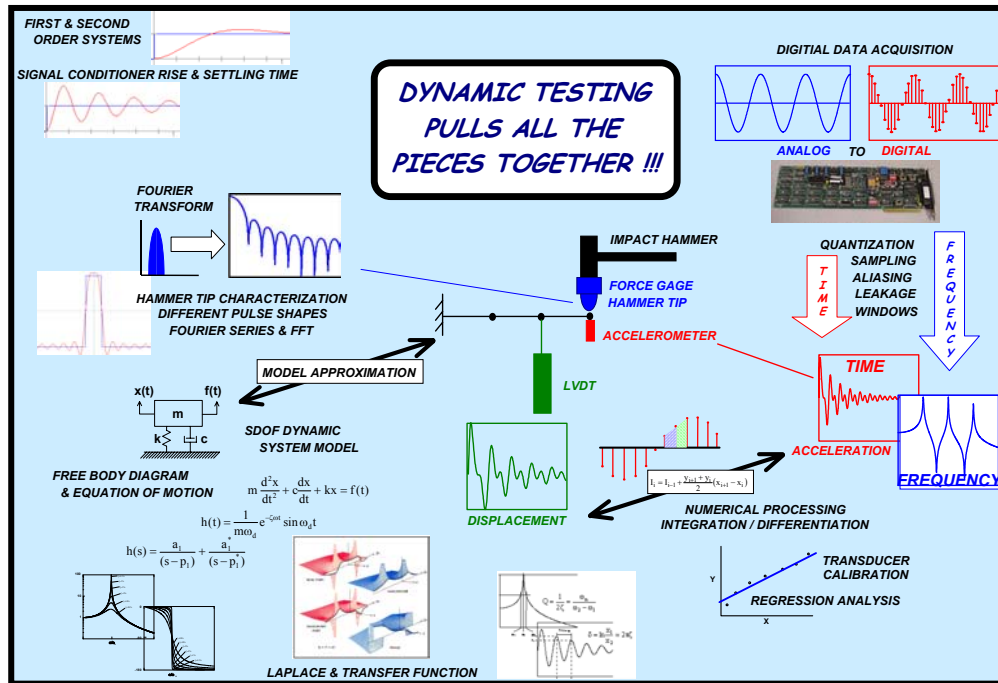




# AN INTEGRATED UNDERGRADUATE DYNAMIC SYSTEMS TEACHING METHODOLOGY UTILIZING ANALYTICAL AND EXPERIMENTAL APPROACHES



**Peter Avitabile**  
**Mechanical Engineering Department**  
**University of Massachusetts Lowell**





# The Problem

*Students generally do not understand how basic STEM (Science, Technology, Engineering and Math) material fits into all of their engineering courses*

*Relationship of basic material to subsequent courses is unclear to the student.*

*Practical relevance of the material is not clear.*

*Students hit the "reset button" after each course not realizing the importance of STEM material*

Reset





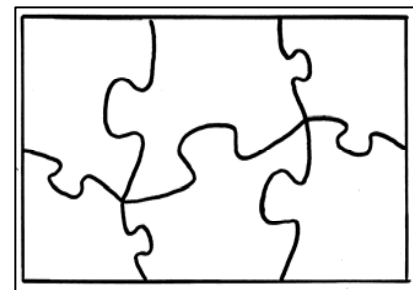
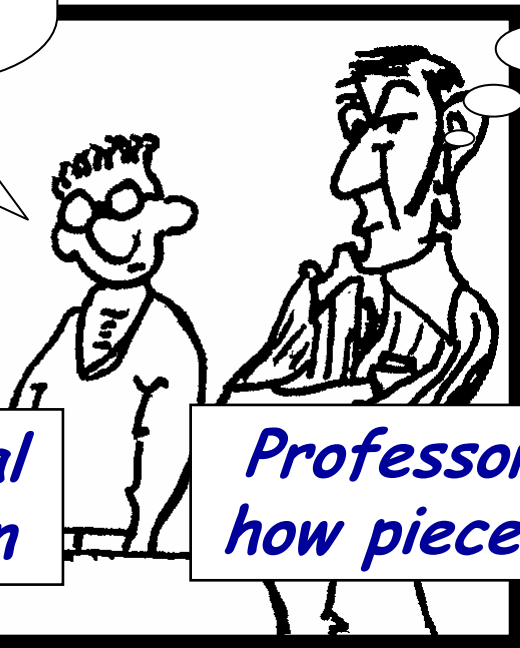
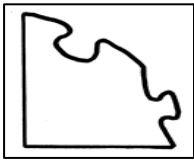
# The Problem

