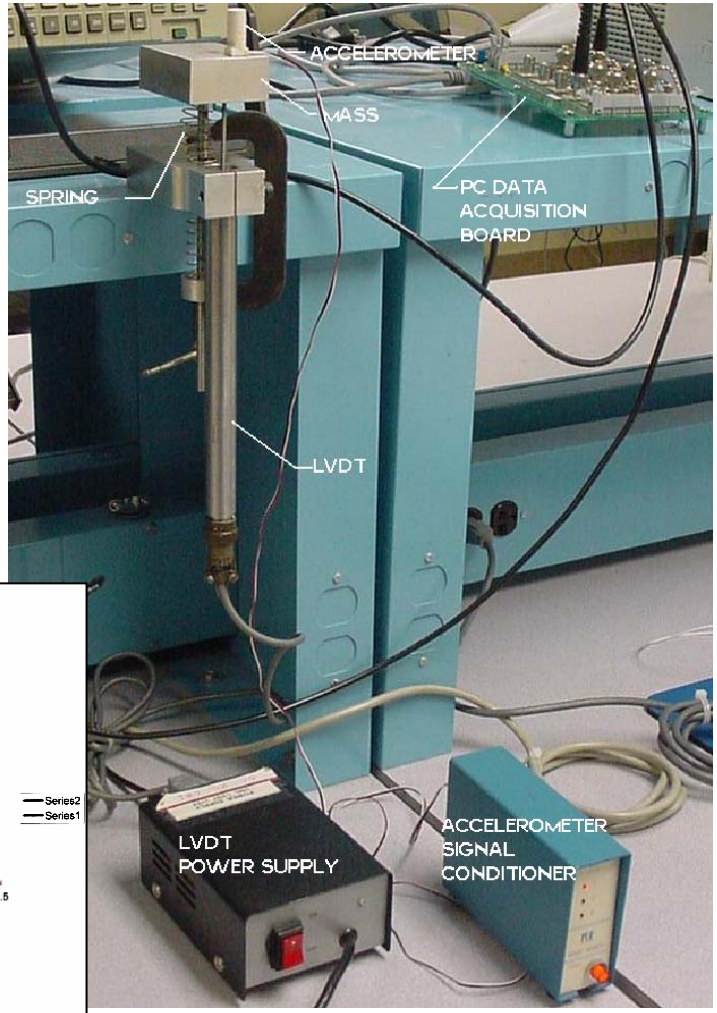
Now what is the mass, what is the stiffness and what is the damping for this system ???

