My first foray into incorporating differential equation modeling projects in my classroom

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About me

- I have been teaching college math classes for 25 years
- I love applications of any kind

A favorite class

Linear Algebra and Differential Equation

- Systems of equations, matrices, vector spaces, and eigenvalues. Linear and nonlinear differential equations, systems of differential equations, and their applications. Designed for engineering students.
- Class size 30-40 students

Textbook

- Edwards/Penney/Calvis: Differential Equations & Linear Algebra, 4e

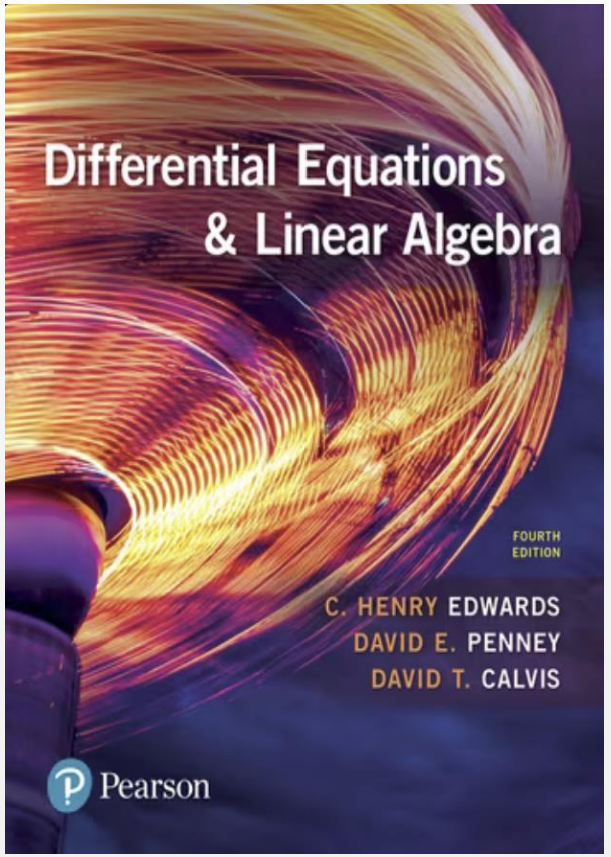
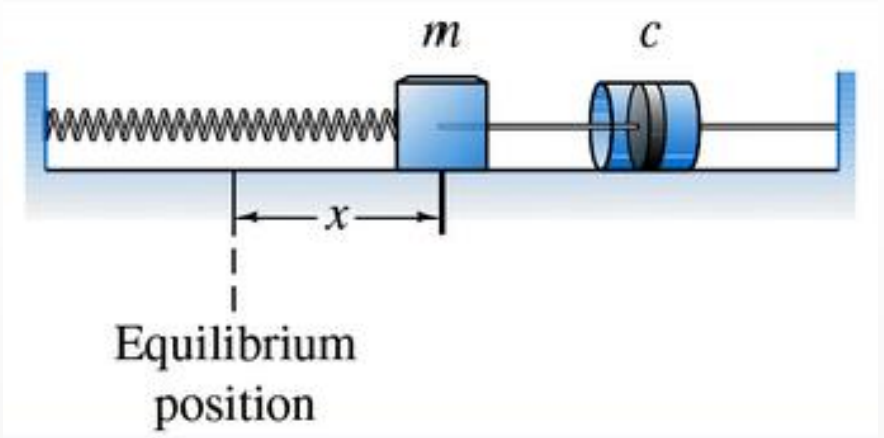
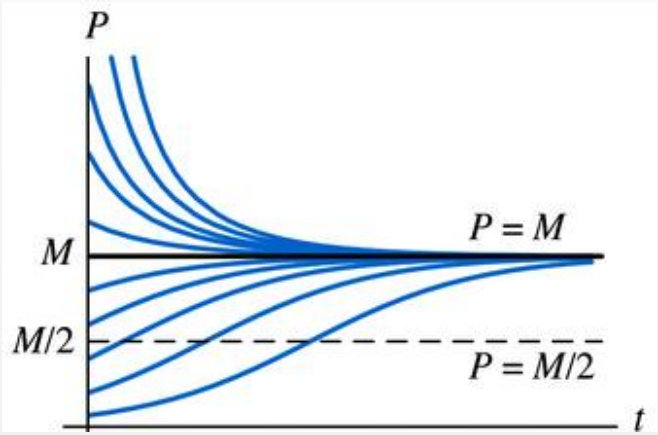


