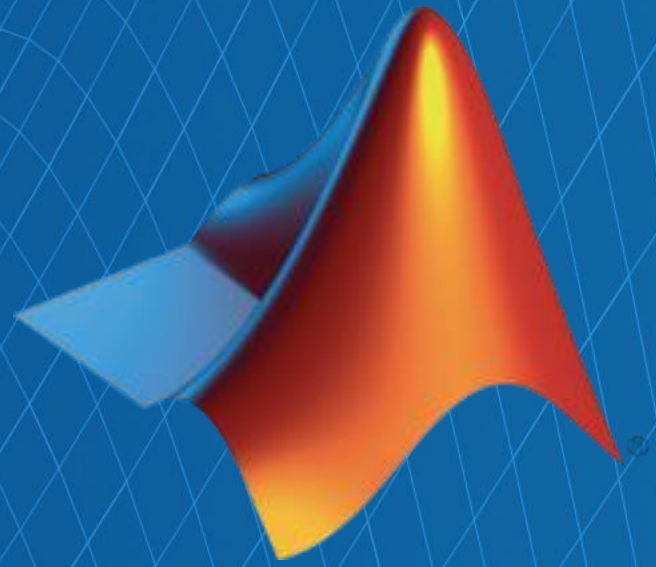
Mechanical Engineering dynamics DEMOS



Bradley Horton

MATLAB + Computational Thinking

Decomposition

- Break 1 complex problem into a collection of smaller/simpler problems

Abstraction

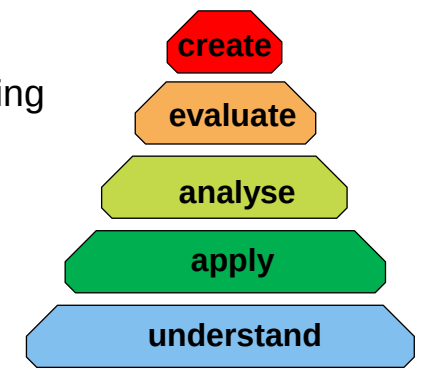
Mathematical modelling
- Symbolic representation
- Block diagrams

Algorithms + Automation

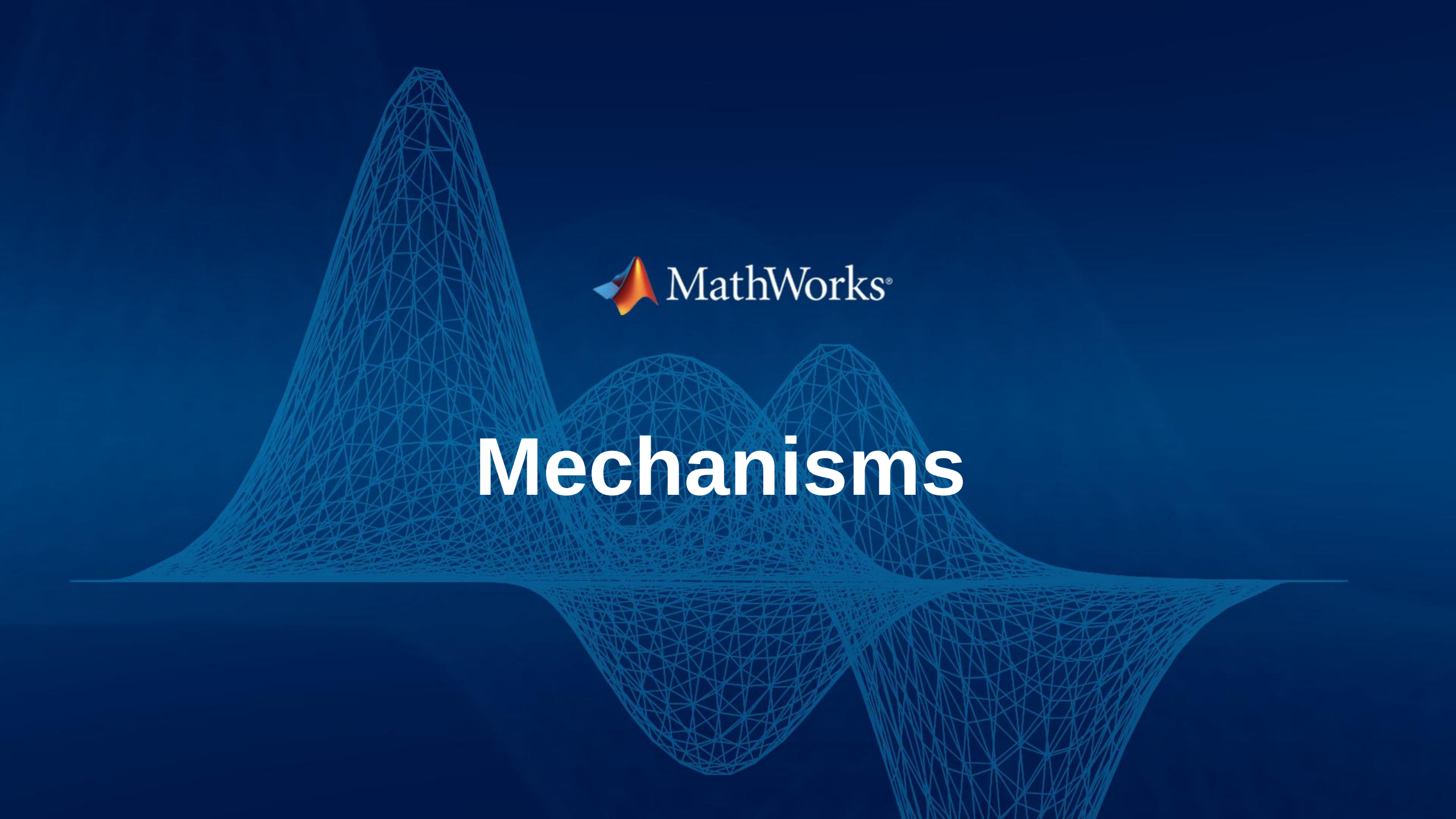
- Formulating solution as a series of steps
- Transforming between Modelling paradigms