Lab Based Project – SDOF System

Every test produces different results

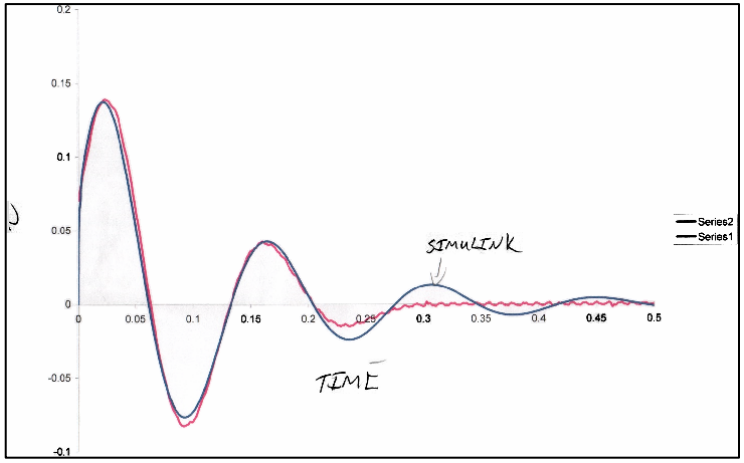


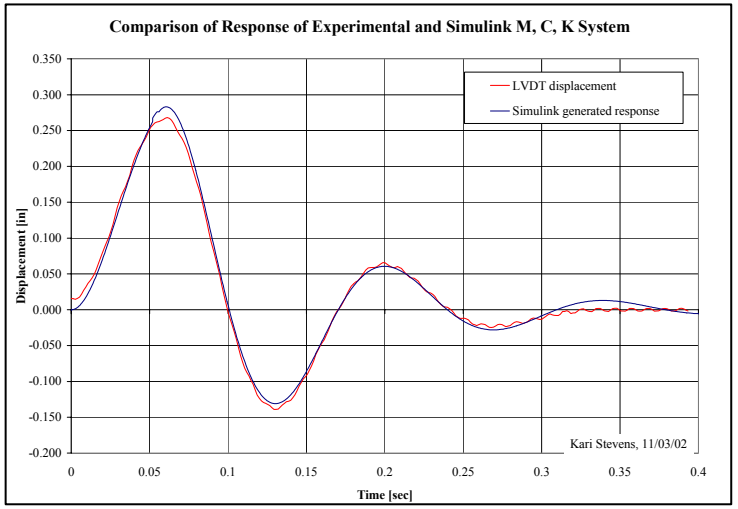




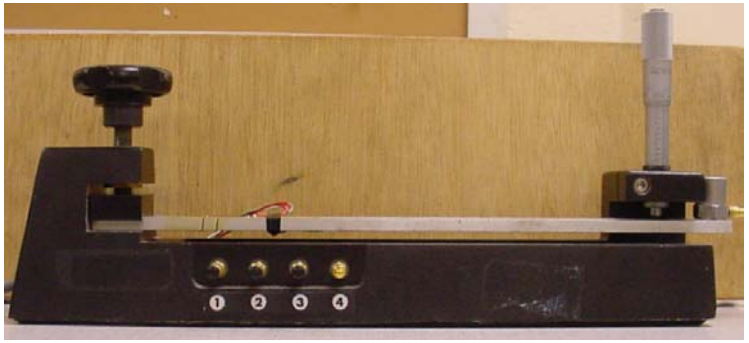
Lab Based Project – SDOF System

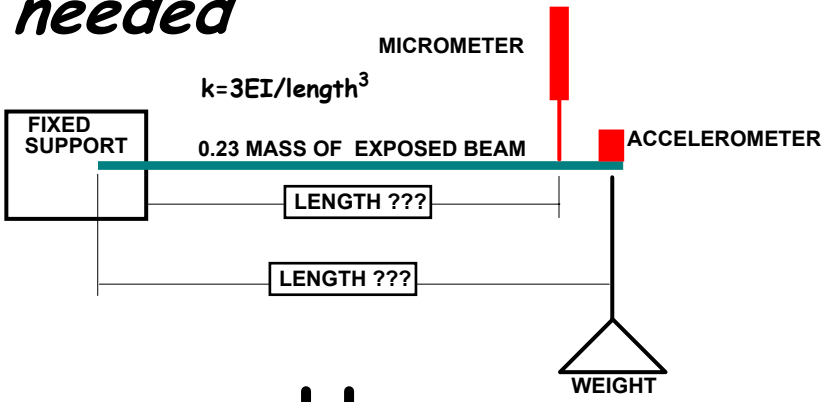
Students realize that there is not one specific way to solve this problem – there are many alternate ways to approach this solution

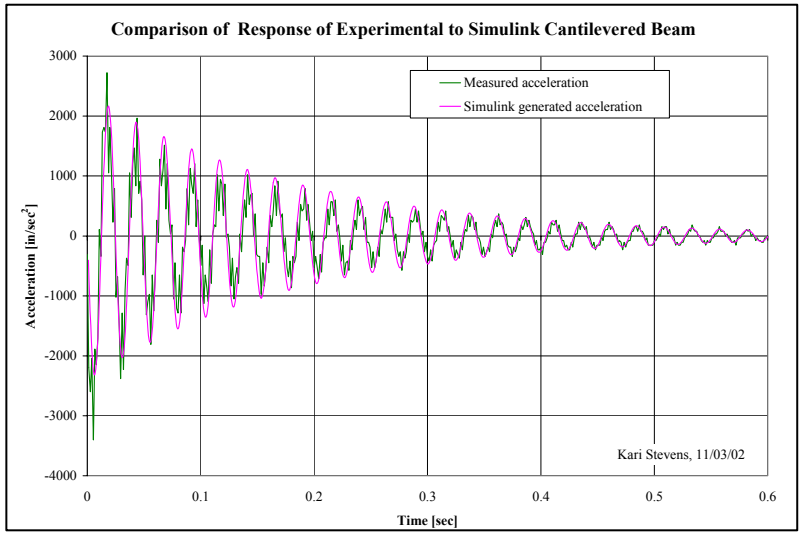


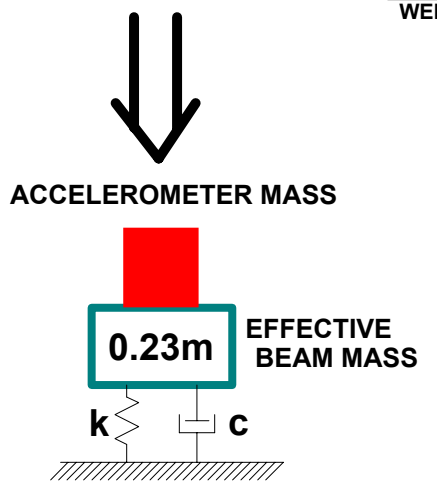


Equivalent characteristics needed









Lab Based Project

Students struggle at times since there is no one way to solve this problem.