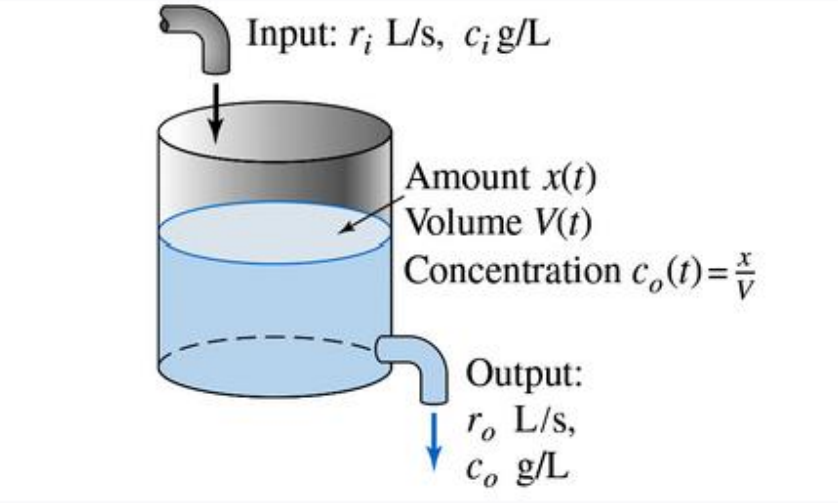
Image source: pearson.com

Modeling in the textbook

- Population Models
- Velocity and Acceleration
- Mechanical Vibrations
- Mixtures







Images source: Edwards/Penney/Calvis: Differential Equations & Linear Algebra, 4e

Challenges

- Time-consuming
  - background explanations
  - DE derivation
  - homework
- and …

Student Evaluations

- Only occasionally saw what purposes this math had and I would like to see more how some of these concepts could apply better.

During my recent sabbatical

- Activity: Prepare for the implementation of student projects
- Goal: Give my students the opportunity to experience the material they are learning in interdisciplinary, real-life applications.

To this end

- Participated in the MAA Open Math SIMIODE workshop, Modeling Inspiration for Differential Equations, and follow-up workshops
  - project examples
  - modeling software
  - experience in the modeling process
  - peer discussion of using modeling in the classroom
- Judged student projects for the SIMIODE Challenge Using Differential Equations Models (SCUDEM)
- Attended the conference SIMIODE EXPO 2023, which focused on modeling

Image source: SIMIODE EXPO 2024 flyer

The nuts and bolts

- Big project(s) at the end of the semester instead of a final exam
- Last 5 class meetings were set aside for projects

Goals

- Teamwork
- Research skills
- Professional writing
- Low pressure
- High learning
- Above all… FUN!

