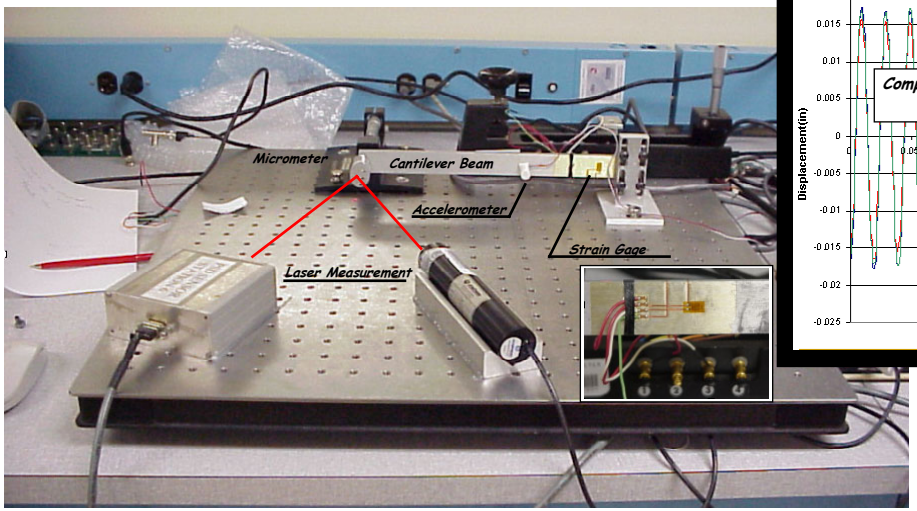
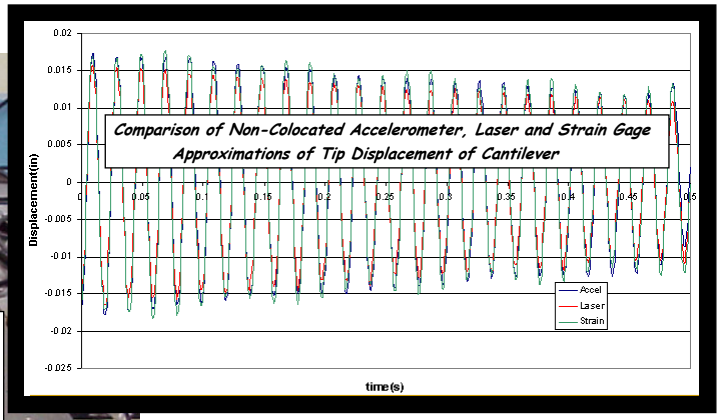
Assessing Dynamic Response from Multiple Sensors

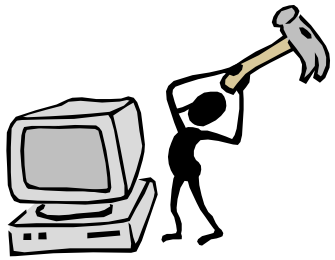




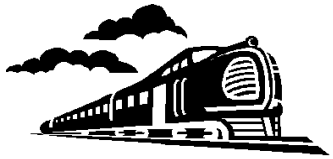
Dr. Peter Avitabile, Assistant Professor
Mechanical Engineering Department

Problem

Computer equipment is subjected to a variety of different loading that must be considered in the design process



MISC LOADS



TRANSPORTATION LOADS

OPERATING LOADS

DROP LOADS

Problem

DYNamic SYStems

Disk drive response due to drop loadings

- Disk drives are sensitive devices
- Drop loads can cause detrimental effects
- Measurements of response are needed
- How can this be accomplished?

