Resources for Instructors Teaching Controls Courses and Labs

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Controls Design Products
MathWorks

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Controls Product Marketing
MathWorks

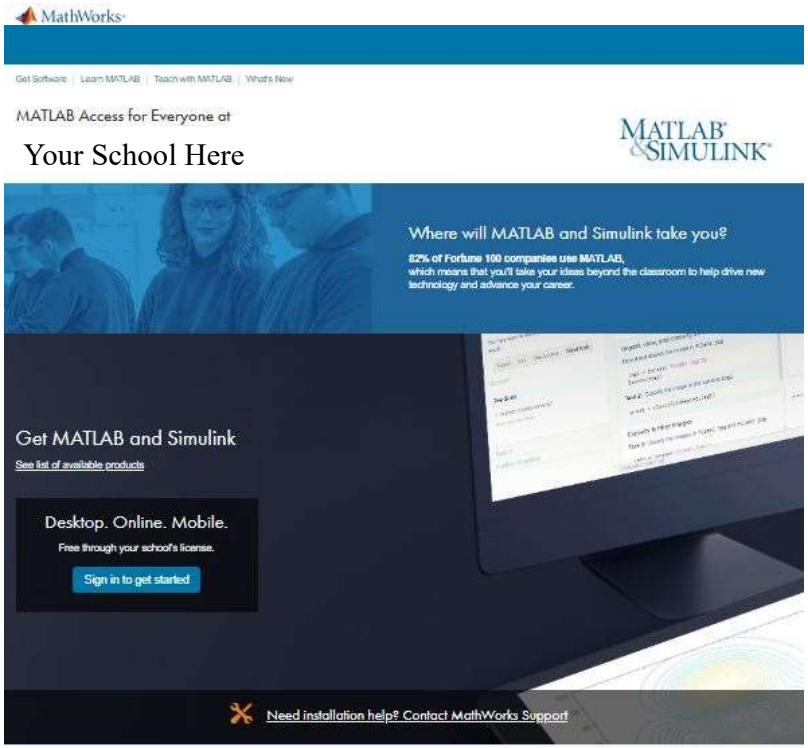
Key takeaways

- We help students learn fundamental concepts; acquire MATLAB and Simulink skills
- We help educators preparing course materials and curriculum
- We make it easy to do real-life projects and access to MATLAB and Simulink from everywhere

ACCESS | INSTRUCTION | ASSESSMENT | GETTING HELP

ACCESS | INSTRUCTION | ASSESSMENT | GETTING HELP

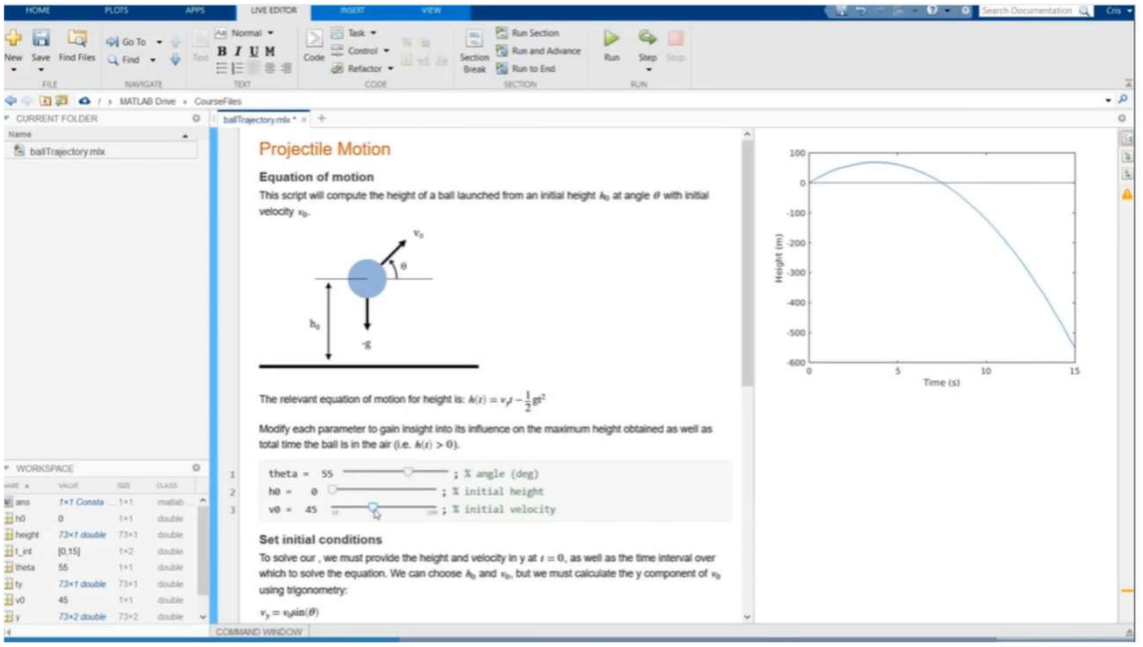
Campus Wide License



https://www.mathworks.com/academia/tah-support-program/eligibility.html

Access MATLAB and Simulink from any standard web browser with MATLAB and Simulink Online

- No downloads or installations required
- Always run latest version of MATLAB and Simulink
- Collaborate with others through online sharing and publishing
- Store, manage, and access your files anywhere



https://www.mathworks.com/products/matlab-online.html

ACCESS | **INSTRUCTION** | ASSESSMENT | GETTING HELP

Free Self-Paced Interactive Tutorials for Students

MATLAB Onramp

Get started quickly with the basics of MATLAB.

Simulink Onramp

Get started quickly with the basics of Simulink.

Control Design Onramp with Simulink

Get started quickly with the basics of feedback control design in Simulink.

Reinforcement Learning Onramp

An interactive introduction to reinforcement learning methods for control problems.

Machine Learning Onramp

An interactive introduction to practical machine learning methods for classification problems.

Deep Learning Onramp

Get started quickly using deep learning methods to perform image recognition.

Stateflow Onramp

Learn the basics of creating, editing, and simulating state machines in Stateflow.

Simscape Onramp

Learn the basics of simulating physical systems in Simscape.

