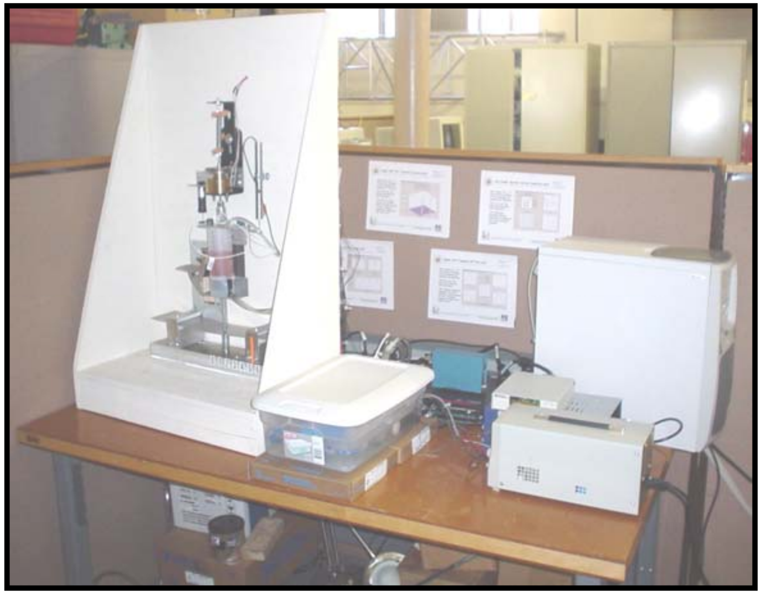
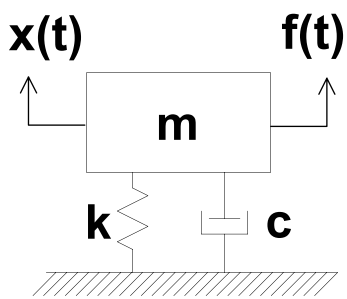
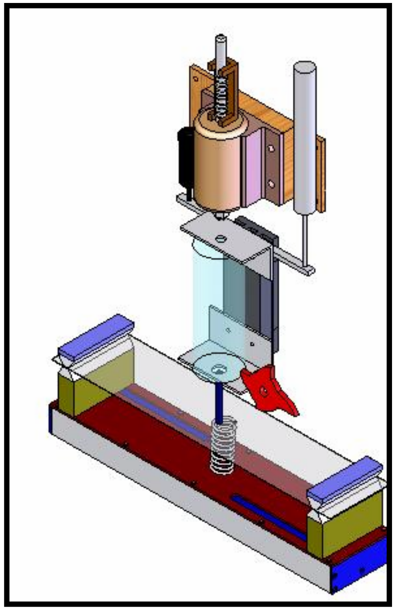
DYNAMIC SYSTEMS TEACHING ENHANCEMENT USING A LABORATORY BASED PROJECT (R.U.B.E.)







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The Problem

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

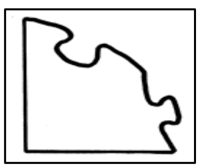
The Problem

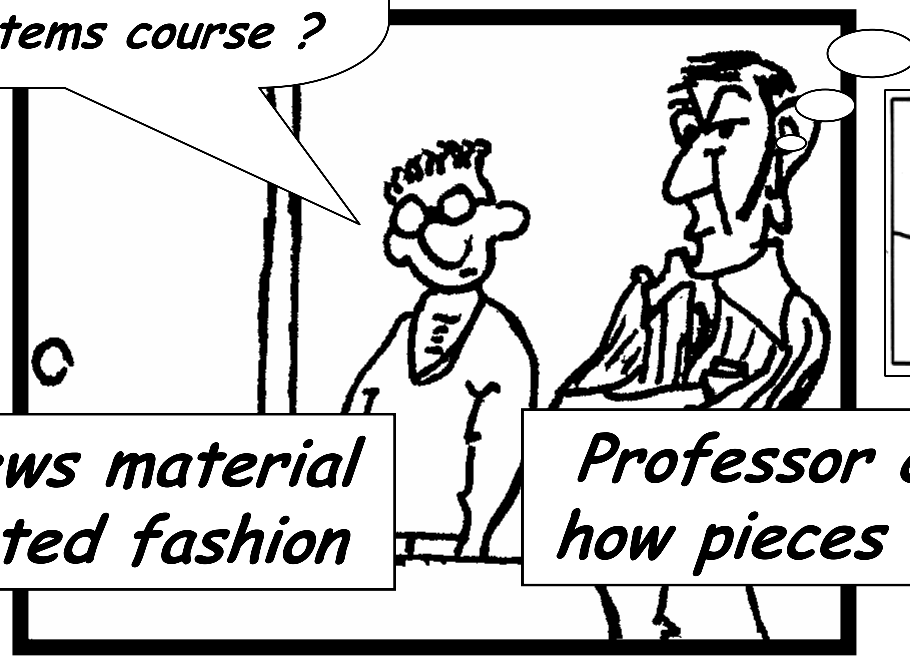
Student Comment:

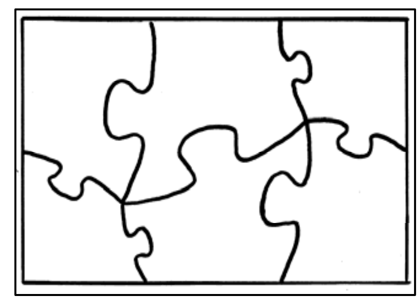
Professor, why didn't you tell us that the material covered in other courses was going to be really important for the work we need to do in this Dynamic Systems course ?

Professor Thoughts:

Hmmmmm...