high speed video showing drop load

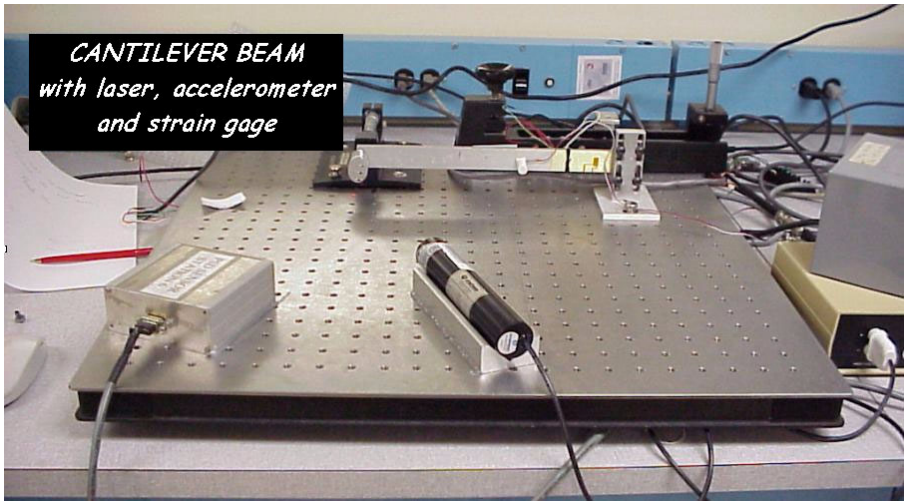
Assessing Dynamic Response from Multiple Sensors

- Delicate structure may be sensitive to various external loadings
- Measurements of response may be needed to determine/assure adequate performance is achieved
- Various transducers are available for measurement of response
- Spatial location to optimize digital measurement is necessary

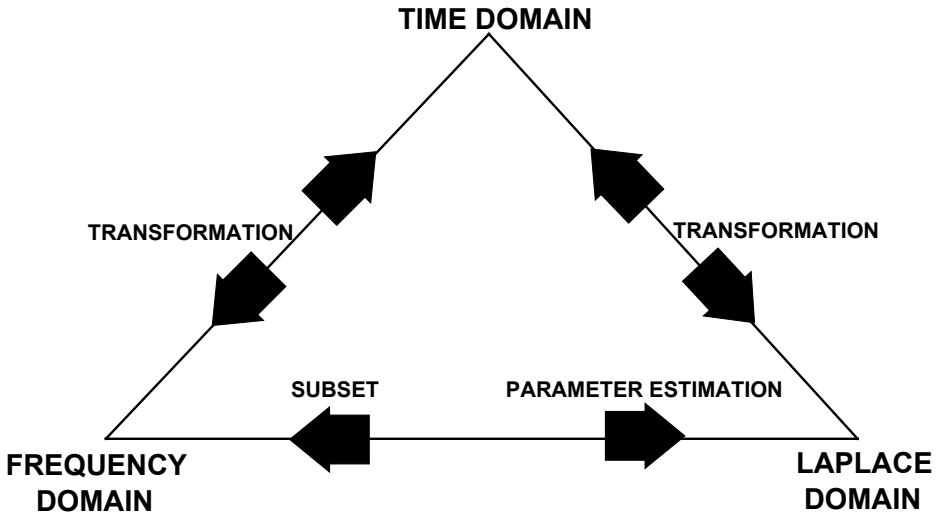
Measurement Considerations

Assessing Dynamic Response from Multiple Sensors

- Response due to loadings needs to be determined
- Measurements of displacement, velocity and acceleration using LVDT, laser, accelerometers, strain gages, eddy current probes are options for transducer selections



Different Ways to Solve the Same Problem



* Time domain represents the physics of the system

* Frequency domain represents the system in terms of it's periodicities

* Laplace domain represents the system in terms of its poles and residues

Equivalent System Model Representation

DYNamic SYStems

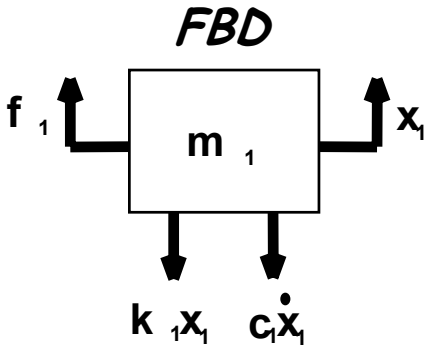
The beam can be modeled in an equivalent sense