Signal Processing Onramp

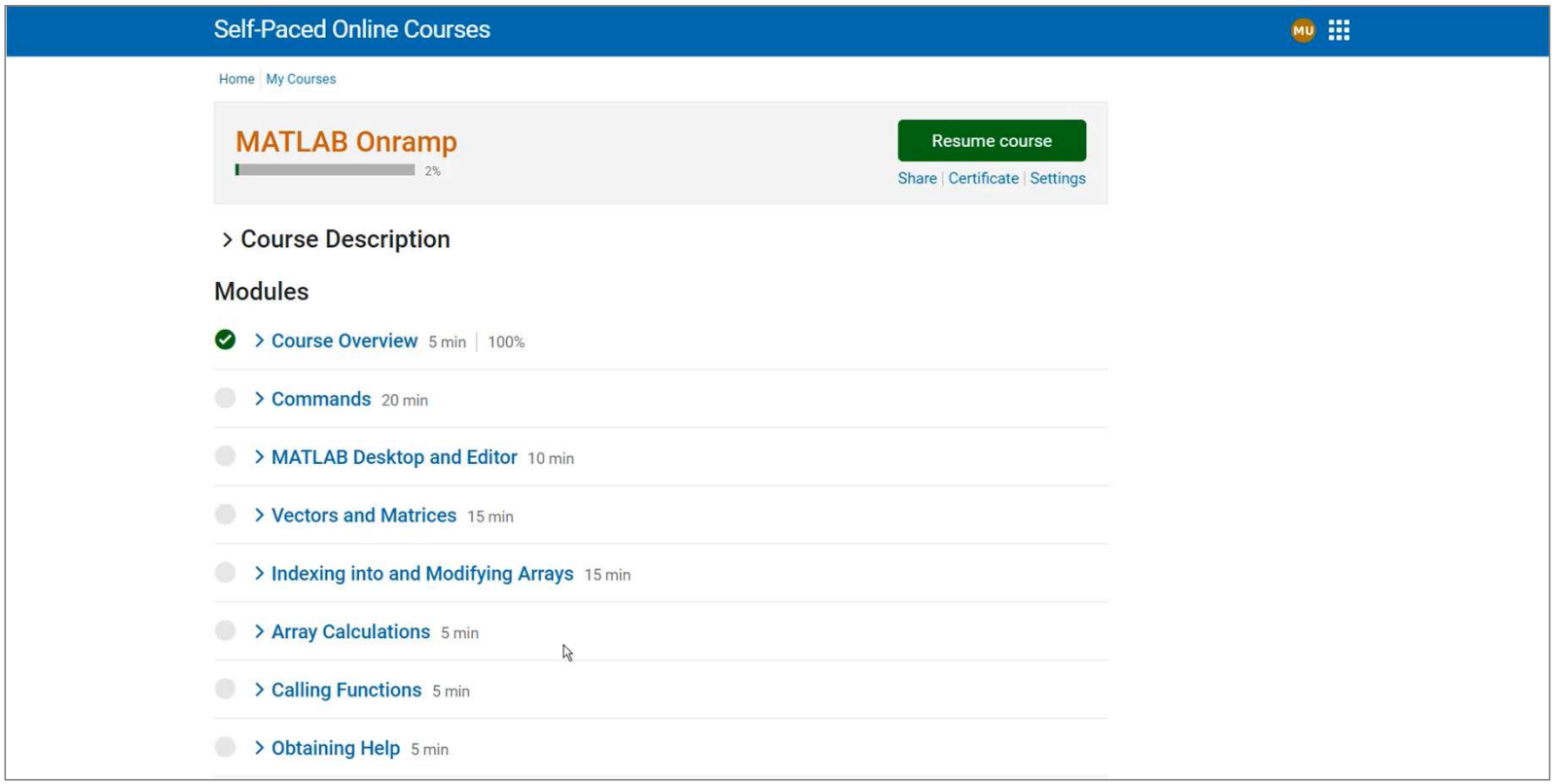
An interactive introduction to practical signal

Image Processing Onramp

Learn the basics of practical image processing

https://matlabacademy.mathworks.com/

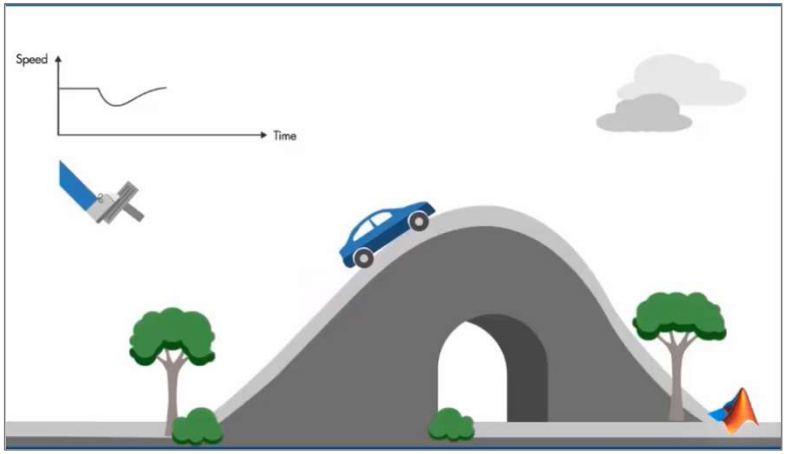
MATLAB Onramp



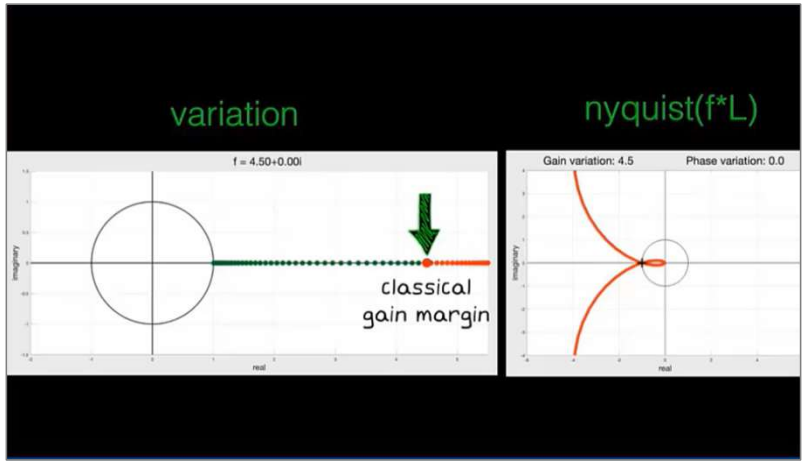
MATLAB Tech Talks: Educational Videos for Students

Use free educational videos to supplement your teaching of controls concepts

- Series of short videos
- Help students gain intuition into complex controls concepts



https://www.youtube.com/c/matlab/videos



https://www.mathworks.com/videos/tech-talks/controls.html

MATLAB Tech Talks Library

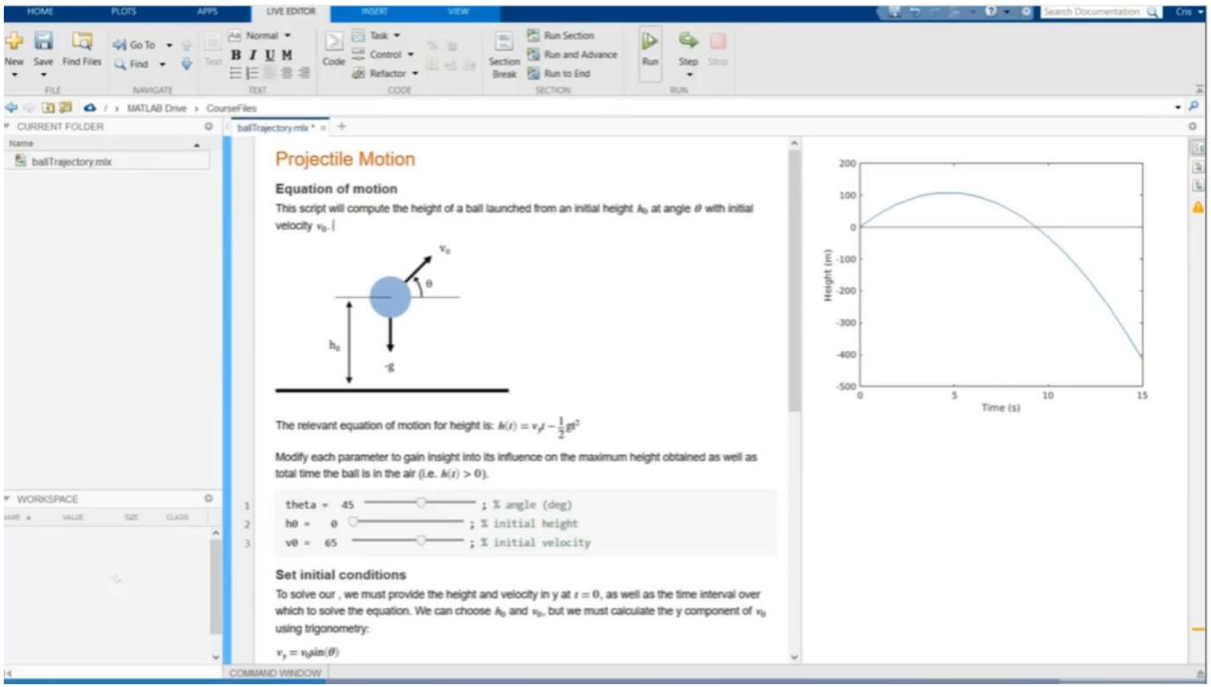
- Learning-Based Control
- Robust Control
- Fuzzy Logic
- Model Predictive Control
- Reinforcement Learning
- Machine Learning
- Deep Learning
- Motor Control
- Kalman Filters
- PID Control
- Bode Plots
- Introduction to Controls
- Trimming and Linearization
- Sensor Fusion and Tracking
- Autonomous Navigation
- Discrete-Event Simulation
- Drone Control and Simulation