## 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:

*Hmmmmmm...*



*Student views material in a disjointed fashion*

*Professor clearly sees how pieces fit together*





## *How to Solve the Problem*

DYNAMIC  
SYSTEMS

*A new multise­mester interwoven dynamic systems project has been initiated*

*This is to better integrate the material from differential equations, mathematical methods, laboratory measurements and dynamic systems*

*This is done across several semesters/courses to help students better understand the relationship of basic STEM material to an ongoing problem*





# *Some Key Components of This Work*

DYNAMIC  
SYSTEMS

*Analytical Modeling Tools/GUIs*

*Website and Online Acquisition System*

*Projects*

*Integration/Differentiation w/contaminants*

*Fourier Series using LabVIEW*

*Design of a Dynamic Measurement System*

*1<sup>st</sup> and 2<sup>nd</sup> Order System Characterization*

*(many additional smaller projects - see paper)*





# Webpage --- [dynamics.uml.edu](http://dynamics.uml.edu)

DYNAMIC  
SYSTEMS

- Project Overview*
- Technical Papers*
- Tutorials*
- Online Acquisition*
- Downloads*
- Acknowledgements*
- People*

*Tutorials cover a wide assortment of integrated material - both paper tutorials with Matlab and Labview modules with voice annotated multimedia overviews*





CLICK HERE FOR <a href="#">ERRATA</a>		1st Order			2nd Order										Miscellaneous				
		RC Step	RC Filtering	Tank Problem	Initial Conditions	S-Plane	Step	Impulse	System Response	Complex FRF	Arb. Convolution		Motor MDOF	Fourier	Regression	Int/Diff	Windowing and Leakage	VMS	
General Theory	PDF	P			P														
Tutorial	PDF	P	P		P		P	P			P	P	P	P	P				
Block Diagram		P			P														
Matlab GUI	Tutorial	P	P	P	P	P	P	P	P				P	P	P		P		
	Download	6	7	6	7	6	7	6	7	6	7	6	7				6	7	
	Voice	MR	MR	MR	MR	MR	MR	MR	MR	MR					MR	MR			
Excercise	PDF	F	F		F	F	F	F	F	F			F	F	F		F		
	Voice	A	A		A	A	A	A	A	A			A	A	A		A		
LabVIEW GUI	Download	VR	VR		VR		VR	VR	VR		VR	VR	VR	VR			VR		
	Tutorial	P	P		P		P	P	P		P	P	P			P			
	Voice	F	F		F		F	F	F				F			F			
Excercise	PDF	A	A		A		A	A	A				A			A			
	Voice	P	P		P		P	P	P				P			P			
		F	F		F		F	F	F				F			F			
		A	A		A		A	A	A				A			A			
		Intro			GUI Instruction														

**Complete Imagemap of all materials available**

Simulink	P	F	A		P	LTI Viewer and MUX Block	P	Block List	P	Modeling an Impulse	P	State Space and Transfer Function	
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	RUBE 1	RUBE 2
Overview	P	P
Pre-Recorded Data Assignment	R	R
Online Acquisition	F	F
	R	R

LEGEND			
P	PDF File (Requires Acrobat Reader)	M	LabVIEW VI File (Requires LabVIEW 7.1)
6	MATLAB p File (Requires MATLAB 6.5)	VR	LabVIEW EXE File (Includes Runtime Engine)
7	MATLAB p File (Requires MATLAB 7.0)	F	Voice Annotated Flash (Requires Flash Plugin)
MR	MATLAB EXE (With Runtime Engine)	A	Voice Annotated AVI (NOT Streamed - Large)
R	RUBE related material		





## *Theoretical Aspects of First and Second Order Systems*

### *First Order Systems*

- *Modeling Step Response with ODE and Block Diagram*

### *Second Order Systems*

- *Step, Impulse, Initial Condition with ODE and Block Diagrams*

### *Mathematical Modeling Considerations*

- *Fourier Series, Integration/Differentiation, Regression Analysis*

### *Miscellaneous Materials*

- *Simulink and MATLAB Primer Materials*
- *LabVIEW Tutorial Materials*
- *Virtual Measurement Modeling Simulations*
- *Integration/Differentiation Considerations with Contamination*