Homogenous equation is

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

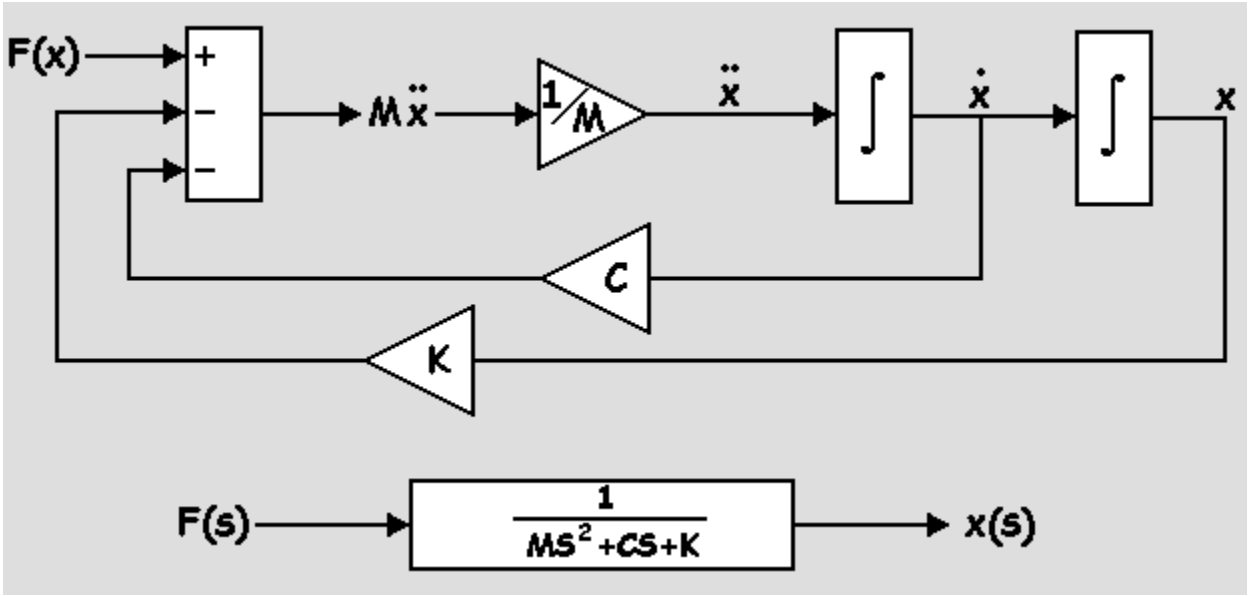
and assuming an exponential solution form gives

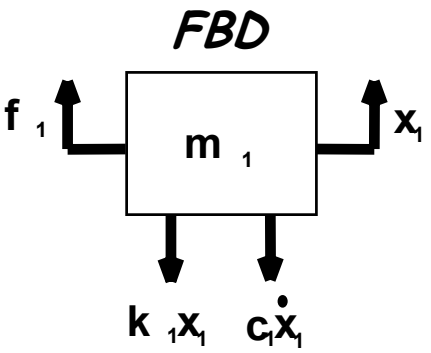
$$\left(ms^2 + cs + k\right)e^{st} = 0$$