Student views material in a disjointed fashion

Professor clearly sees how pieces fit together

Dynamic Systems Course – New Variation

Augment course with Project and Lab Work

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

Laboratory work further reinforces material
- 2nd order system measurement and characterization

Formal reports are peer reviewed

Analytical Modeling Project

Analytical Modeling Project

Develop closed form solutions for a 2^{nd} order system using

- Ordinary Differential Equations
- Laplace Transformation Approach

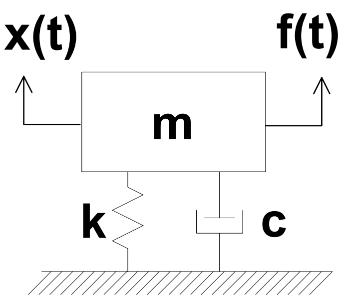
Develop computer simulation tools to confirm the closed form solution using

- MATLAB
- Simulink

Every student given a different 2nd order system

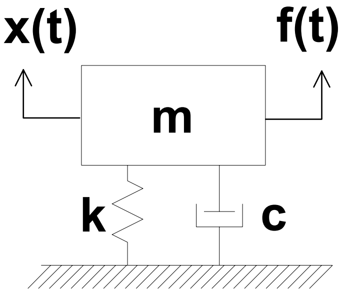
Social Security Number identifies M, C, K

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	

Students refresh their basic math skills



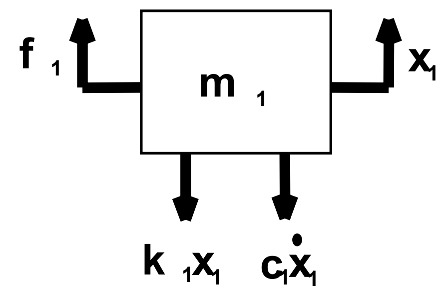
Homogenous equation is

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

and assuming an exponential solution form gives

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

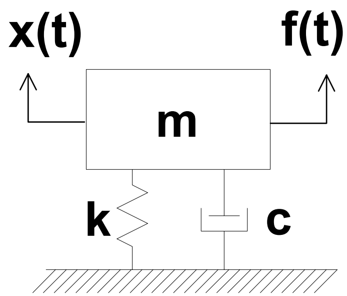
FBD



Students refresh their basic math skills

The second order differential equation is

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



Laplace Transformation gives

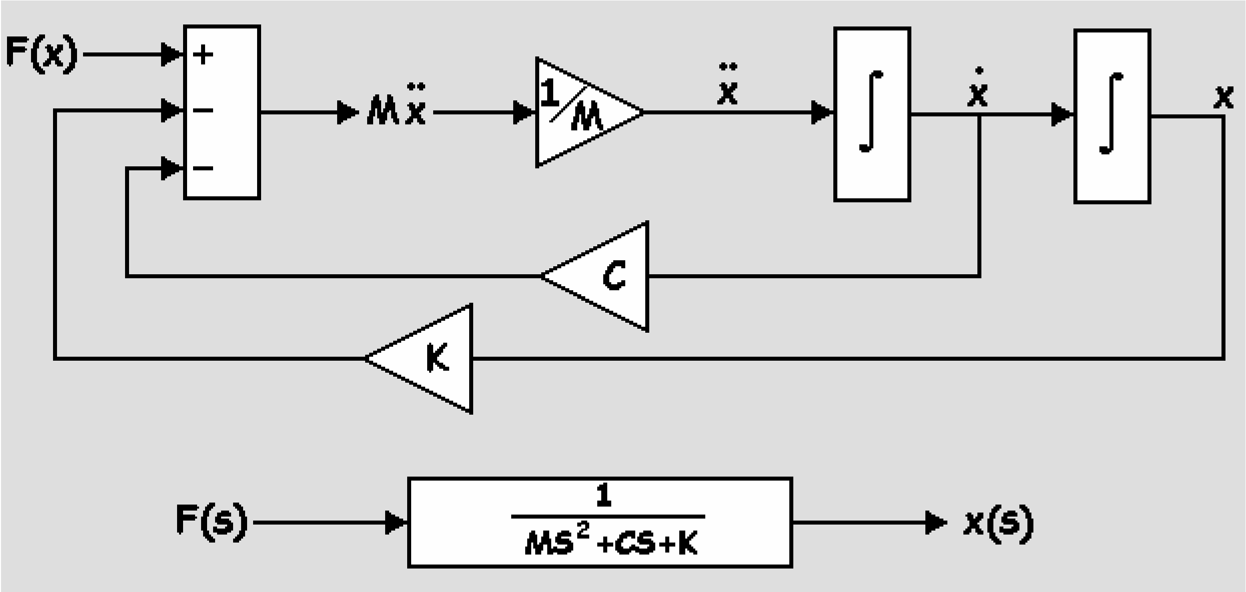
$$(ms^2+cs+k)\quad x(s) \quad = \quad f(s) \quad + \quad (ms+c)x_0 \quad + \quad m\dot{x}_0$$

- (ms^2+cs+k) — *Characteristic Portion*
- $f(s)$ — *Applied Force*
- $(ms+c)x_0$ — *Initial Displacement*
- $m\dot{x}_0$ — *Initial Velocity*