# Analytical Modeling Tools/GUIs

DYNAMIC SYSTEMS

**MATLAB & LabVIEW**

**UMASS Lowell Single Degree of Freedom System Response GUI**

Mass: 1.0000 (kg) / 2.2046 (lbm)  
 Stiffness: 13.0000 (N/m) / 2.9433 (lbf/in)  
 Damping: 0.1400 (Ns/m) / 0.0315 (lbf·s/in)

Natural Frequency: 1.1697 (rad/sec)  
 Critical Damping: 0.5785 (Ns/m)  
 Damping Ratio: 0.1198  
 Damped Natural Frequency: 1.1601 (rad/sec)

**UMASS Lowell RC Circuit Unit Step Response**

RC Circuit Unit Step Response

**UMASS Lowell RC Circuit Low Pass Filter**

UMASS Lowell RC Circuit Low Pass Filter

**UMASS Lowell Regression Analysis GUI**

UMASS Lowell Regression Analysis GUI

Line Equation:  $0.003x^3 - 0.106x^2 + 1.456x + 0.375$   
 R2 Constant: 0.998817

**UMASS Lowell Single Degree of Freedom System Response GUI**

Initial Displacement: 0  
 Initial Velocity: 0  
 Impulse Magnitude: 0  
 Step Magnitude: 0

Response Type:  Free Response  
 Impulse Response  
 Step Response

Time Response, Frequency Response, Root Locus, All Plots

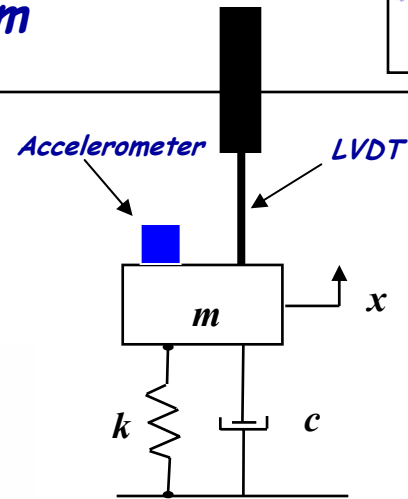
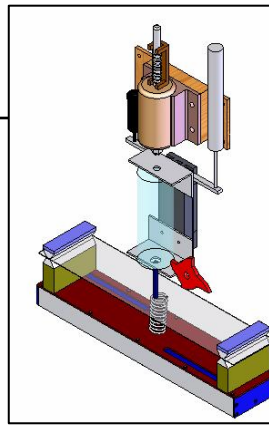