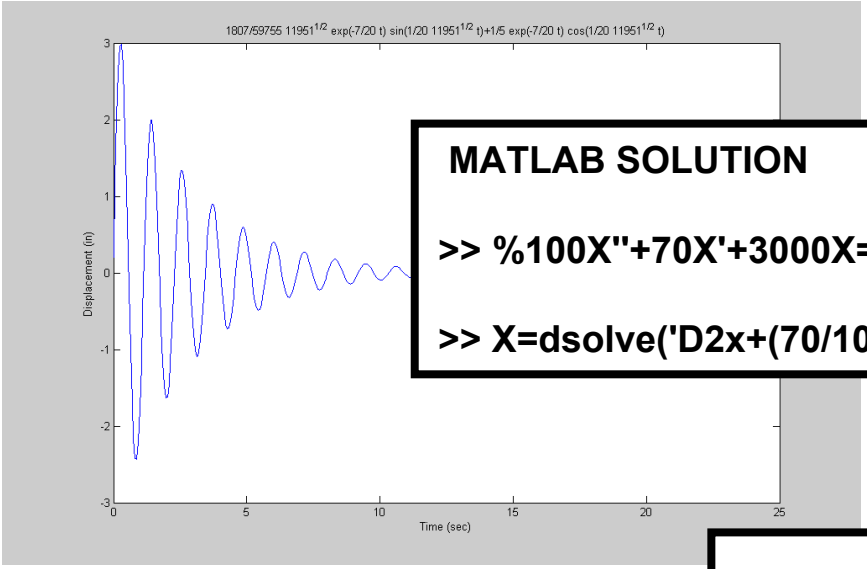
Block Diagram Form

The system can be modeled in block diagram form





MATLAB and SIMULINK Solutions

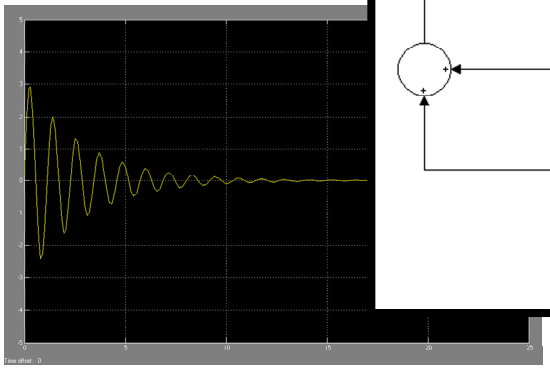


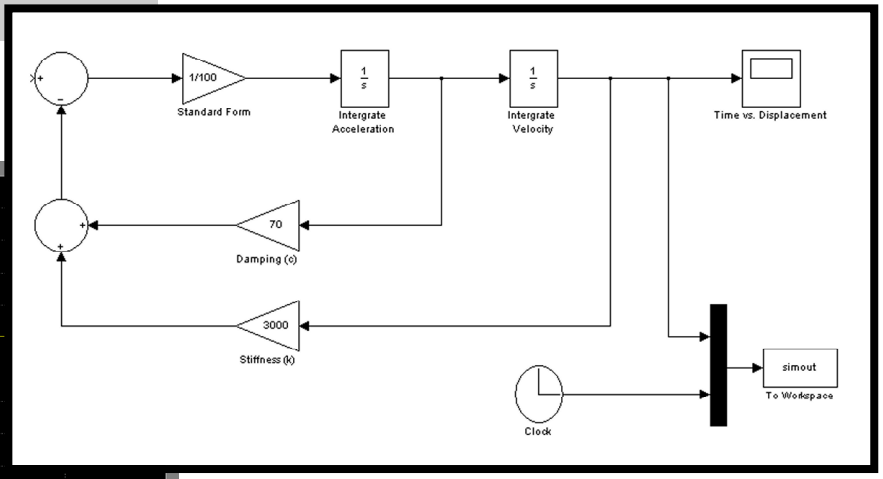
MATLAB SOLUTION

```
>> %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



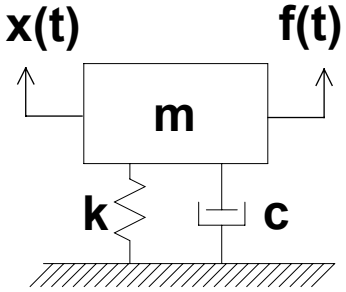


Laplace Transform – Flow Diagram

DYNamic SYStems

The second order differential equation can be written as

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



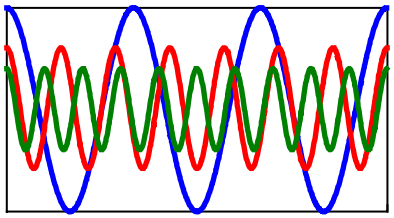