Project topics

Other educators ideas

- SIMIODE

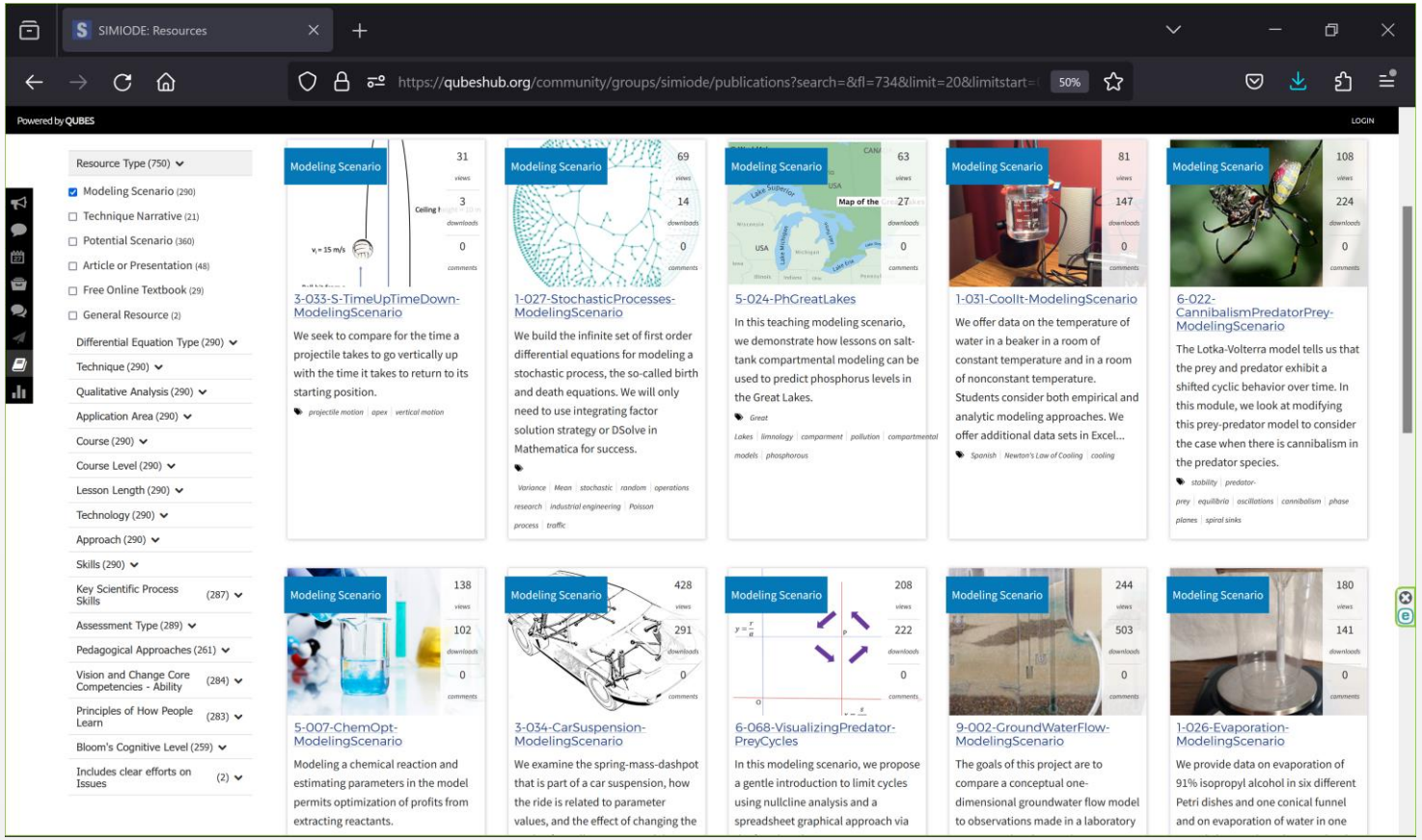
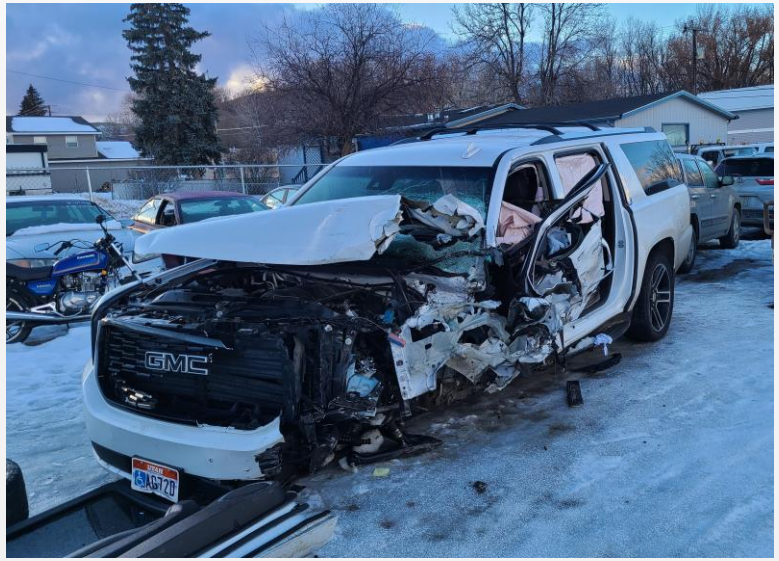