# Online Measurement System

## RUBE

### Response Under Basic Excitation

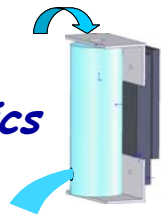


Measurement Devices

Variable Damping

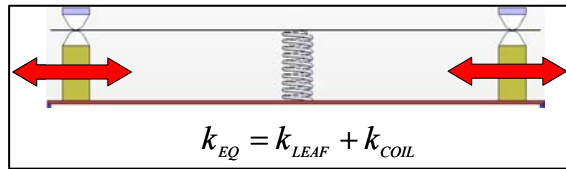


Variable Mass

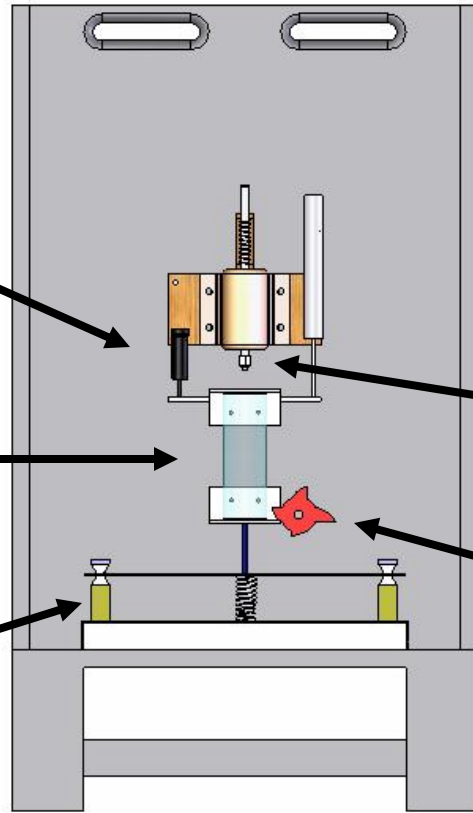


System Characteristics

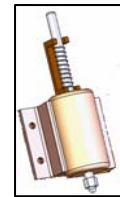
Variable Stiffness



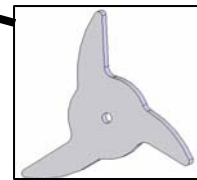
$$k_{EQ} = k_{LEAF} + k_{COIL}$$



Excitation



Impact Force



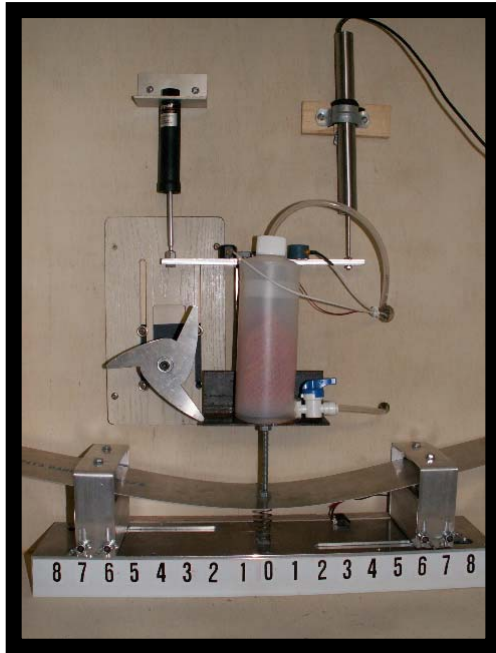
Initial Displacement



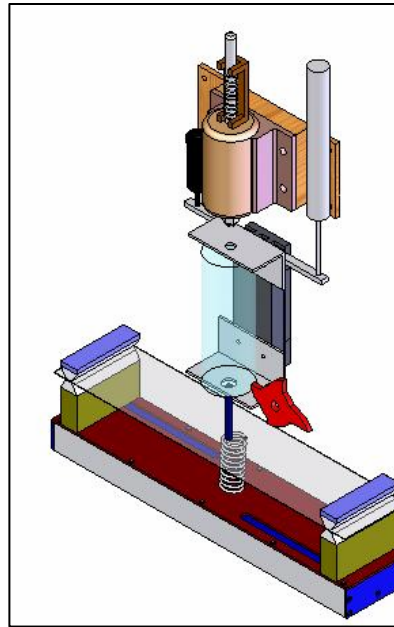


# Online Measurement System

DYNAMIC SYSTEMS



**RUBE I**



**RUBE**  
Response Under  
Basic Excitation



**RUBE II**





# Online Measurement System

DYNAMIC SYSTEMS

RUBE

NSF Dynamic Systems - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address <http://dysys.uml.edu/>

## "RUBE" Response Under Basic Excitation

Edit Operate

Impact is still in development  
Use 'Initial Displacement' only

To gain control of the VI, right-click and select "Request Control of VI"

Start Acquisition STOP

Change Stiffness

Sampling Rate: 500

Excitation Type:  
 Impact  
 Initial Displacement

LVDT Accel 2  
 Accel 1 Accel 3

LVDT  
 Accel 1  
 Accel 2  
 Accel 3

Amplitude

Time

URL to download data (copy and paste into a new browser window)  
[http://dysys-daq.uml.edu:8999/dysys\\_092605\\_0952AM\\_46.html](http://dysys-daq.uml.edu:8999/dysys_092605_0952AM_46.html)