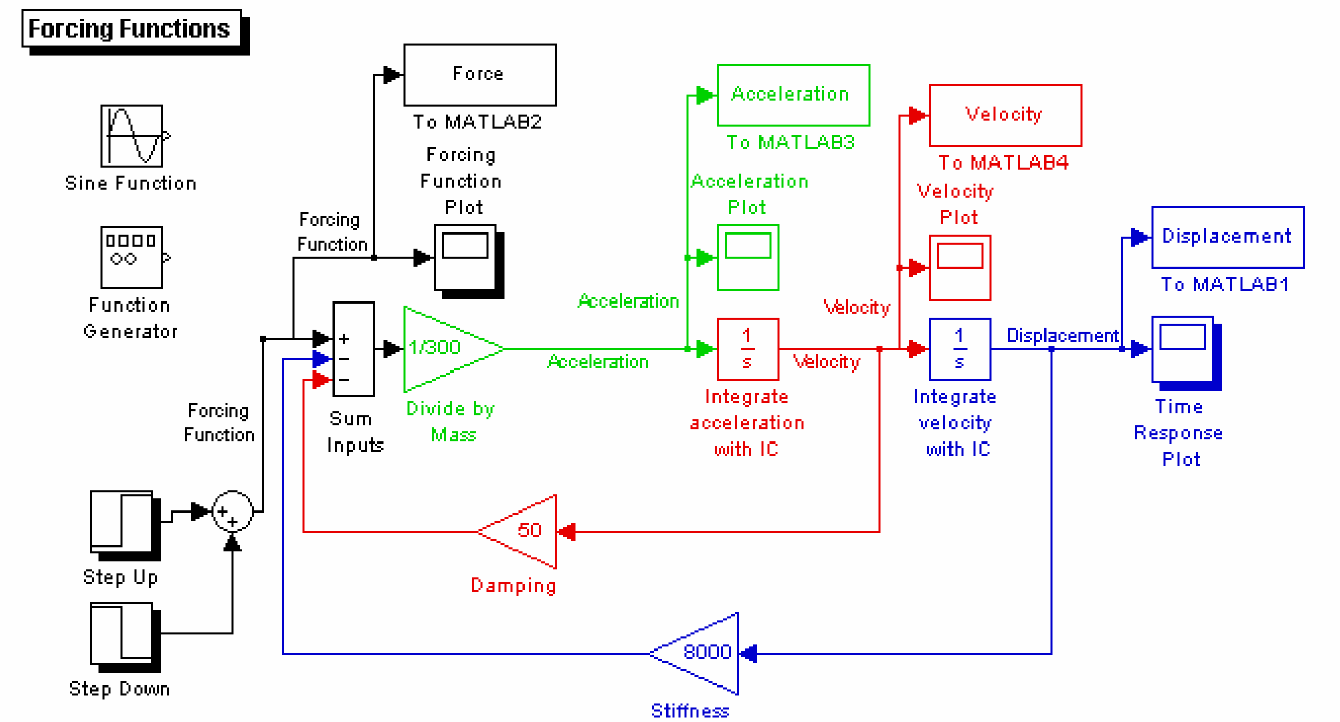
Block Diagram Form

Students also develop new skills

The system must be modeled in block diagram form

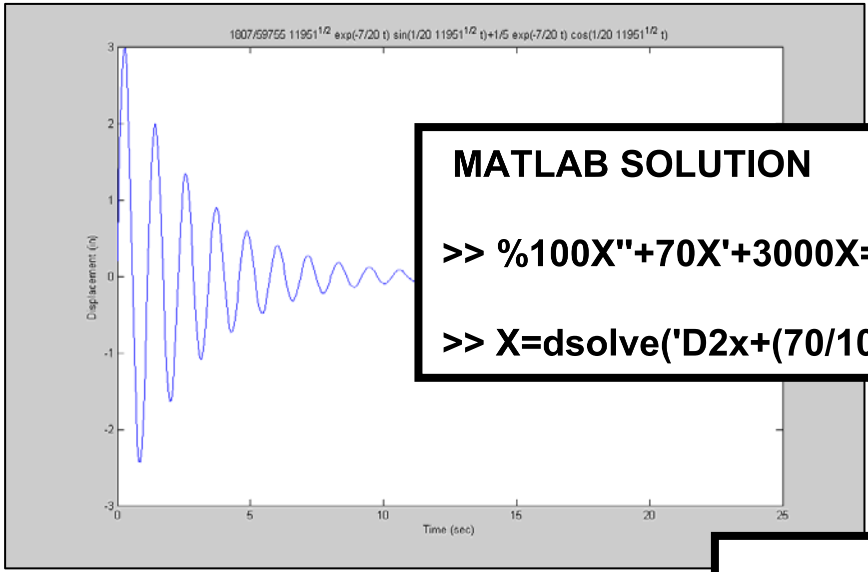


The block diagram leads into Simulink



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

Second Order System Solutions

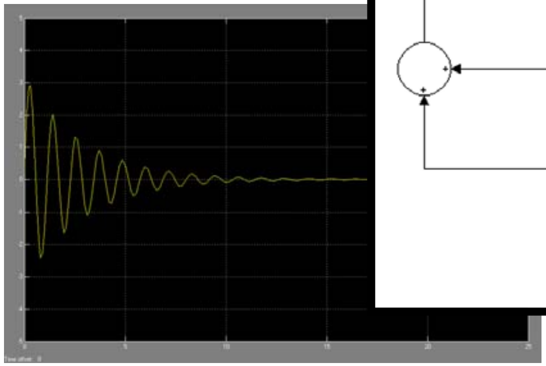


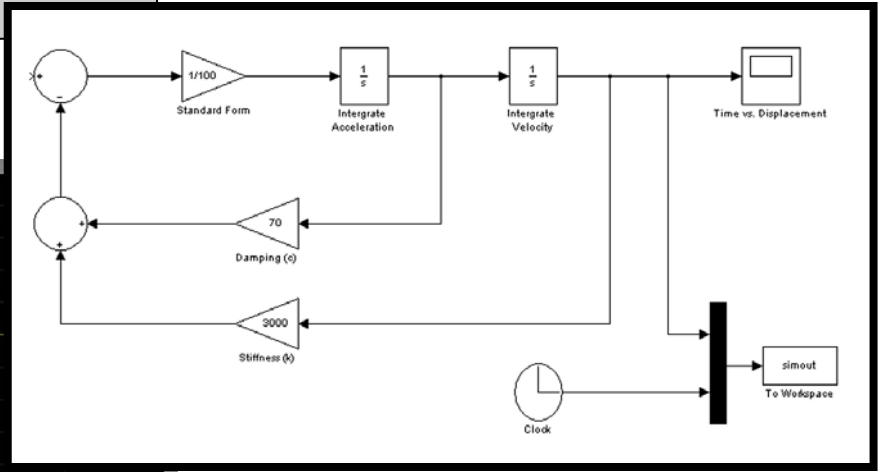
MATLAB SOLUTION

```
>> %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





Analytical Modeling Project

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

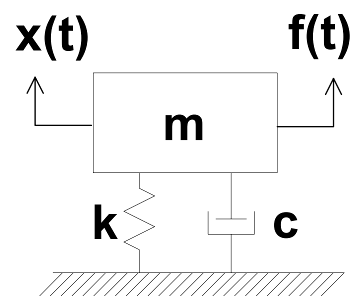
It also guarantees that all team members can contribute constructively to the second project

Laboratory Based Project

Laboratory Based Project

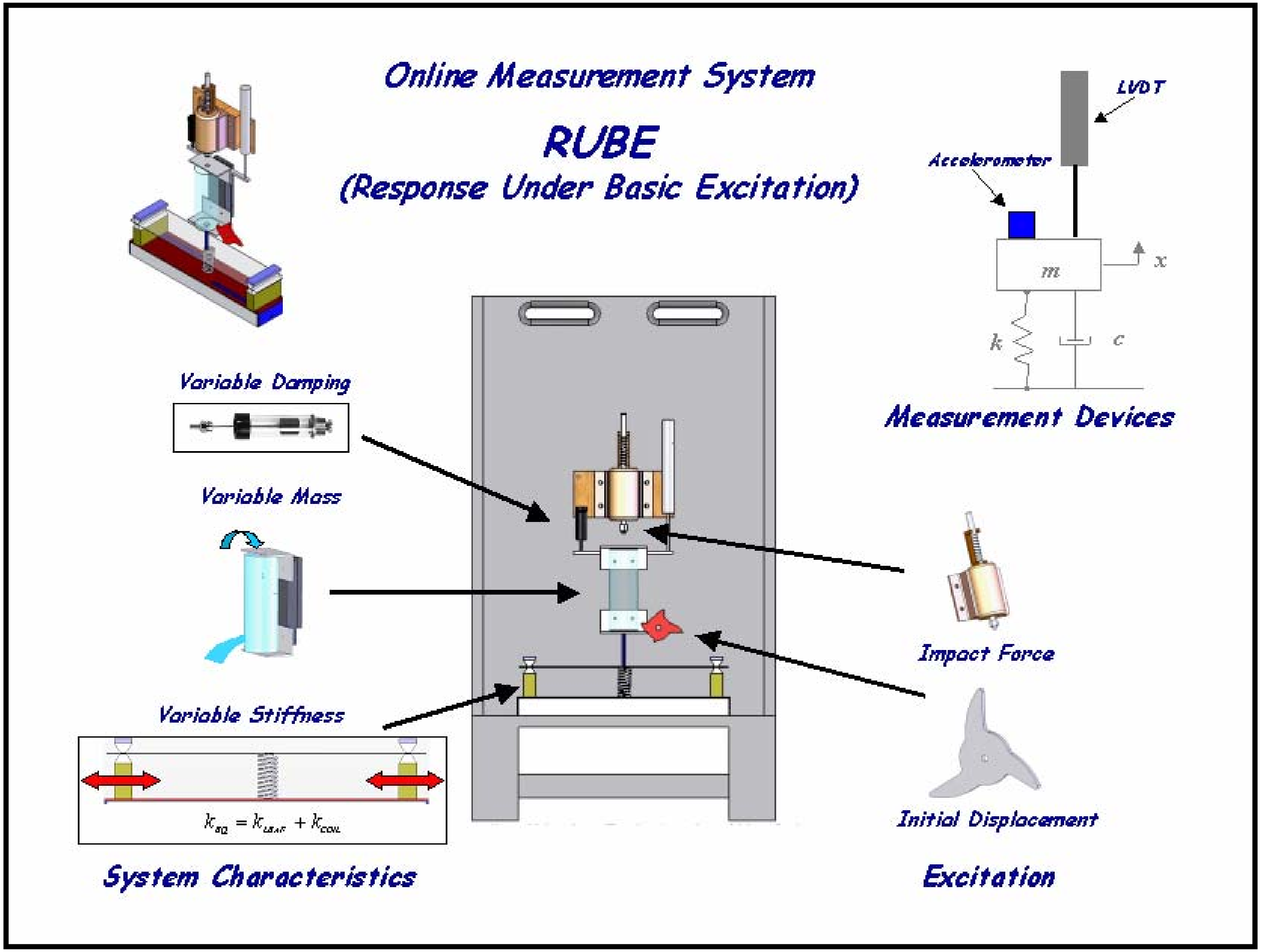
A real mass, spring, dashpot system is measured and analyzed

- *single degree of freedom system*
  - *multiple excitations*
  - *variable parameters*