Image source: https://qubeshub.org/community/groups/simiode/publications

Ideas around me

- Trampoline
  - length
  - rectangular vs circular
  - size
- Collision problem
  - vehicle spun
- Football
- Covid



Images source: personal photos

I asked students for ideas

- Thinking about any projects or research you have done in the past, is there anything you would like me to incorporate into our end-of-semester project? Are there topics or ways of going about a project that you prefer?

Their answers—general ideas

- have choices
- work in groups
- clear expectations
- research books related to class topics
- engineering applications
- implement technology
- visual simulations
- hands-on
- discuss careers/DEs with engineering professionals

Their answers—specific topics

- out-flows, rainwater fill of a dam
- football
- gas consumption and efficiency of vehicles
- displacement/acceleration of buildings due to earthquakes
- springs and dampers

The result

- Decided to allow students to pick their topics

Groups

?

Options

- Entire class work on one project
- Small groups
- Individual projects

The result

- Groups of 1 to 4 students

Assignment

- Last five class meetings of the semester were devoted to projects
- Students were to use the class time to work on the projects
- Divided up the projects in smaller assignments

Day 1 (Due by midnight before Day 2)

1) Form groups of 1 to 4 people. Give your team a name.

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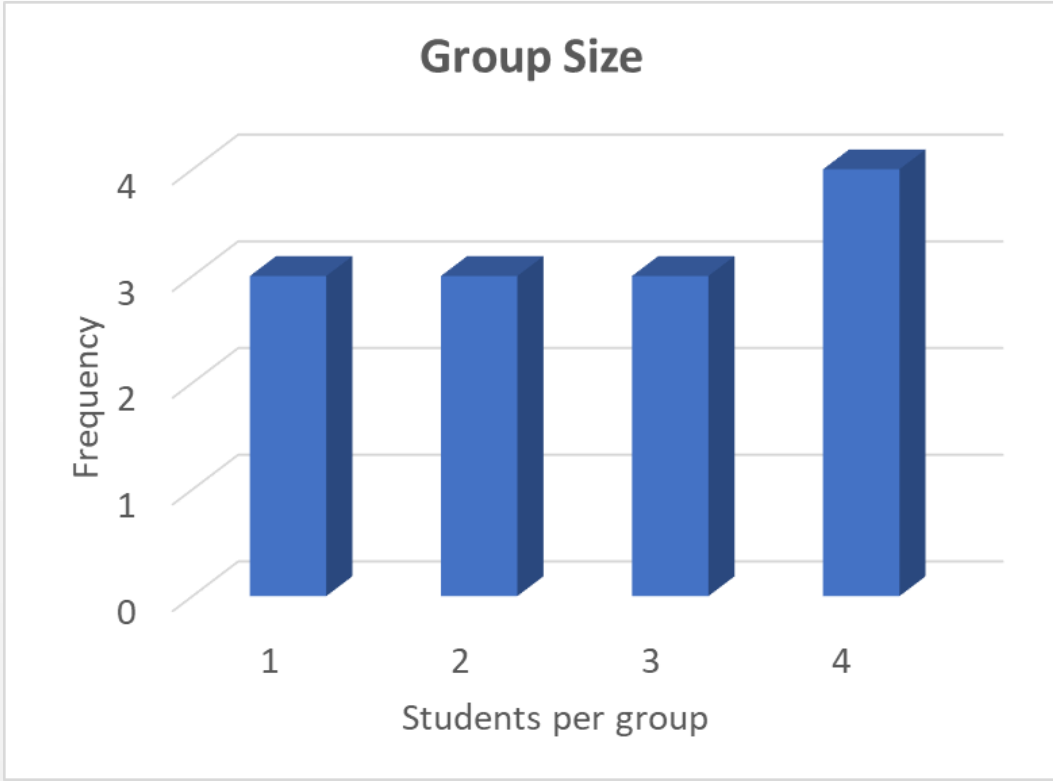

Day 1 (Due by midnight before Day 2)

1) Form groups of 1 to 4 people. Give your team a name.