https://www.mathworks.com/videos/tech-talks

Teach with Interactive Live Scripts

Create engaging lectures that combine

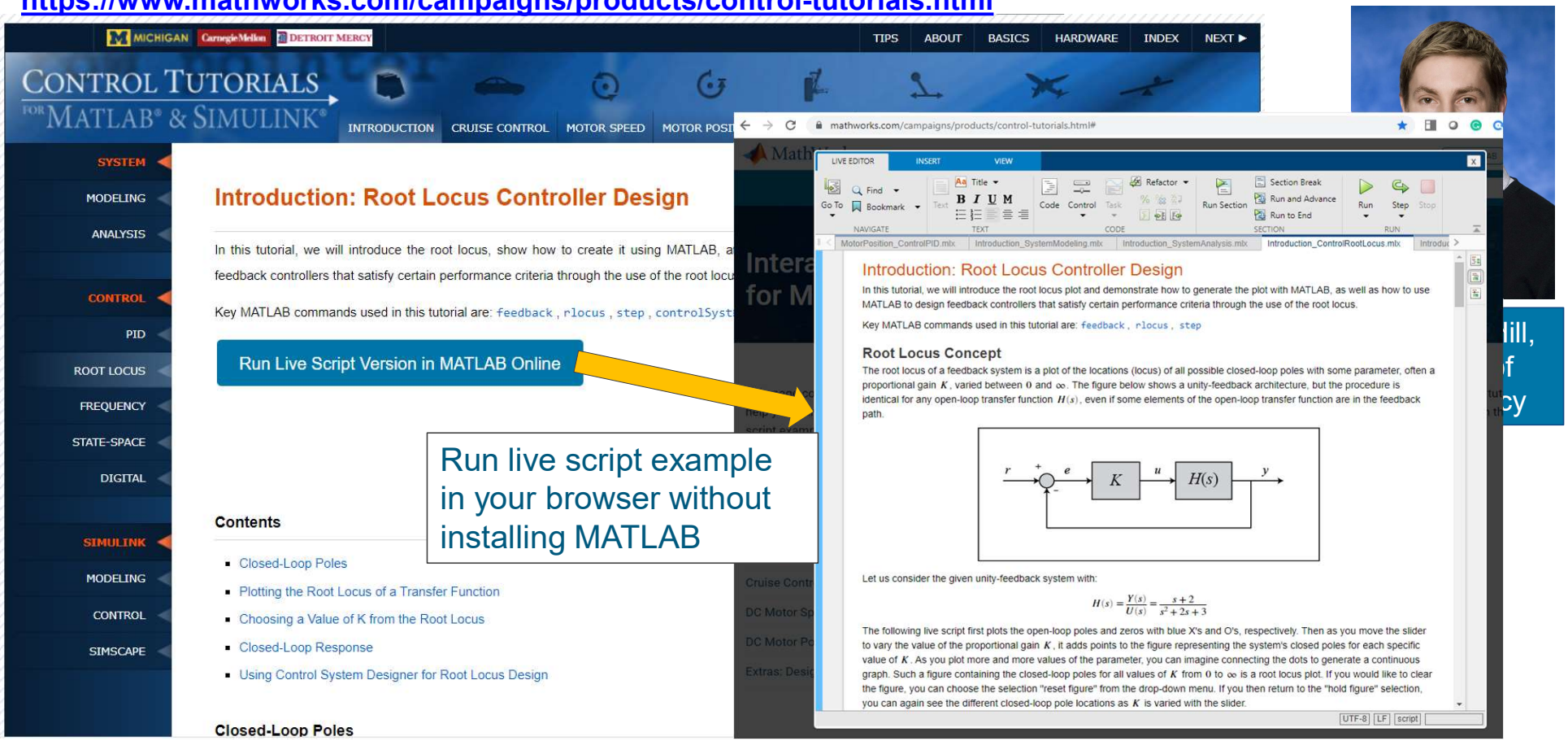
- Code
- Interactive controls
- Outputs
- Visualizations
- Formatted text



https://www.mathworks.com/products/matlab/live-editor.html

Interactive Live Script Control Tutorials for MATLAB and Simulink

https://www.mathworks.com/campaigns/products/control-tutorials.html



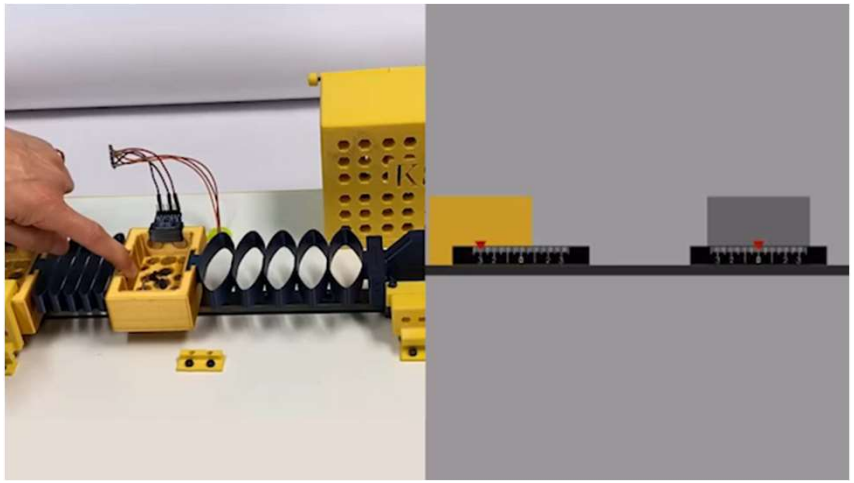
Run live script example in your browser without installing MATLAB

Project-Based Learning: Virtual Labs

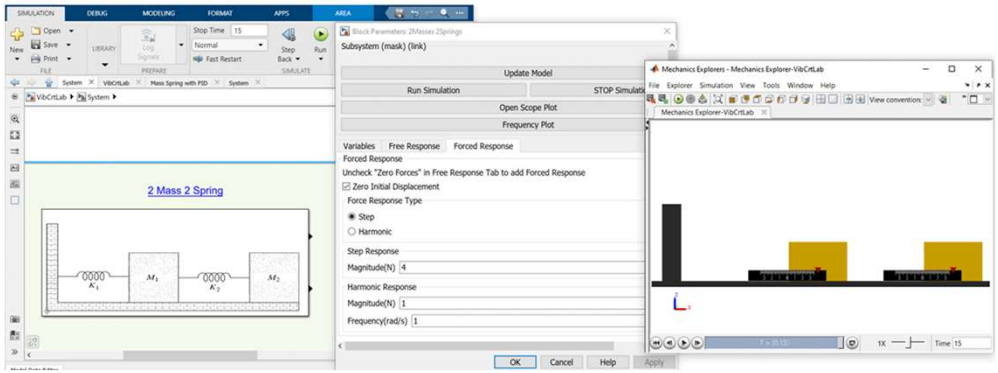
Vibration and Controls Labs using Simscape