  - *computer controlled*
  - *accessible online*



Students work in teams of 3-4 on this project

Lab Based Project – SDOF System



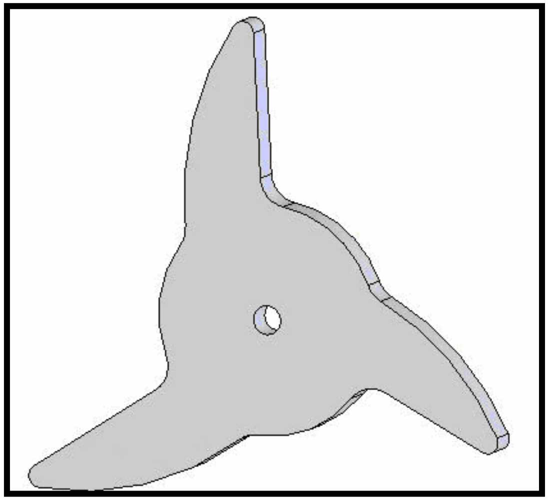
System excitations

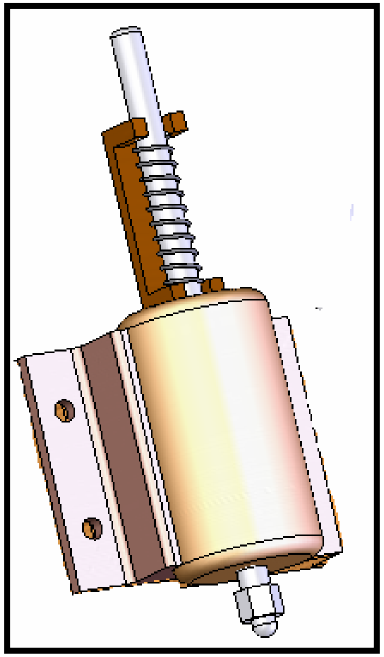
three different initial displacements

cam with different height lobes

impact excitation

electric solenoid



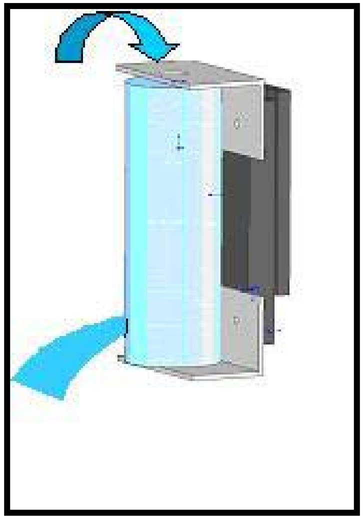


Variable parameters

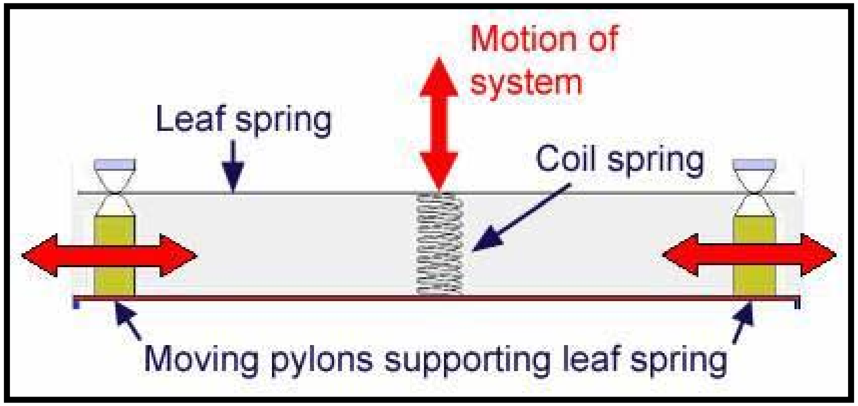
each data set unique

variable mass (reservoir based system)

variable stiffness (leaf spring with changing effective length)



much like analytical project, each group must formulate its own solution to a unique data set



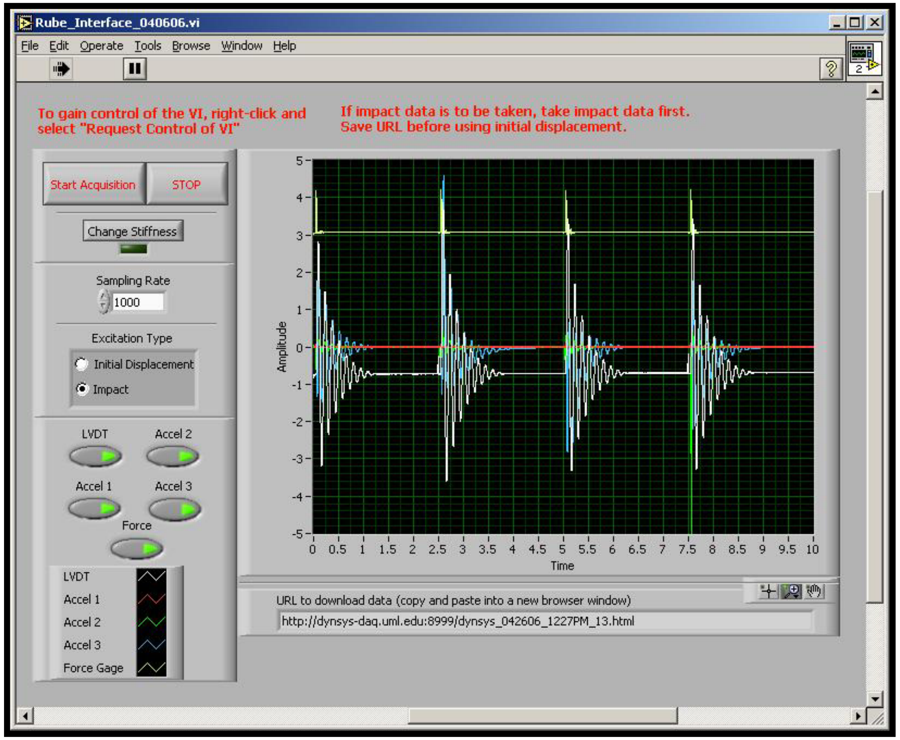
Laboratory Based Project

Computer controlled

Labview based VI

accessible via the internet

http://dynsys.uml.edu/

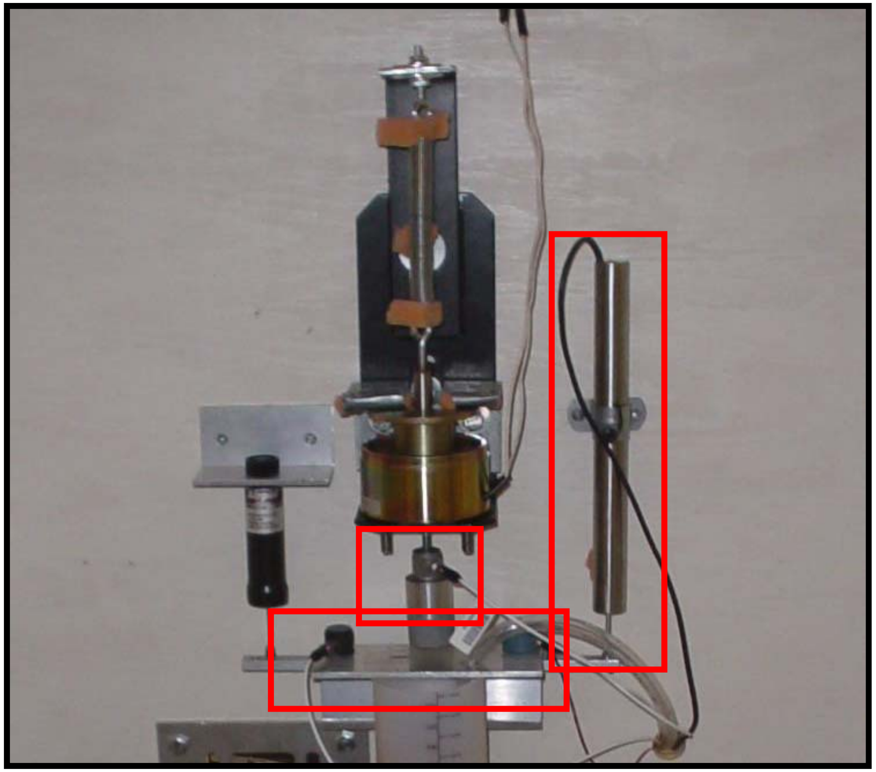


Measurement system

- 3 different sensitivity accelerometers