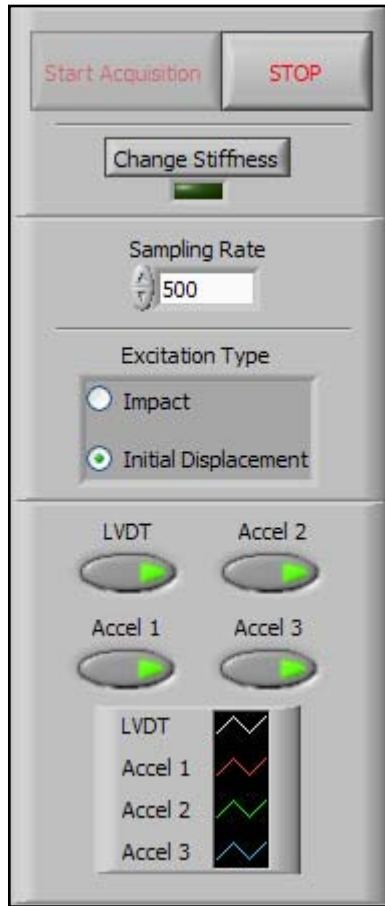
<C> Server: dysys-daq.uml.edu

Done Internet





## RUBE



*System can be remotely run*

*Stiffness is changed for each run*

*Sampling rate can be set*

*Impact is available*

*Initial displacements - three inputs*

*LVDT and accelerometers can be turned on and off as desired*

*Data saved and captured to browser*

URL to download data (copy and paste into a new browser window)  
[http://dynsys-daq.uml.edu:8999/dynsys\\_092605\\_0952AM\\_46.html](http://dynsys-daq.uml.edu:8999/dynsys_092605_0952AM_46.html)