- Students can adjust the parameters of the virtual dynamic system such as mass-spring-damper and view system response in 3D
- Virtual labs can be downloaded at http://facultyweb.kennesaw.edu/atekes/GUI%20Program.php

Prof. Ayse Tekes, Kennesaw State University



Mass-spring system lab equipment (on the left) and the simulation (on the right)



Virtual labs for vibration and control analysis in Simscape

Project-Based Learning using Low-Cost Hardware

Hardware Support Packages for MATLAB and Simulink

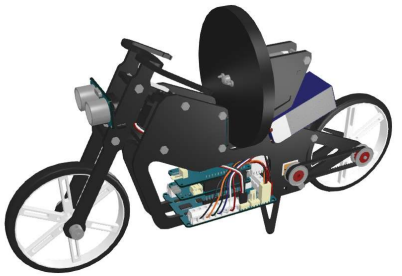
- Connect MATLAB and Simulink to hardware platforms for project-based learning
- Over 150 support packages, for Arduino, Raspberry Pi, LEGO Mindstorm, Parrot minidrones, iPhone, webcams, Kinect and more

http://www.mathworks.com/hardware

Project-Based Learning using Arduino Engineering Kit

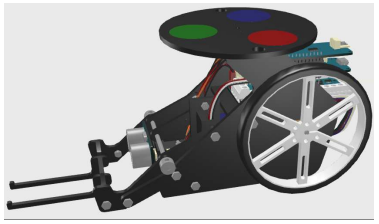
Self-balancing motorcycle

- Maneuvers itself on varying terrain and remains upright using a flywheel for balance
- Concepts: Controls, IMU sensing, filter design, system modeling, simulation



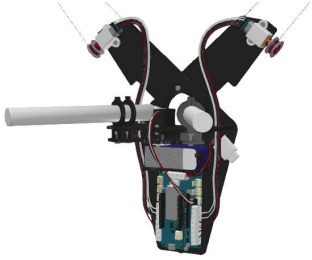
Mobile rover

- Navigates between reference points, locates and moves objects with a forklift
- Concepts: Robotics, system modeling, simulation, controls, object tracking, localization



Drawing robot

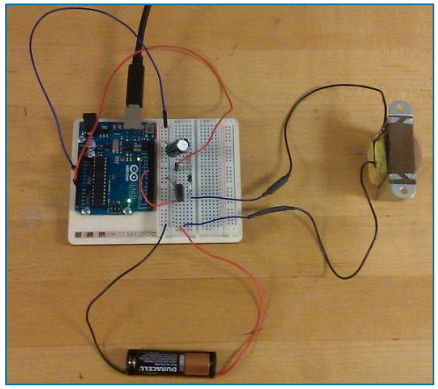
- Takes a reference drawing and duplicates it on a whiteboard
- Concepts: Image acquisition & processing, optimization, kinematics



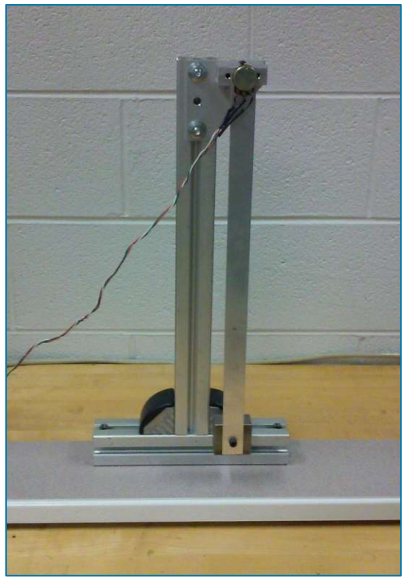
https://www.mathworks.com/campaigns/products/arduino-kit.html

Project-Based Learning using Low-Cost Hardware

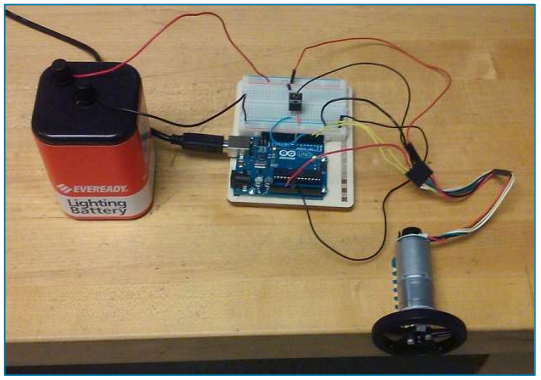
- **Simple and Inexpensive Hardware Experiments for the System Dynamics and Controls Curriculum (ACC 2015 Sponsored Special Session)**
  - Professor Rick Hill, University of Detroit Mercy