- Three Final Brain Cells
- Just Surviving
- Vector Spaces
- Green Card Seekers
- Back Row Joes

Day 1

2) Pick a topic that interests your group that relates to differential equations.

Day 1

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- dance
- spring systems
- suspension in a car
- predator-prey relationship
- free fall

Day 1

2) Pick a topic that interests your group that relates to differential equations.

- rock climbing
- kinematic equations
- population
- robotics
- car accidents
- green cards

Day 1

3) Create a project title.

Day 1

3) Create a project title.

- Collision Calculus: Analyzing Car Accidents through the Lens of Differential Equations
- Kinematics, let's get moving
- Population Growth and Decline of the Predator Prey Relationship of Deer and Mountain Lions as it Relates to Differential Equations

Day 1

4) Write a brief introduction about
- the topic you are researching
- the questions you are endeavoring to answer
- why the topic is important and/or interesting.

Day 1

- The United States, renowned as the land of opportunity, attracts individuals from across the globe seeking to build a better future. One crucial aspect of this journey involves the attainment of a green card, granting permanent residency and opening the doors to lots of possibilities. As The Green Card Seekers, we delve into the realm of differential equations to understand the dynamics influencing the percentage of people successfully obtaining this status.

Day 2 (Due by midnight before Day 3)

1. Outline what you would like to accomplish and break it down into tasks.
2. Assign team members to various tasks. The tasks should not take more than 3 hours per person.
3. Make a list of possible sources.
4. Make a list of possible technologies you may use.

Day 2 (Due by midnight before Day 3)

Make a list of possible sources.

- Google Scholar
- YouTube
- Textbooks
- Articles

Day 2 (Due by midnight before Day 3)

Make a list of possible technologies you may use.

- simulators
- MatLab
- Python
- Excel
- Desmos
- AI

Day 3 (no specific due date)

- Work on accomplishing tasks. Treat Day 4 as the deadline for stopping.

Day 4 (due by midnight on Day 5)

- Write a brief progress report of how the tasks went.
- I managed to find a few simulations of population growth online and after reading through some articles about environmental sciences I better understand what factors can affect population growth in an environment, and how multiple competing species can impact one another in a given environment.

Day 5 (due by midnight on the first day of finals week)

- Write a rough draft of a project report that is at least 5 pages.

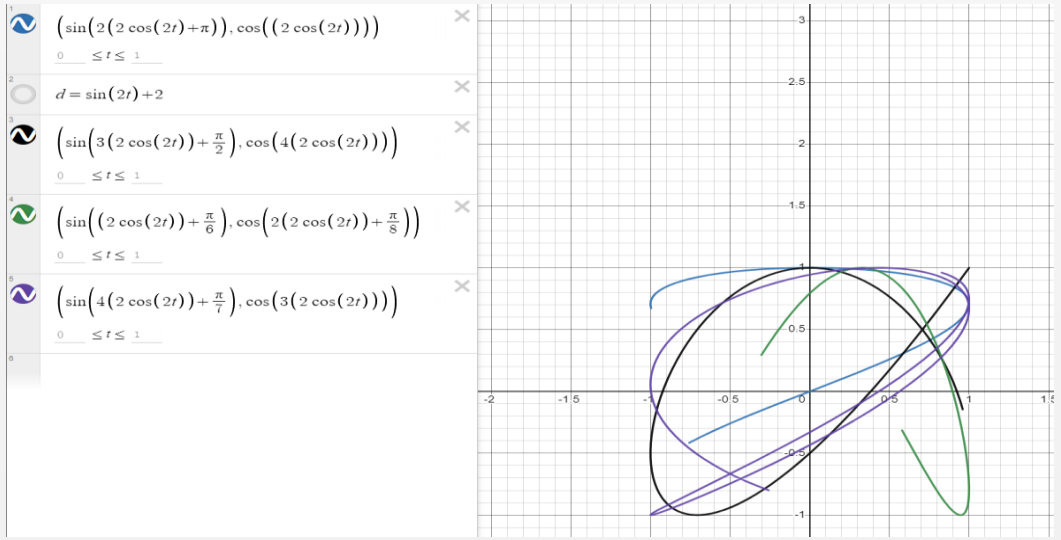
Finals week (due by midnight the last day of finals)