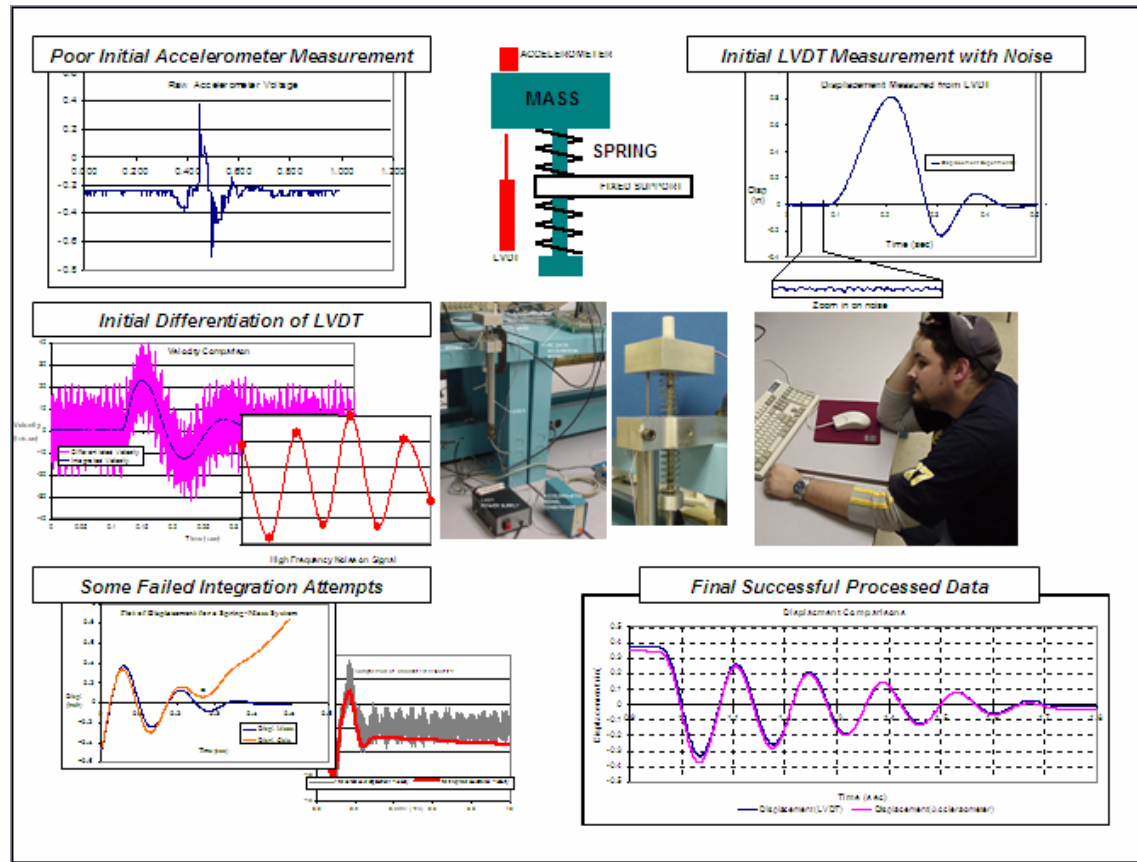




# Contaminants Cause Difficulty

DYNAMIC SYSTEMS

*Students learn with problems that make them think*





# Learn by Doing (not Listening)

DYNAMIC SYSTEMS

## Fourier series come to life with LabVIEW

**Typical Student LabVIEW Block Diagram**

**Typical Student Front Panel GUI**

**Webpage & Voice Annotated Materials**

The Labview Project [Labview Project](#) is contained here and is due... Please make sure that you remember to include your Labview VI... If it is not included then a full assessment of your VI cannot be made...

LabVIEW notes are available here  
[LabVIEW Writing](#) and - a voice annotated executive summary of  
[LabVIEW Introduction Executive Summary](#) overview (needs Flash)

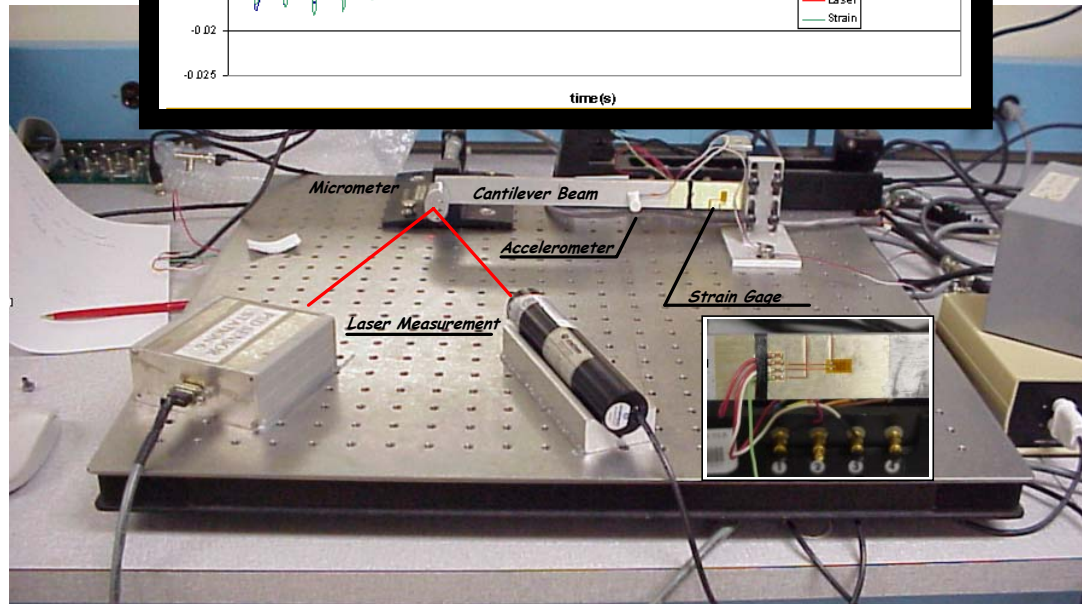
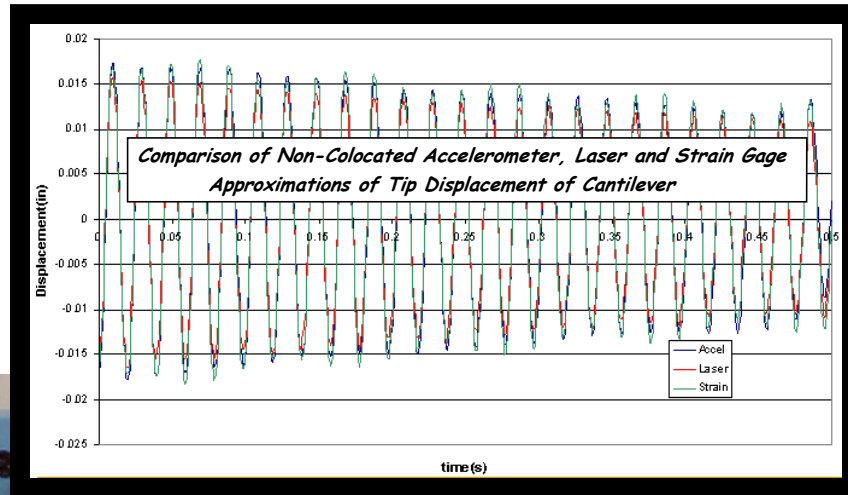
The following voice annotated notes discuss the use of individual tools