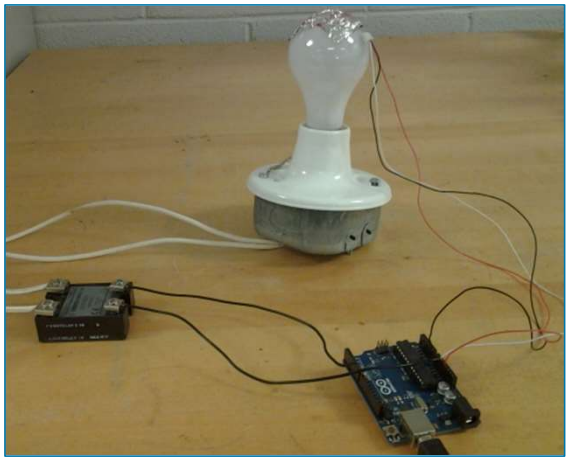
Electrical Circuits



Mechanical Systems

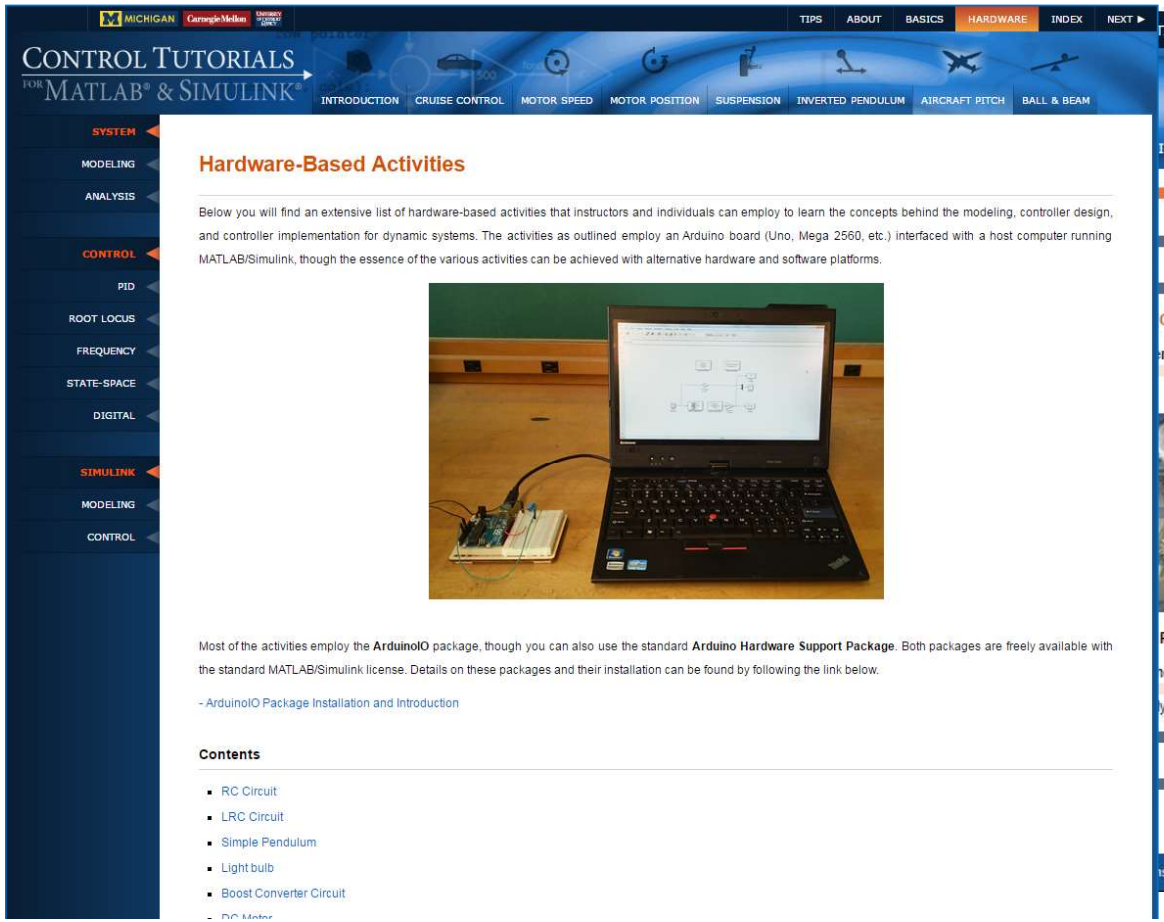


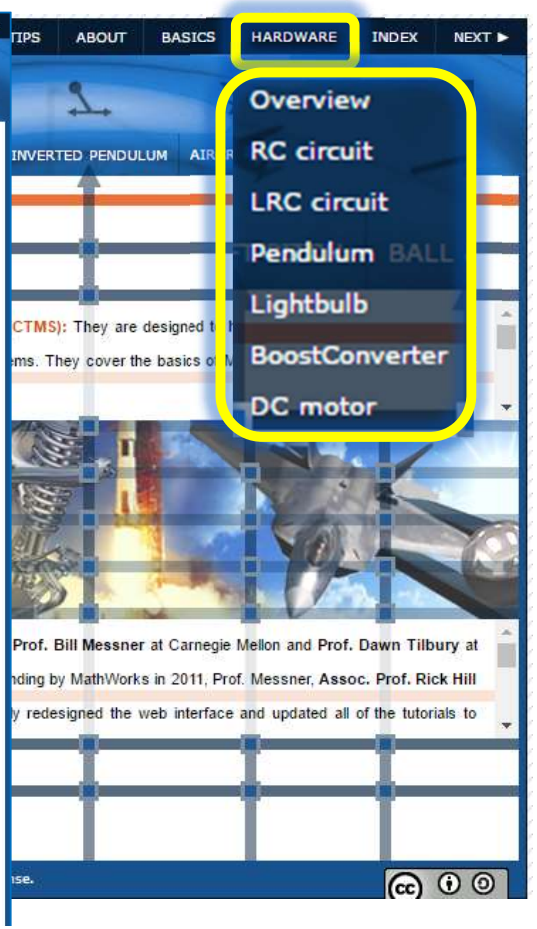
Electromechanical Systems



Thermal Systems

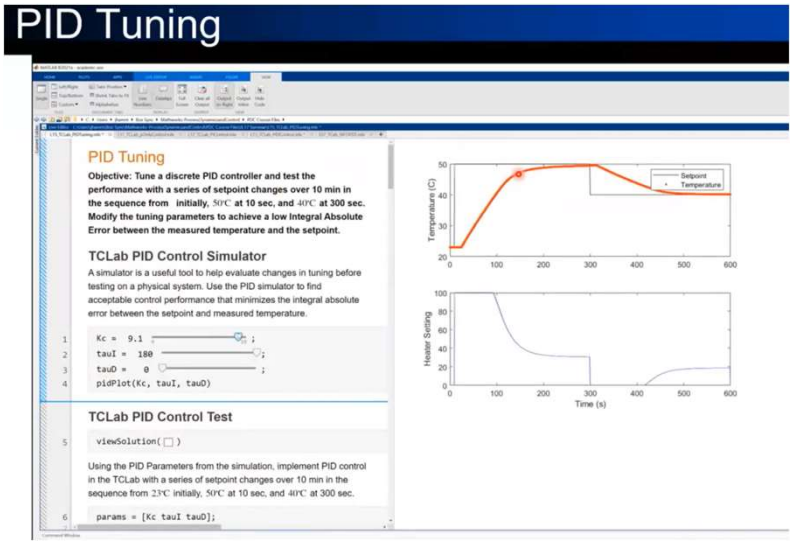
Project-Based Learning using Low-Cost Hardware





Project-Based Learning using Low-Cost Hardware

- **Hands-on Process Control Experiments with the Arduino-Based TCLab**
  - Interactive live script-based modules (35) include
    - Theory: Lesson
    - Simulation: Assignment
    - Labs: Temperature control
  - Modules available at: https://github.com/APMonitor/mdc



Prof. John Hedengren, Brigham Young University

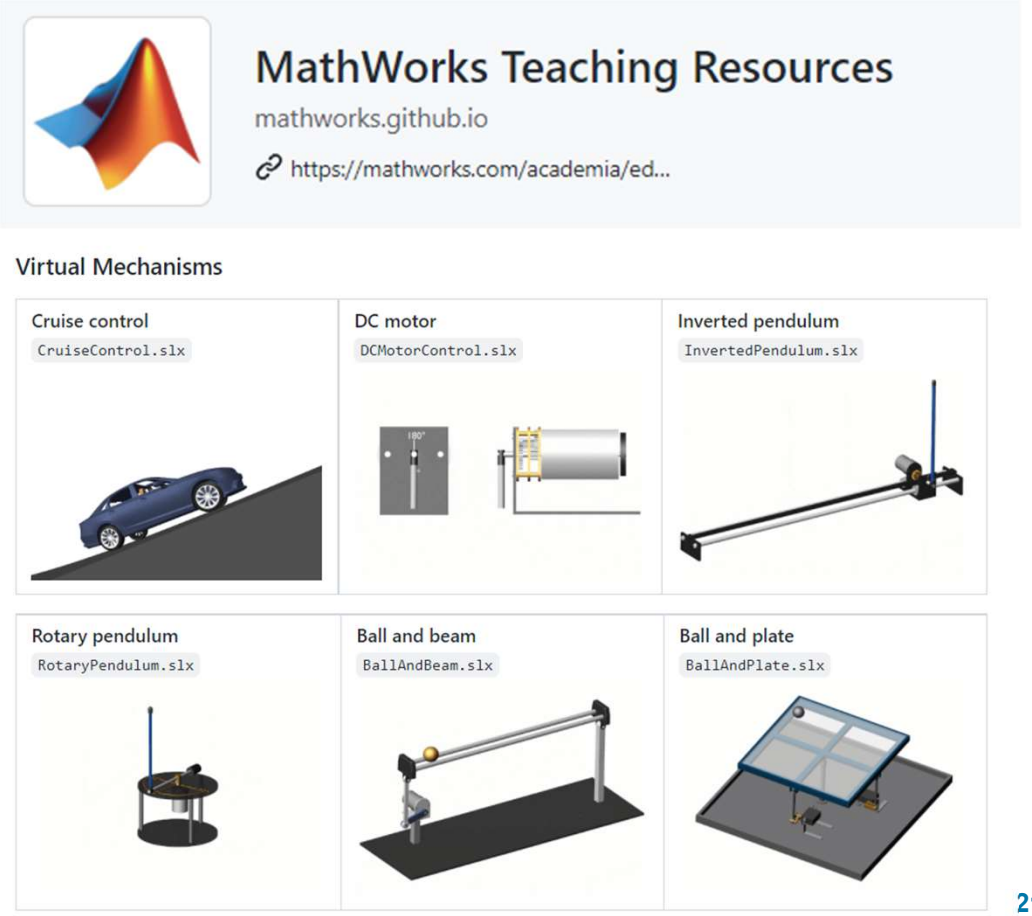
Project-Based Learning using Low-Cost Hardware