Eventually reasonable results are obtained

Students generally have a much better, deeper understanding the STEM prerequisite material

Report Evaluation – Peer Review

The group must submit a report.

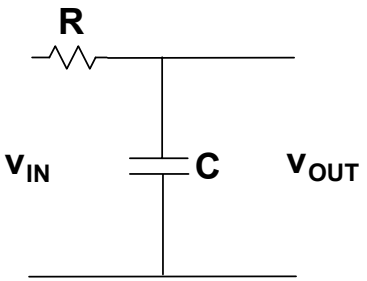
This report is then given back to a different group for peer review ! ! ! ! !

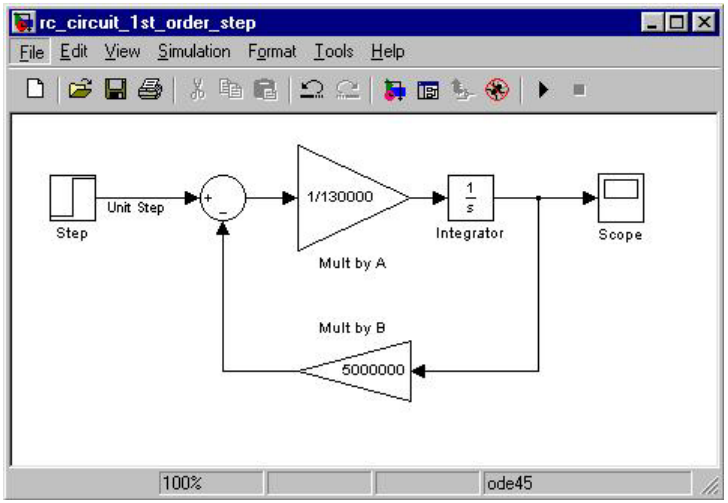
This forces the students to better understand the material and to see common pitfalls in writing style