- [LabVIEW Change Controls](#) identifies how to create and or...
- [LabVIEW Change Indicators](#) identifies how to create and or...
- [LabVIEW While Loop](#) identifies how to insert user controlled...
- [LabVIEW ADD](#) identifies how to add signals together (needs...
- [LabVIEW MERGE](#) identifies how to merge frequency signals...
- [LabVIEW FFT](#) identifies how to insert Spectral Analysis FFT...
- [LabVIEW Filter](#) identifies how to insert Filter Express VI (s...





## Integration of all material to design system

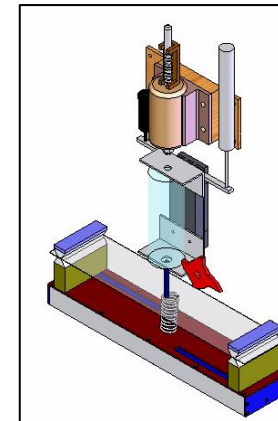
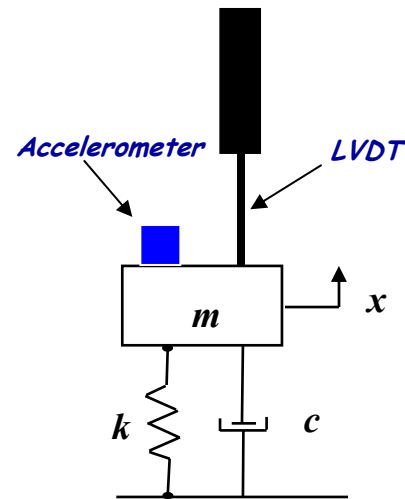






## Projects integrated in with Lecture Material

- Analytical project to force understanding of ODE and Laplace along with MATLAB/Simulink
- RUBE used to strengthen understanding through system identification on less than perfect measurements
- Filtering data through 1<sup>st</sup> order RC filter in Simulink





## *Brief Summarizing Statements*

DYNAMIC  
SYSTEMS

*Only a brief smattering of material presented here*

*The 30 page paper has much more material.*

*The website has a significant amount of material  
(tutorials, exercises, GUIs, etc)  
along with the online measurement system*