Laplace Transformation gives

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

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

Fourier Domain – Signal Flow Diagram

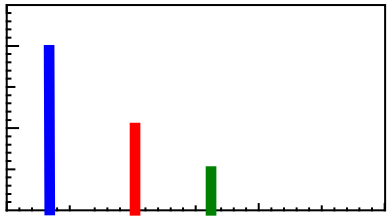
The Fourier Domain is just a subset of Laplace



INPUT TIME FORCE

f(t)

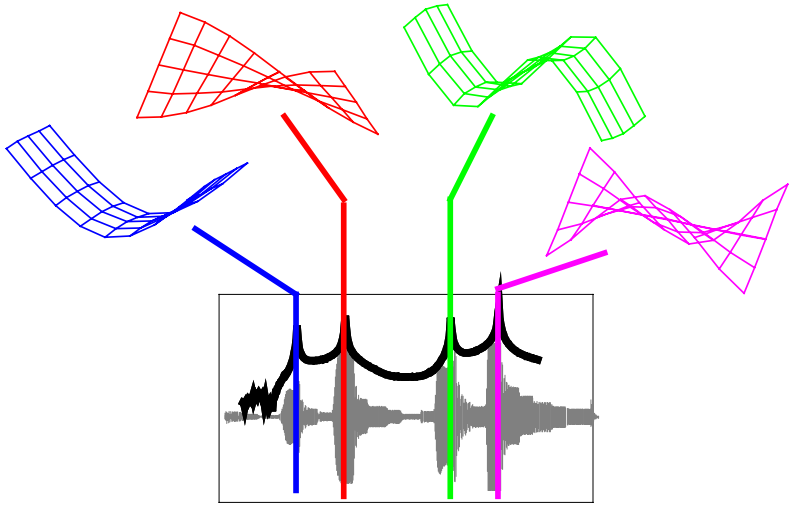
FFT



INPUT SPECTRUM

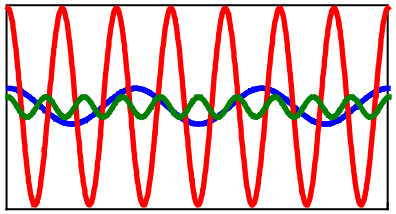
f(jω)

Sinusoidal Forcing Functions



FREQUENCY RESPONSE FUNCTION

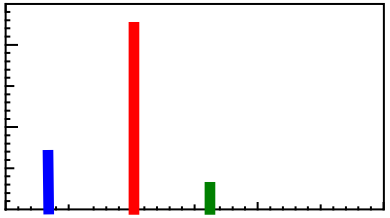
h(jω)