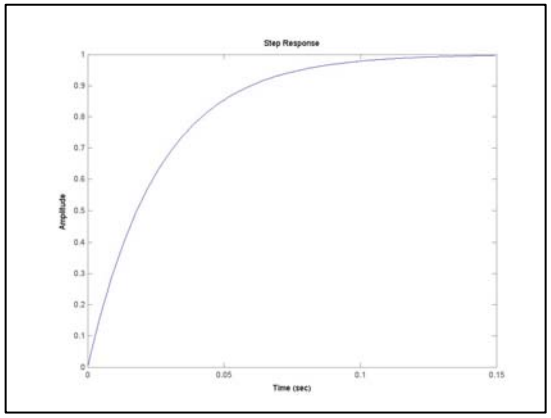
1st Order System Evaluations

1st Order System

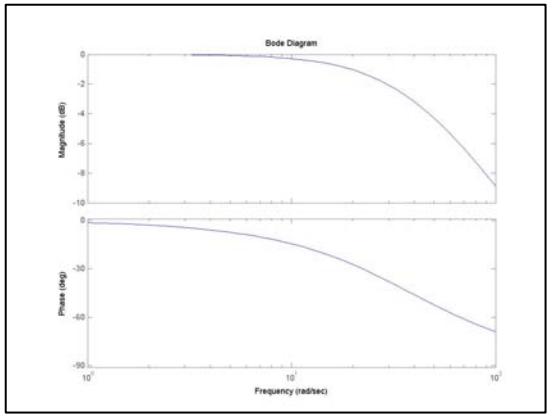
RC Circuit and SIMULINK Model







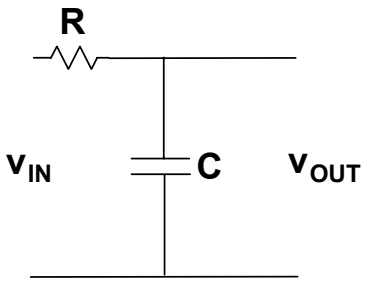
Time Response

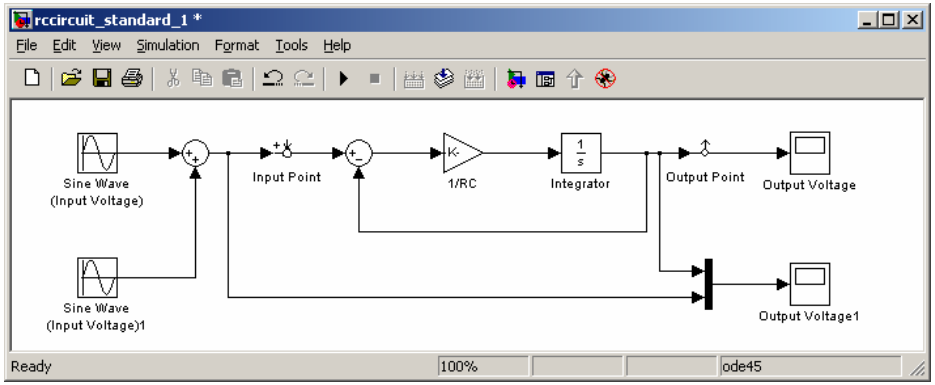


Bode Plot

1st Order System

SIMULINK Filter Effects on Sine Waves using the Variable RC Circuit





Another project described in the paper – 1st order system which can be a low pass filter

Student Observations & Assessments

Student Observations & Assessments

Prior to this course, the important concepts of a particular subject did not necessarily "click"

Projects not only reinforced the material covered in lecture, but also went a few steps further by forcing us to think about which variables can affect the response of the systems

The projects did not have simple solutions and involved interpretation of data, application of concepts discussed in lecture, and understanding of the physical system in the lab.

Student Observations & Assessments

Relevant hands-on experience is much more effective than theory by itself

Struggling with a project makes me think harder

The group dynamics in project work are beneficial.

When members of our group disagreed, we were forced to dig deeper into what we were doing to find out who was right

Student Observations & Assessments

This class has taken an approach to material presentation that is unlike any previous class.

The theory and materials are presented in the class periods, and are driven home during project preparation.

The projects have forced the students to indeed "think outside the box"

Student Observations & Assessments

Dynamic System course required more work and time than many other courses

The hands-on approach and struggling through the projects is exactly the process by which the information was absorbed
– by not only learning, but really understanding.

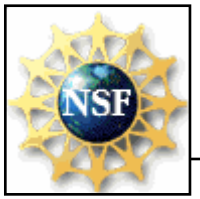
During the peer reviews you find yourself thinking 'why didn't I think of that?'

Student Observations & Assessments

The required collection of data definitely helped me understand that these problems are not as simple as they might seem

We became aware that there are multiple ways to determine the system characteristics of a physical system, and the importance of using multiple methods and comparing the results

The peer review of other group project reports actually was quite enlightening. This should be done about three years earlier in our curriculum!



DYNamic SYStems

Professor Observations & Assessments

Professor Observations and Assessments

In terms of understanding Ordinary Differential Equations after completing that course:

48% felt that they had a vague understanding on the material overall and

45% felt they understood the material well

Professor Observations and Assessments

DYNamic SYStems

Upon completing the Dynamic Systems course (which instituted the new hands-on, laboratory-based open-ended project with a substantial review of ODE, Laplace, etc):

more than 75% stated that they understood the basic ODE, Laplace, etc. well and

the remaining 25% stated that they understood the material very well.

Professor Observations and Assessments

When asked if the project were not included how well would they understand the material:

over 45% responded that they would probably only vaguely understand how to solve a dynamic system problem

Professor Observations and Assessments

When asked if the project challenged them:

85% felt that the problem was significant and pushed them to be creative in solving the problem

over 75% of the students felt that the physical measurement tremendously enhanced their understanding of the problem

Professor Observations and Assessments

And when asked if the project should remain as part of the course:

85% felt that it was a critical part of the course and is necessary in order to firmly instill the underlying STEM concepts

(even though 100% of the students stated that it was a significant burden in terms of workload)

Summary

Summary

A new hands-on, laboratory-based project has been added as a supplement to a traditional senior level Dynamic Systems course.

The students tend to better understand the material as evidenced from overall capabilities and student comments regarding how they feel with respect to their overall understanding of the material.

Summary

The hands-on, laboratory-based project helps the students to better understand the basic core STEM material necessary for solving these types of problems

The students appear to better understand the material overall through "living the material" rather than learning/memorizing equations that do not appear to have any practical relevance

Summary

Student comments relative to inclusion of the project were overwhelming positive.