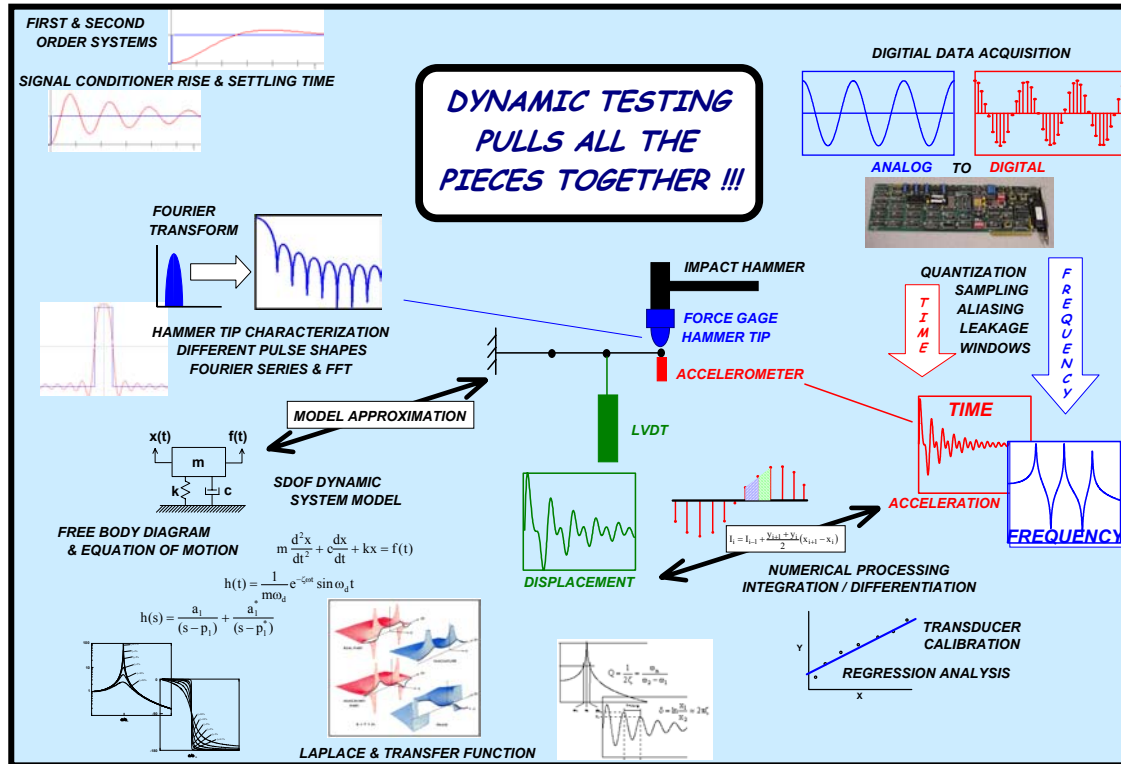




# Acknowledgements

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





# Acknowledgements

*A special thanks to the students who have really been the driving force in making all this happen*



*Tracy Van Zandt, Nels Wirkkala,  
Wes Goodman and Jeffrey Hodgkins  
Mechanical Engineering Department  
University of Massachusetts Lowell*



*I could not have done any of this  
without their dedication and devotion  
to making this all happen*



*I have the pleasure of working  
with them and having them  
contribute to this effort*





# Acknowledgements

*And to the additional students  
who have also participated  
during the final year of the project*



*Adam Butland, Dana Nicgorski,  
Aaron Williams, Chris Chipman  
Mechanical Engineering Department  
University of Massachusetts Lowell*



*They have also  
made significant contributions  
to the overall project*

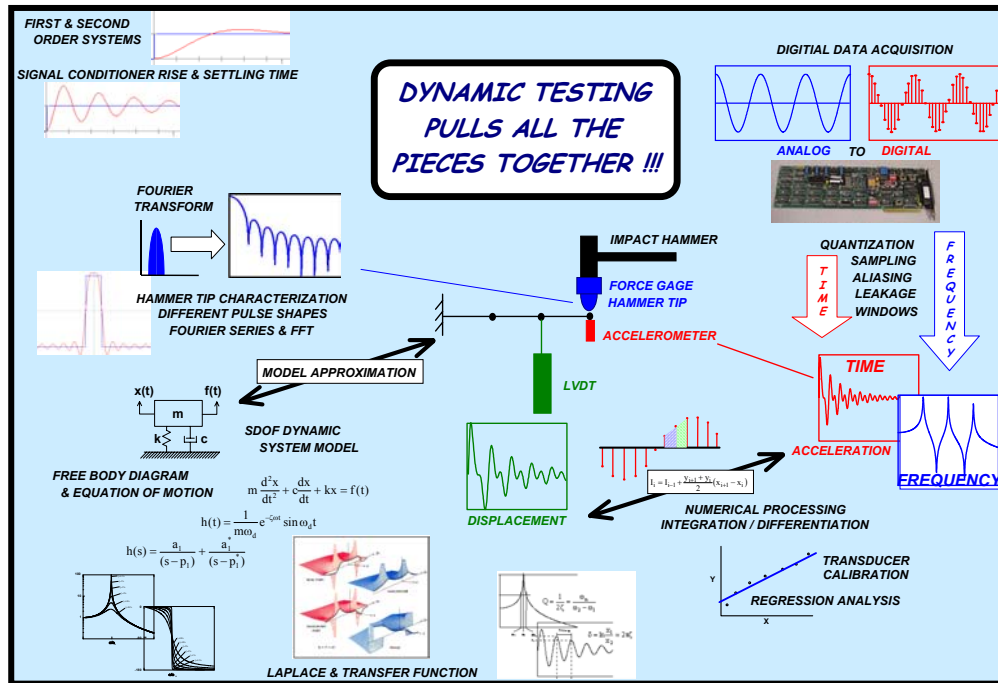


*I am very happy for their  
continued support and dedication*





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