OUTPUT TIME RESPONSE

y(t)

IFT



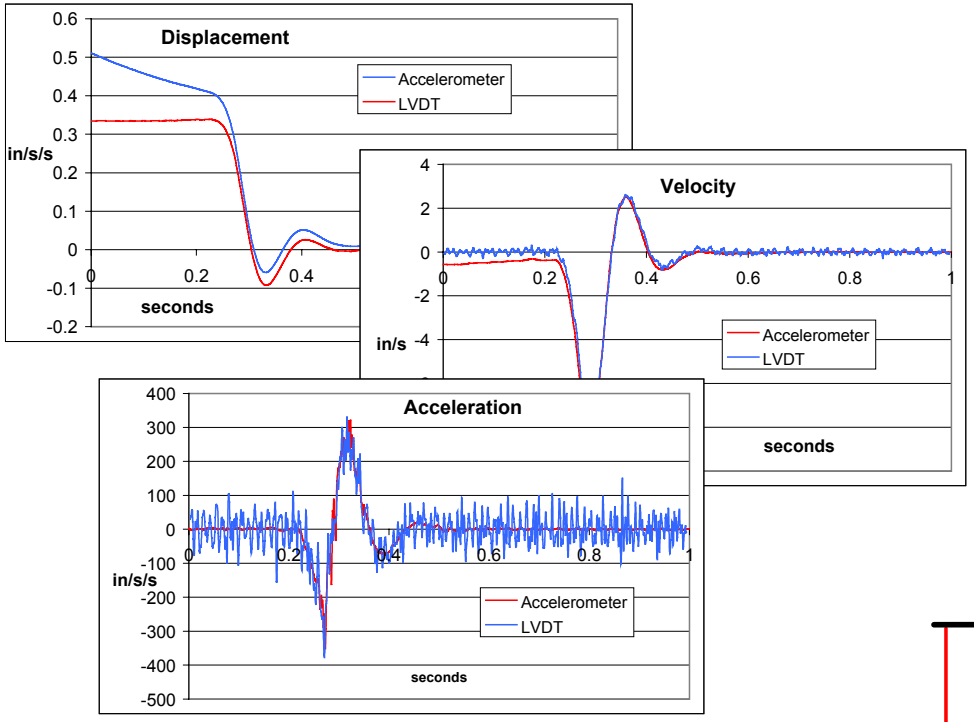
OUTPUT SPECTRUM

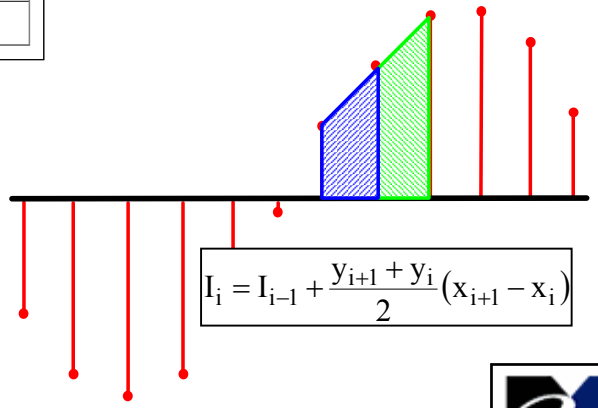
y(jω)

Numerical Integration/Differentiation

DYNamic SYStems

The differential equation could also be processed in the time domain using numerical techniques





$$I_i = I_{i-1} + \frac{y_{i+1} + y_i}{2}(x_{i+1} - x_i)$$

Evaluation of Measurement Locations

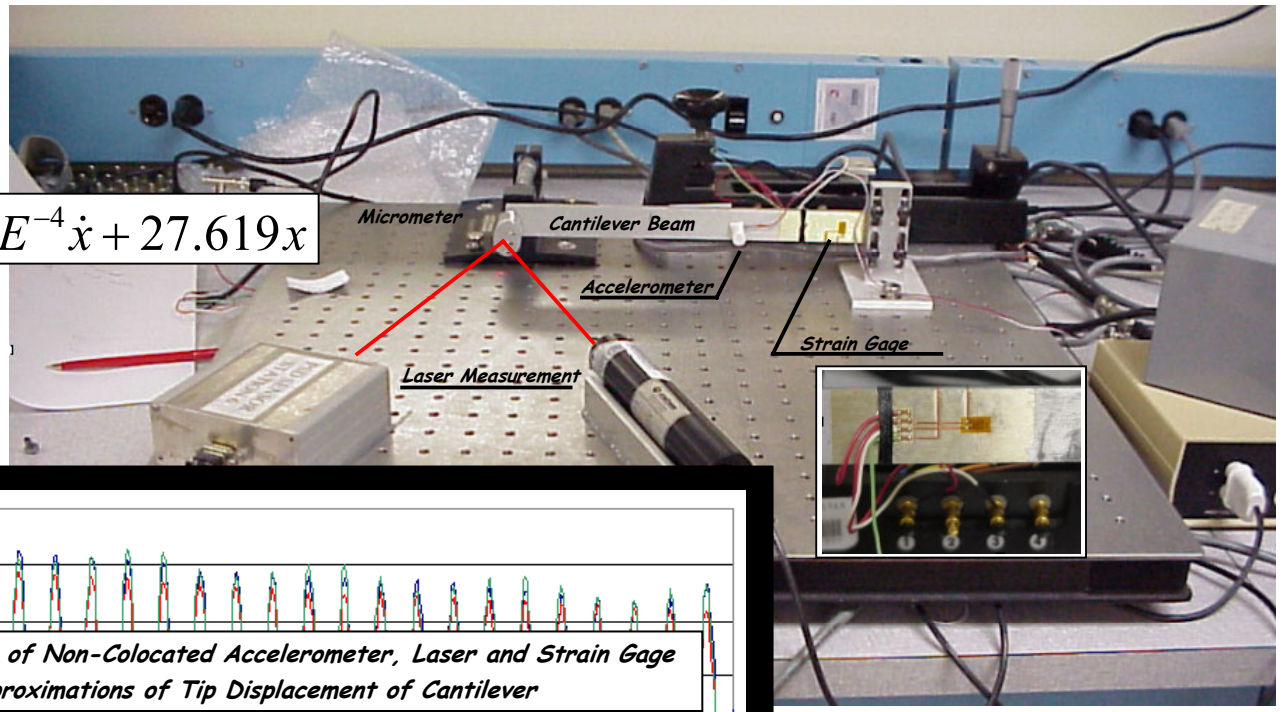
DYNamic SYStems

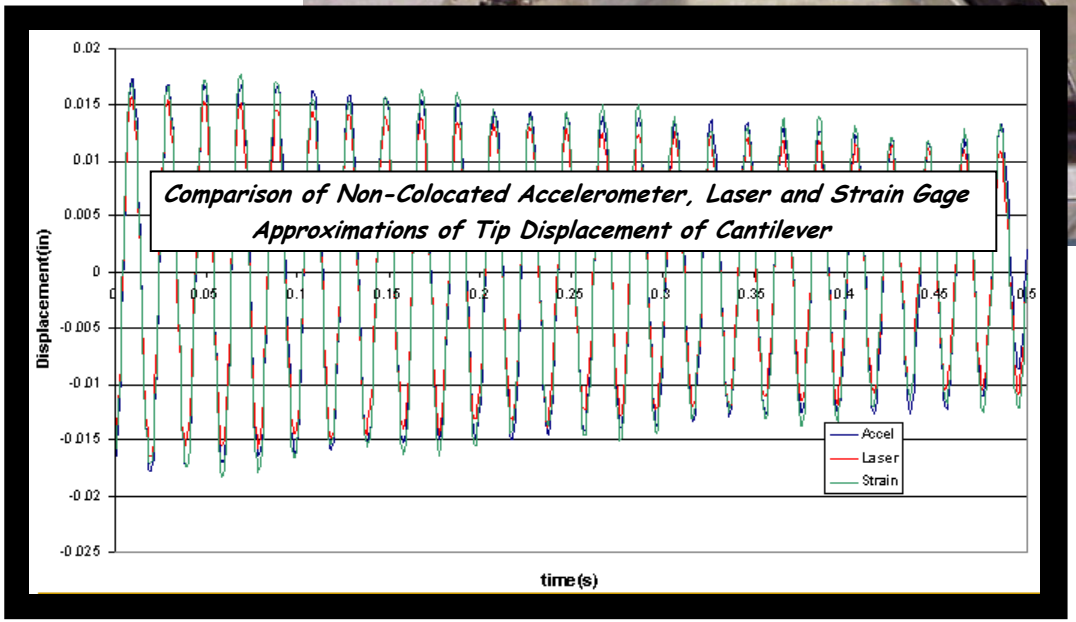
Need to know ……

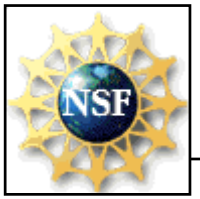