- LVDT
- Force transducer

Various measurement issues to deal with

- quantization error
- drift, bias
- filtering
- clipping



Lab Based Project – SDOF System

Students must characterize the system

- **what is the mass, damping and stiffness**
- **what were the initial conditions**
- **what was the input force**

Forces use of STEM material

Lab Based Project – SDOF System

Students presented system characteristics in pieces throughout a set of documents

Parameters scattered much like in a real world situation

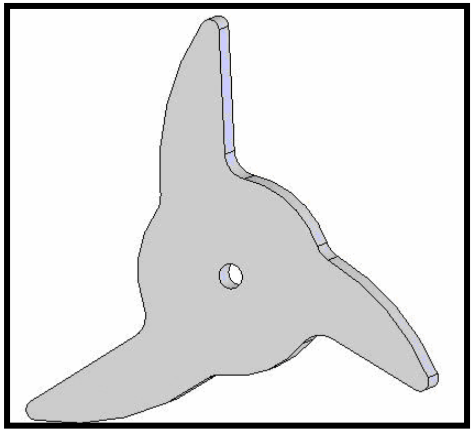
- transducer sensitivities
- mass of system/volume of water container
- leaf and coil spring material properties and measured stiffness

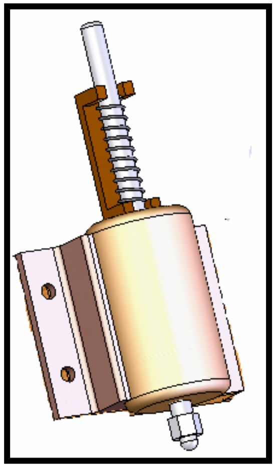
DYNamic SyStems

Open ended assignment

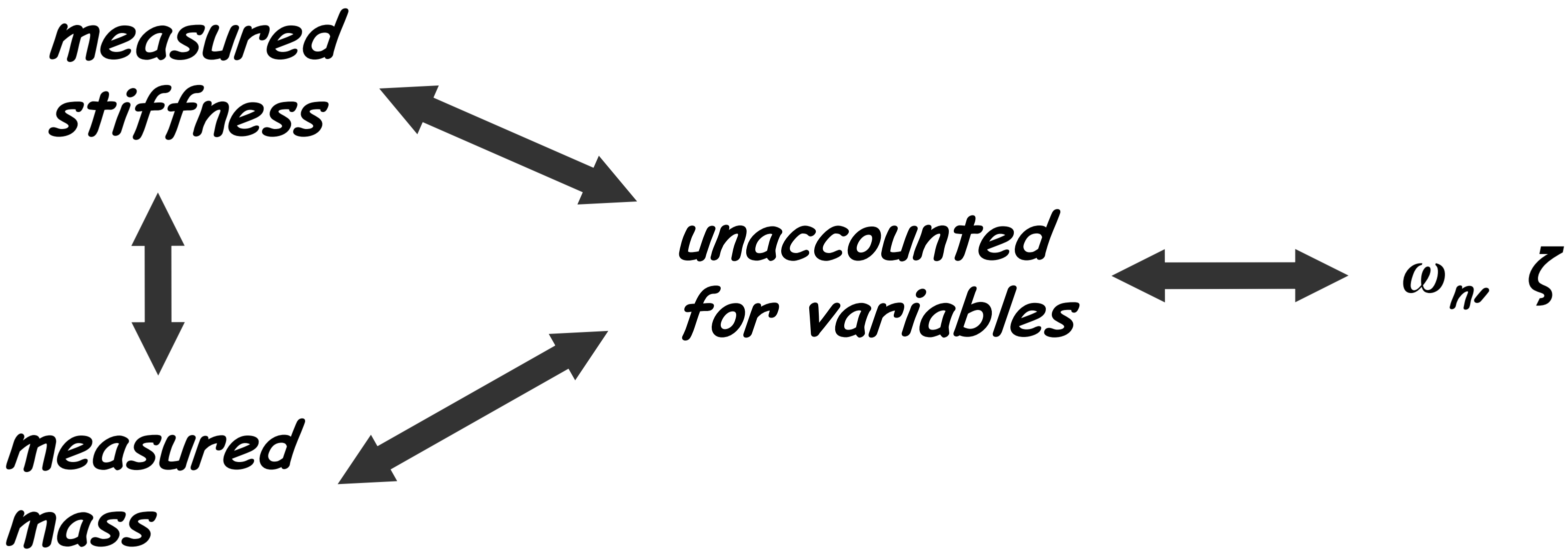
students not told which data sets or transducers to use, but the model created must be validated with other data sets