- Write the final draft of the project report.

Dance

Dancing Through Differentials: How Differential Equations Explain Dance

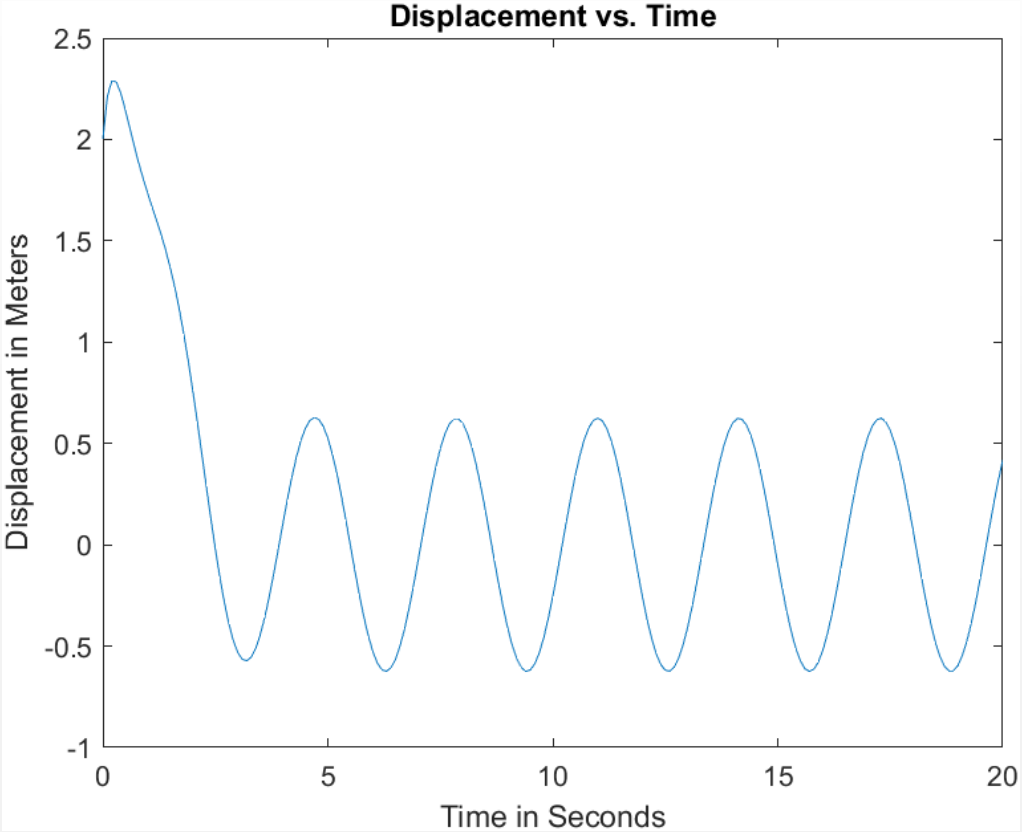
- … each exercise had … a mathematical equation attached to it explaining how each muscle is affected, as well as how each muscle affects the others around it. This inspired our project…



Spring Systems

Calculating Spring Systems with External Sine Forces

- … creating a Matlab program that will take various defined variables and return the kind of spring function, vectors of displacement and velocity, and a graph of displacement vs time, as well as a velocity vs time graph.



Mass Spring System

Modeling Mass Spring Systems with Damping

- describing how different scenarios affect a mass spring system with damping. The three different scenarios are underdamped, overdamped, and critically damped.