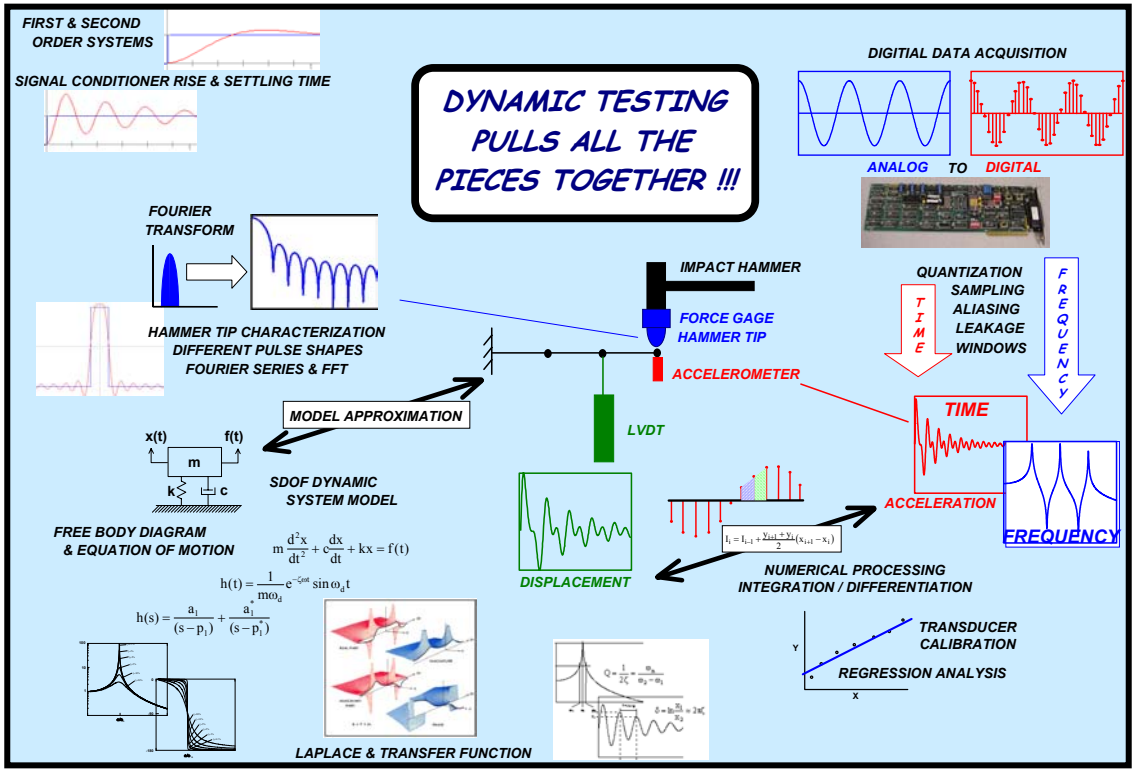
The students feel that the project is a critical part of the course that helped them to better understand all the material presented in the Dynamic Systems course

as well as material in related courses.

Acknowledgements

This project is partially supported by
NSF Engineering Education Division Grant EEC-0314875

Multi-Semester Interwoven Project for Teaching Basic Core STEM Material Critical for Solving Dynamic Systems Problems



Peter Avitabile, John White, Stephen Pennell

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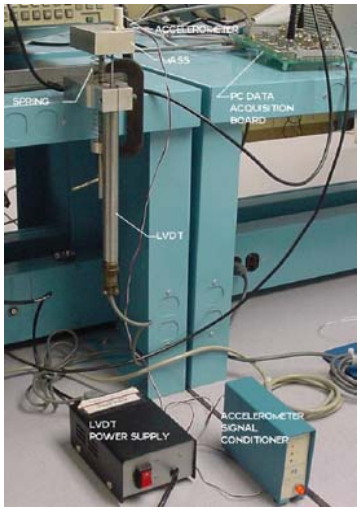

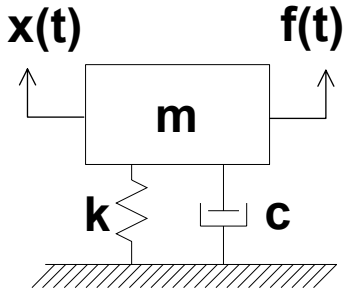

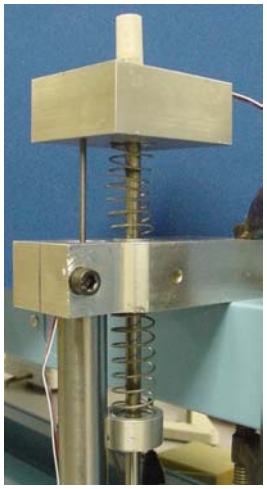

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