- **Teaching Feedback Control Systems with one Palm-size Drone for Each Student**
  - Lectures teach design, simulation, code generation with Simulink
  - Problem sets let students practice at home
  - Palm size make them easy to carry
  - Safe and reliable
  - Hardware Support package for Parrot Minidrone

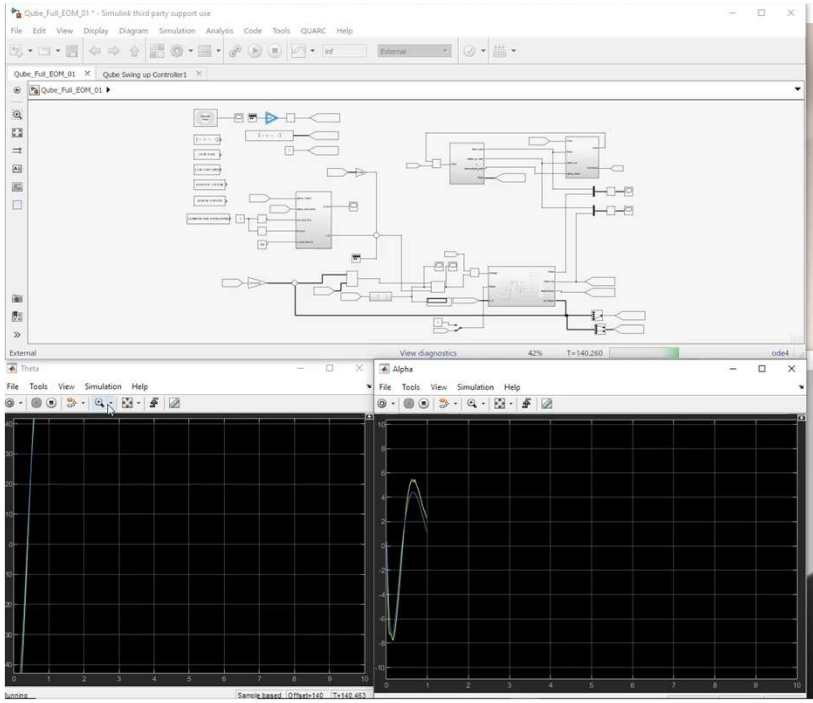
Prof. Sertac Karaman, MIT

Virtual Control Laboratory developed by MathWorks

- Virtual controls labs introduce basic controls concepts – feedback control
- Students implement and test controllers in Simulink and visualize dynamics of systems such as a DC motor, rotary and inverted pendulums
- Labs available on GitHub
  https://github.com/MathWorks-Teaching-Resources/Virtual-Controls-Laboratory

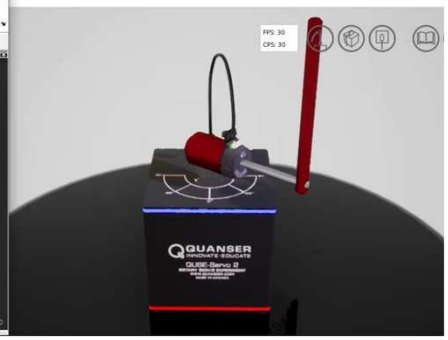


Teaching Control with Quanser Hardware and Interactive Labs



Quanser Qube Servo

Hardware Lab

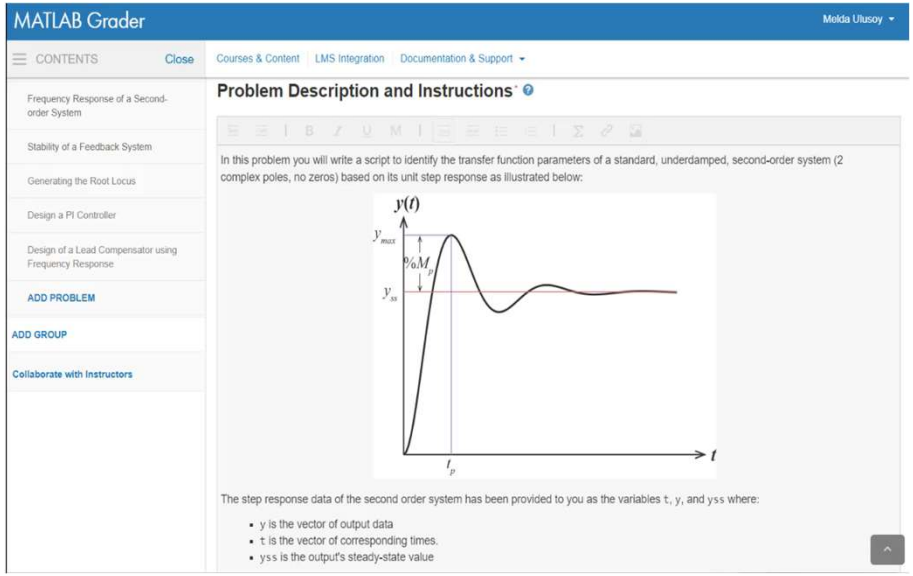


Virtual Lab

ACCESS | INSTRUCTION | **ASSESSMENT** | GETTING HELP

Autograde code with MATLAB Grader

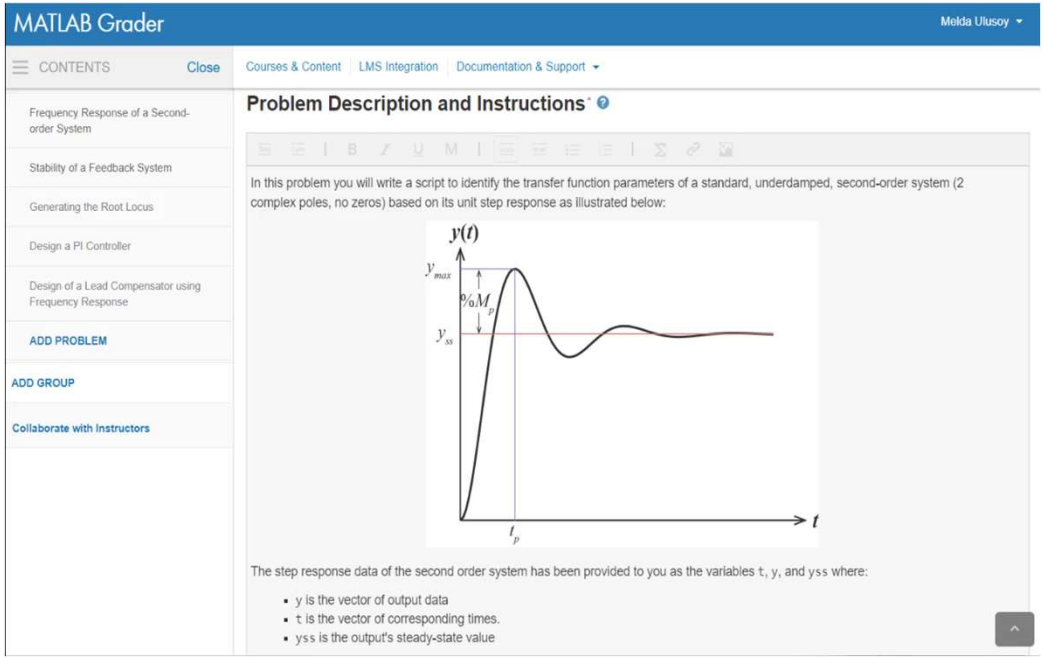
- Create online private courses and assignments
- Students execute MATLAB code on the web
- Control the visibility of the test suites from students
- Visualize solution results using MATLAB graphics
- Solution map informatics for instructors
- Download all student attempts and report on grading data