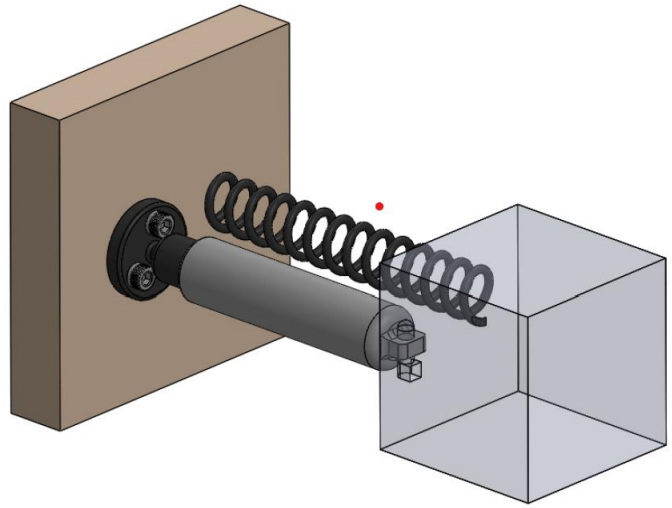
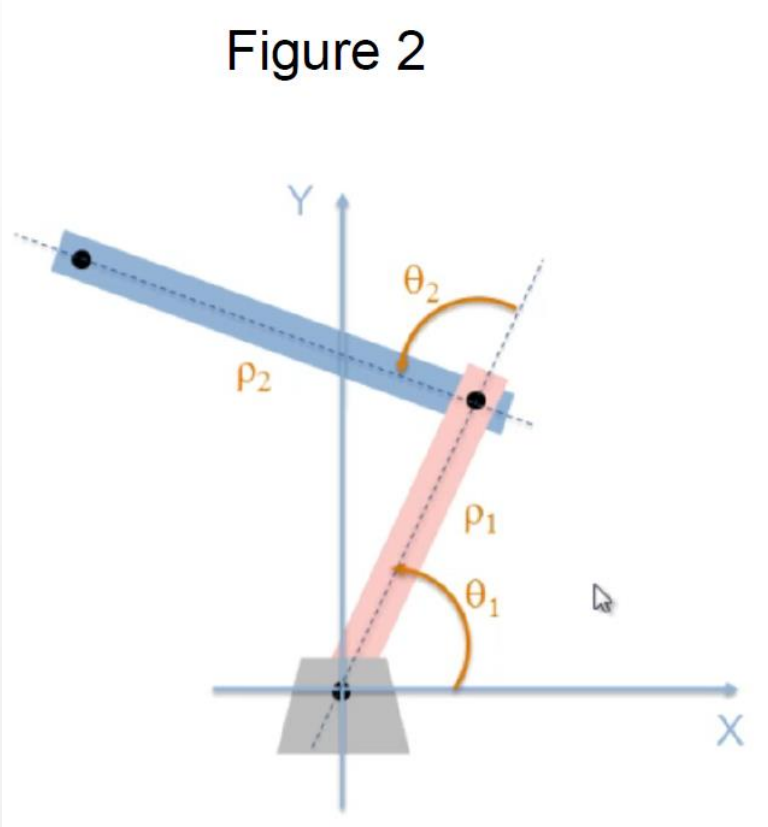


Figure 2: SolidWorks mass spring damping system in compression

Robotics

Turning Differential Equations into a Robot

- how to incorporate differential equations into coding for a moving robotic arm.



What went right

- Teamwork
- Excellent writing
- Variety of topics
- Not overly burdensome to students

What went not so right

- missing the creative modeling process
- missing technology

Adjusting upcoming projects

Encourage

- use of technology
- use of a variety of sources
  - Search engines
  - Articles and books
  - Talk with experts
- experiment and create

What I can do in my classroom

- teach where various DEs come from
- experiment with modification of basic models
- increase use of technology

Acknowledgements

- Brian Winkel, director of SIMIODE
- My last semester's class who served as guinea pigs and excelled in the process

Thank you!