Simulation

- What happens when ?

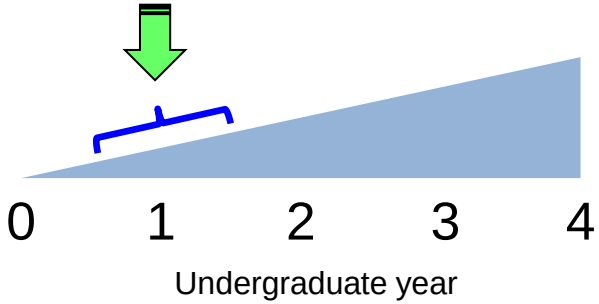


Blooms revised taxonomy: https://tips.uark.edu/using-blooms-taxonomy/

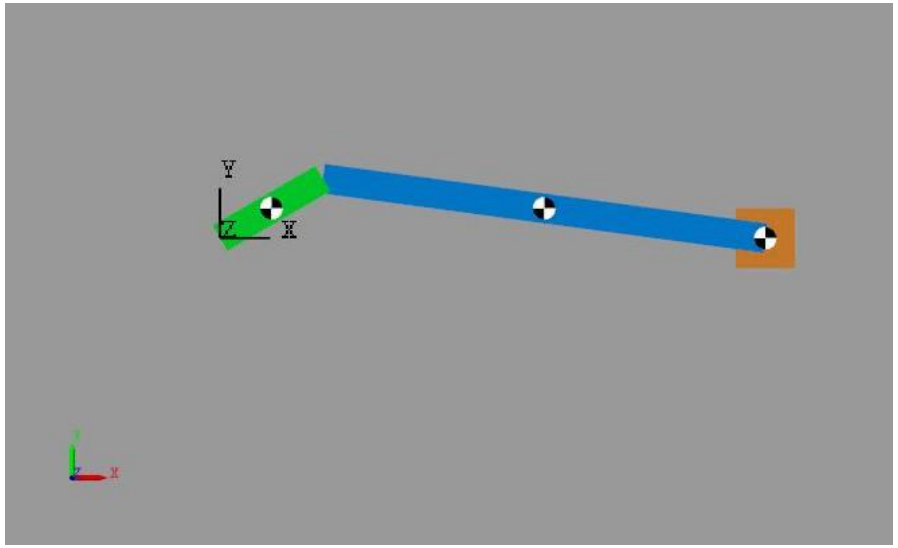


Mechanisms

Slider Crank mechanism



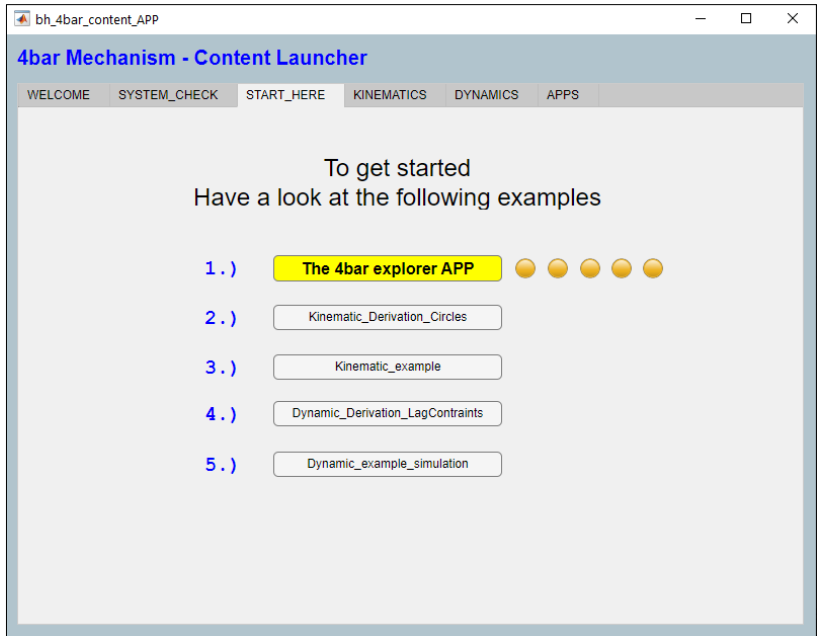
- **Benefits**
  - Validate hand computations
  - Visualize motion of mechanism
- **Concepts**
  - Kinematics: Velocity Analysis of a mechanism
  - Kinetics: Newton's 2nd Law
- **Getting started**
  - `>> DEMO_START_HERE_PLEASE`