- *Strength of Materials (beam characteristics)*
- *Dynamics (mass, inertia properties)*
- *ME Lab (digital data acquisition)*
- *Numerical Methods (integration, differentiation)*
- *Math (ODE, Laplace, Fourier Series)*

Senior Project Results

$$2.96E^{-4}\ddot{x} + 4.15E^{-4}\dot{x} + 27.619x$$







Skill Sets Needed

DYNamic SYStems

MATLAB/SIMULINK assist in problem evaluation

- Must have a firm understanding of underlying math related to problem
- Computer software helps provide solution to underlying mathematical formulation
- Upper level students are expected to have a firm understanding of basics to solve the problem
- Engineers utilizing tools to solve critical problems clearly must understand the basic underlying mathematical principles involved

Acknowledgements

This project is partially supported by
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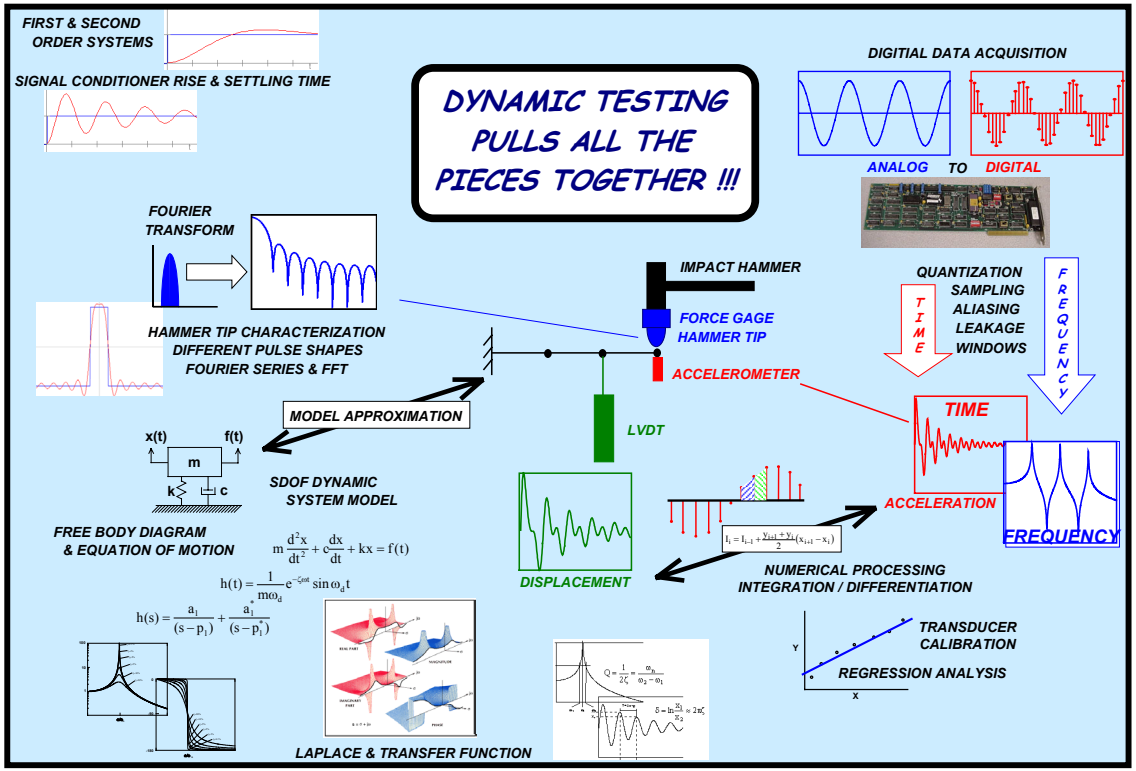
Multi-Semester Interwoven Project for Teaching Basic Core STEM Material Critical for Solving Dynamic Systems Problems



Peter Avitabile, John White, Stephen Pennell