Students must determine the set of characteristics which represents the system best





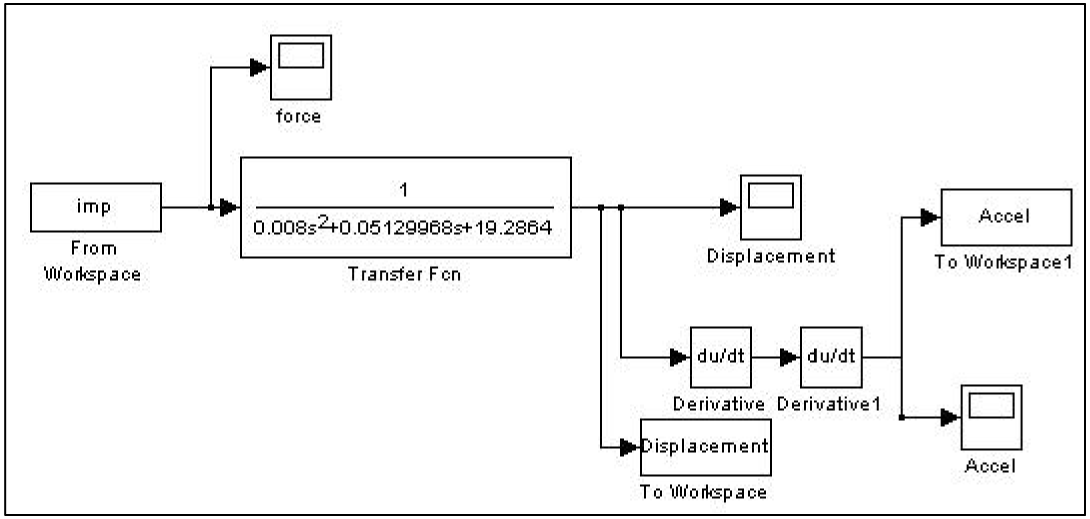
Students must reconcile agreement issues between system characteristics

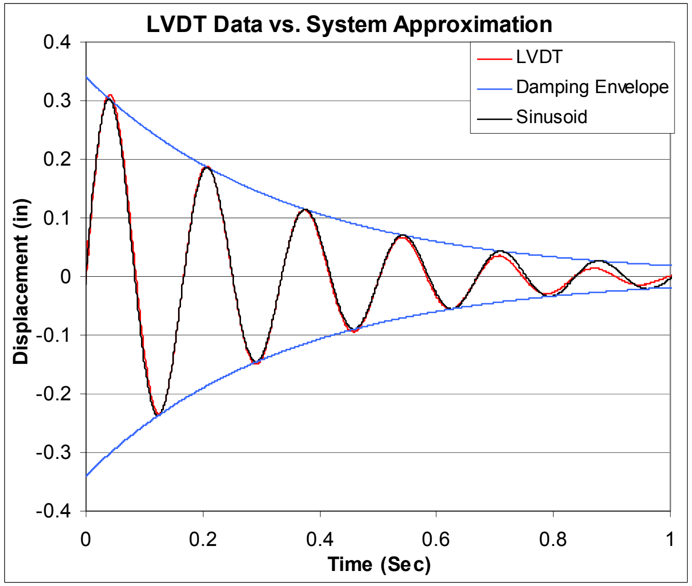


Lab Based Project – SDOF System

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

Students apply skills learned in first project





Dr. Peter Avitabile, Associate Professor
Mechanical Engineering Department

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 at the end of the project

Report Evaluation – Peer Review

Each group must submit a report.

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

Students better understand the material and see common pitfalls in writing style

Report Evaluation – Peer Review

Groups are allowed to see how others approached the problem

Students quickly realize how difficult it is to write a good report and how hard it is to review a report if it is not well organized