https://www.mathworks.com/products/matlab-grader.html

MATLAB Grader – Student Feedback

- **Optimal Control and Dynamic Programming with MATLAB**
  - Professor Duarte Guerreiro Tomé Antunes TU/Eindhoven
  - 150 students
- **Benefits**
  - Significantly improved learning outcomes
  - Enabled the teaching assistants to spend more time working directly with students
  - Motivated the students by providing immediate feedback on their work
  - Identified what concepts students were learning well and where they needed help



MATLAB Grader – Student Feedback

Student Feedback

Student feedback on Cody Coursework was overwhelmingly positive. Here is a sample of the responses we received:

"The fact that you can get immediate feedback (or confirmation) on a quite complicated piece of code is really neat, and without it, debugging your own code would really be a mess. It also motivated me to get 100% score on all the MATLAB assignments." Joost P.

"Cody Coursework is a great platform. It gives me more confidence about my solution rather than waiting for the instructor evaluation. " Manoj P.

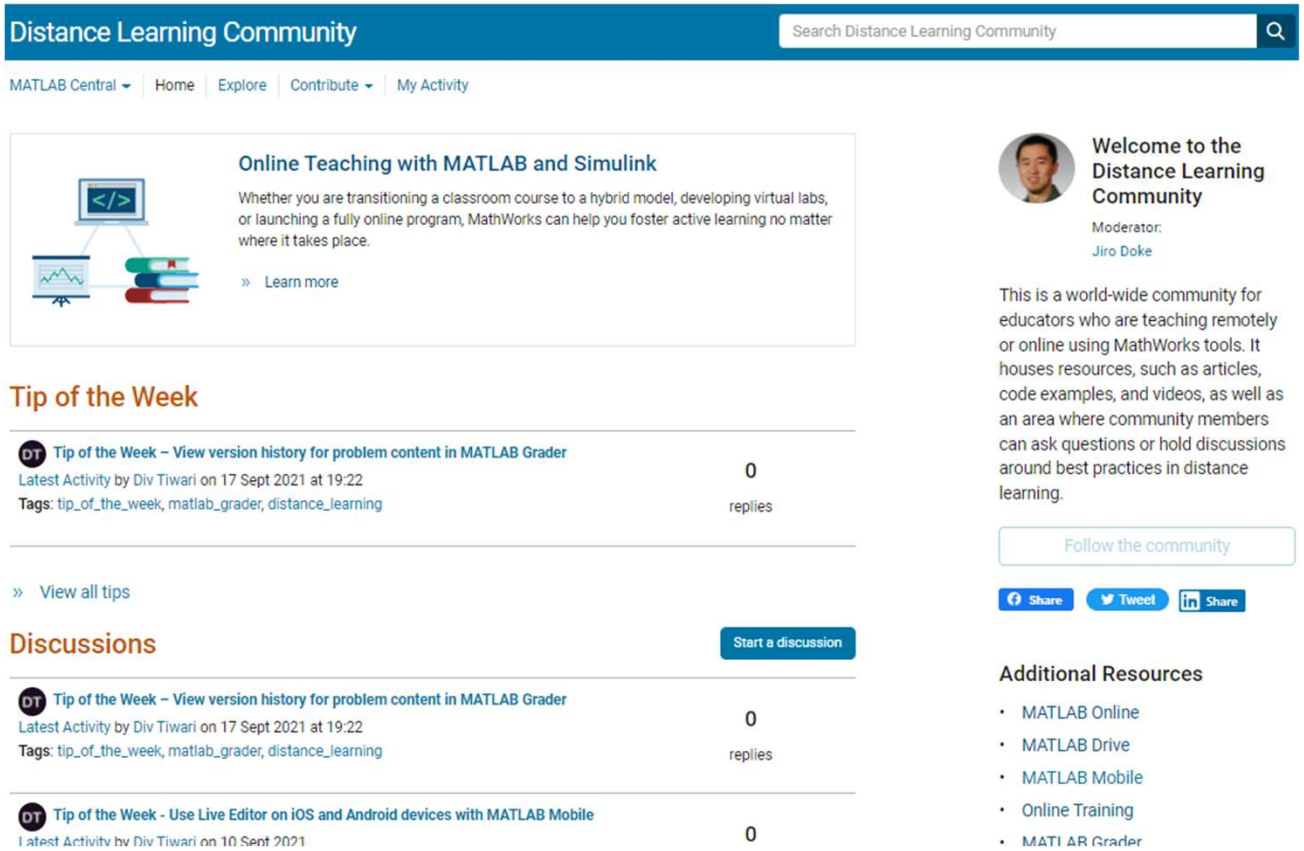
"My experience with Cody Coursework was very positive. The green checkboxes are an extra motivation to get a high grade." Koen B.

"The most useful feature of Cody Coursework was the ability to check our solutions against various test cases, which helped in debugging our code and formulating it in a much more generalized manner." Amrith V

"I like that you receive feedback immediately, which makes it much easier to find problems in your code… I learned a lot from the MATLAB assignments in a relative short period." Ruud S.

ACCESS | INSTRUCTION | ASSESSMENT | **GETTING HELP**

Distance Learning Community



https://www.mathworks.com/matlabcentral/topics/distance-learning.html

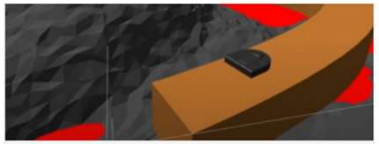
Curriculum Materials developed by MathWorks and Educators from Leading Universities

Featured Courseware

Explore interactive teaching content and examples developed by MathWorks and educators from leading universities.

https://www.mathworks.com/academia/courseware.html

Virtual Labs



MECHANICAL AND ELECTRICAL ENGINEERING

Robo Ninja Warrior

Paul Ruvolo, Olin College

Module that teaches math, physics, and engineering and applying them to programming a mobile robot

Includes: Code, Assignments

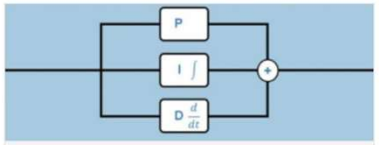
MECHANICAL AND ELECTRICAL ENGINEERING

GUI for Vibrations and Control Theory

Ayse Tekes, Kennesaw State University

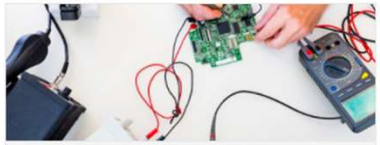
Virtual equipment for conceptual laboratory demonstrations of dynamics, vibrations, and control theory

Includes: Models



MECHANICAL AND ELECTRICAL ENGINEERING

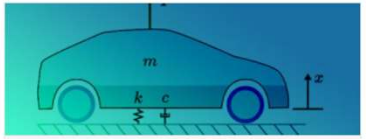
Duino-Based Learning



MECHANICAL AND ELECTRICAL ENGINEERING

Modeling, Analysis, and Control of

Interactive Examples



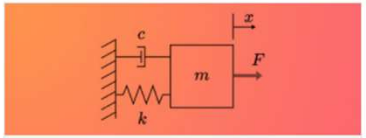
MECHANICAL, AEROSPACE, AND CIVIL ENGINEERING

Mass-Spring-Damper Systems

MathWorks

MATLAB live scripts and Simulink models that explore mass-spring-damper systems

Includes: Code, Models, Assignments



MECHANICAL, ELECTRICAL, AND AEROSPACE ENGINEERING

Control Tutorials for MATLAB and Simulink

Richard Hill, University of Detroit Mercy

Live script examples using MATLAB for the analysis and design of automatic control systems

Includes: Code

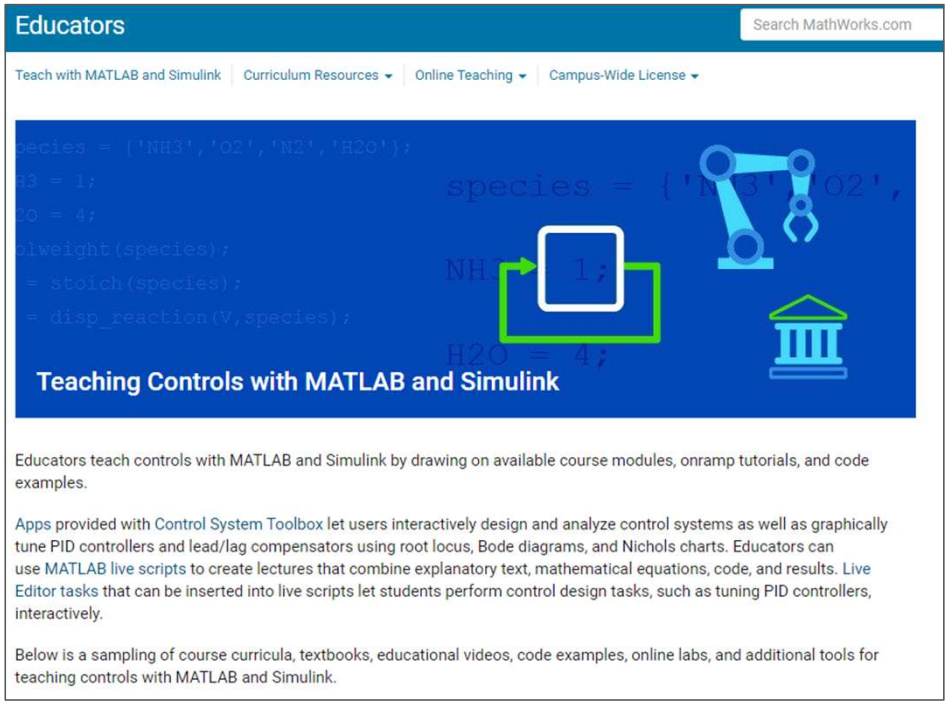
MECHANICAL, ELECTRICAL, AND AEROSPACE ENGINEERING

MECHANICAL AND ELECTRICAL ENGINEERING

Transfer Function Analysis of Dynamic

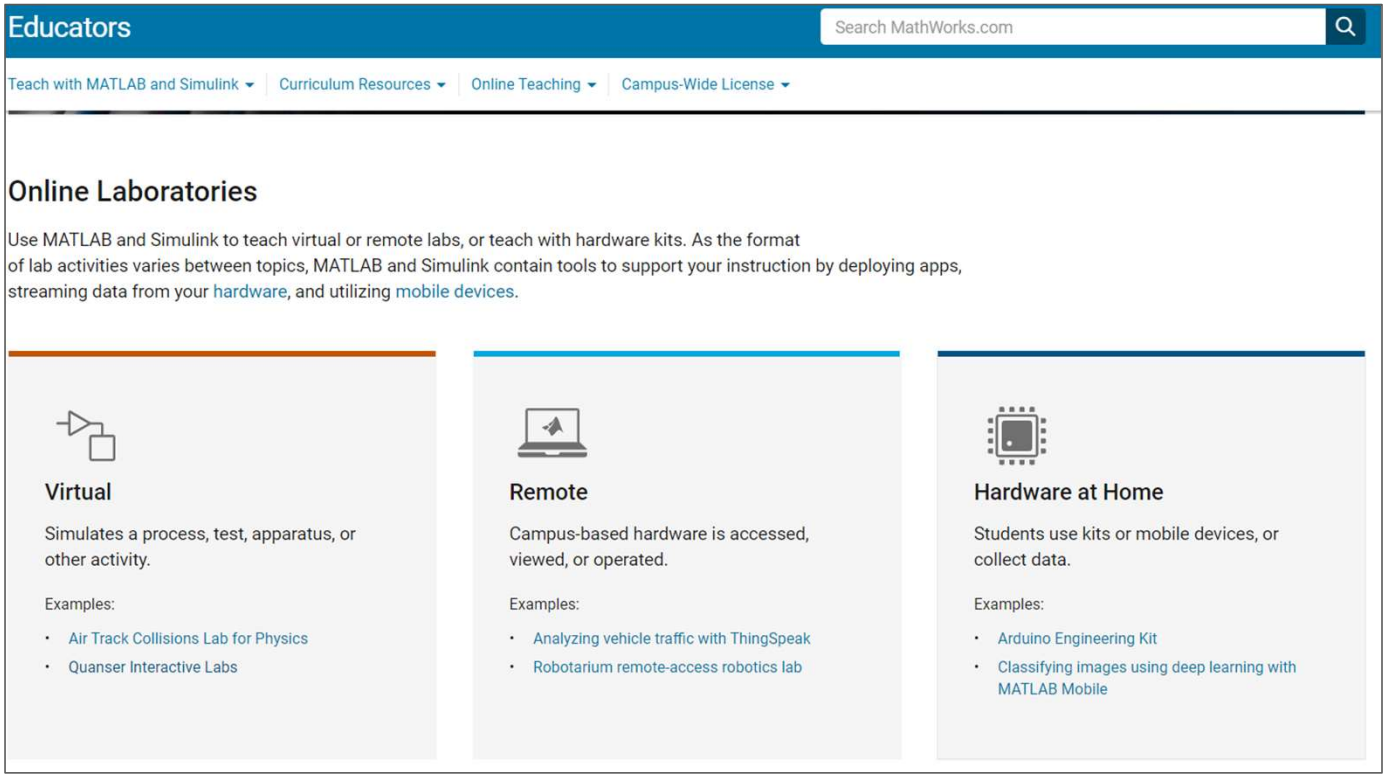
Controls Resources for Instructors

- Course curricula
- Virtual labs
- Educational videos
- Textbooks
- Onramps



https://www.mathworks.com/academia/courseware/teaching-controls-with-matlab-and-simulink.html

Virtual Labs and Projects with MATLAB and Simulink



https://www.mathworks.com/academia/online-teaching/virtual-labs.html

Contact us for questions on MathWorks controls teaching resources

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- Craig Buhr
  cbuhr@mathworks.com