Students also realize where their own report was deficient

Professor Observations & Assessments

Professor Observations and Assessments

In terms of understanding Ordinary Differential Equations after completing the ODE 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

Without application, the ODE remains abstract and the student has no clear reason to retain the material

Math was taught for the sake of math and not for engineering solution

To quote one professor at the beginning of an ODE course:

> "we will not cover any applications in this course"

Luckily this is changing

Professor Observations and Assessments

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 they would understand the material:

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

Dr. Peter Avitabile, Associate Professor
Mechanical Engineering Department

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)

Without the project dynamic systems would be like any other math course

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.

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.

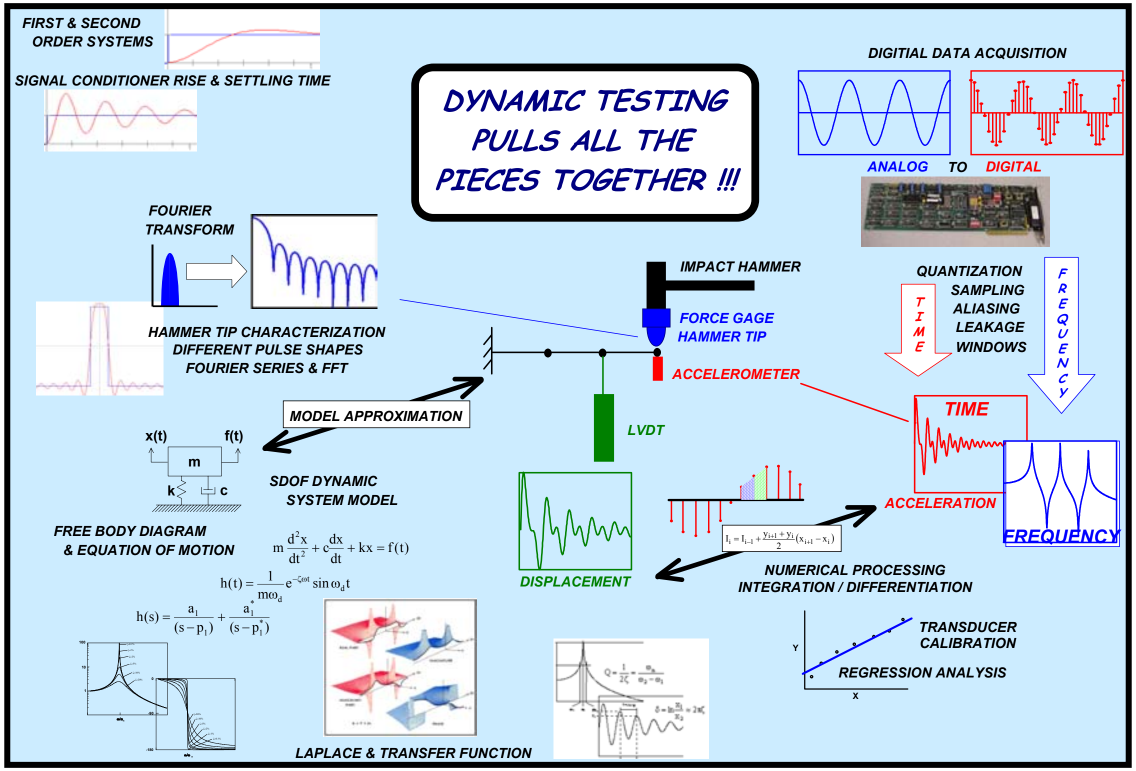
The students feel that the project is a critical part of the course that helped them to better understand all the material presented in the Dynamic Systems course,

as well as material in related courses.

Acknowledgements

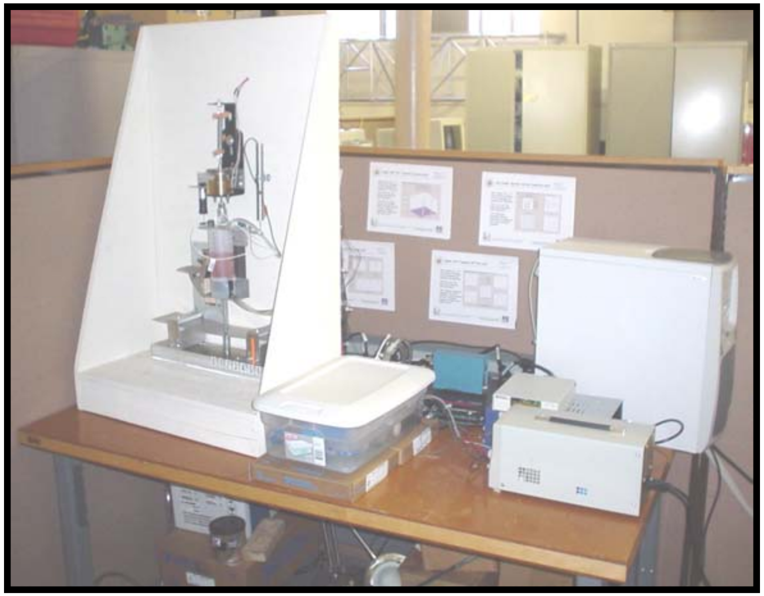
This project is partially supported by
NSF Engineering Education Division Grant EEC-0314875

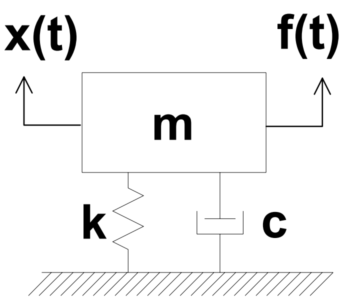
Multi-Semester Interwoven Project for Teaching Basic Core STEM Material Critical for Solving Dynamic Systems Problems

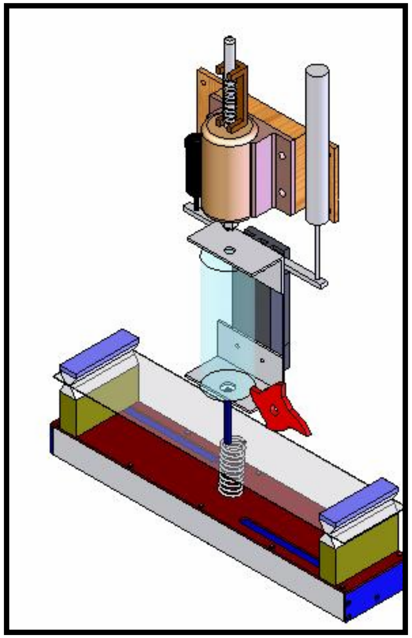


Peter Avitabile, John White, Stephen Pennell

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







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