https://insidelabs-git.mathworks.com/ww-edu-technical/demos/demo-slider-crank-computational-thinking

4-bar mechanism

- **Benefits**
  - Validate hand computations
  - Visualize motion of mechanism
- **Concepts**
  - Kinematics: Velocity Analysis of a mechanism
  - Kinetics: Newton's 2nd Law
  - Kinetics: Lagrange with Holonomic constraints
- **Getting started**
  - `>> bh_4bar_startup`



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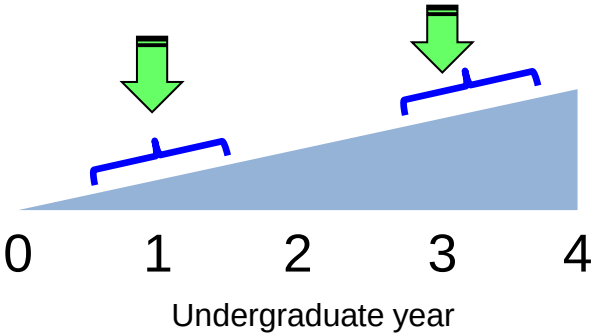

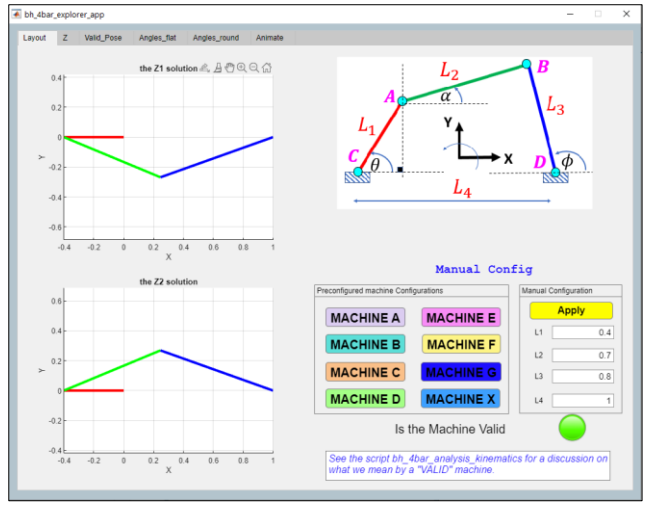

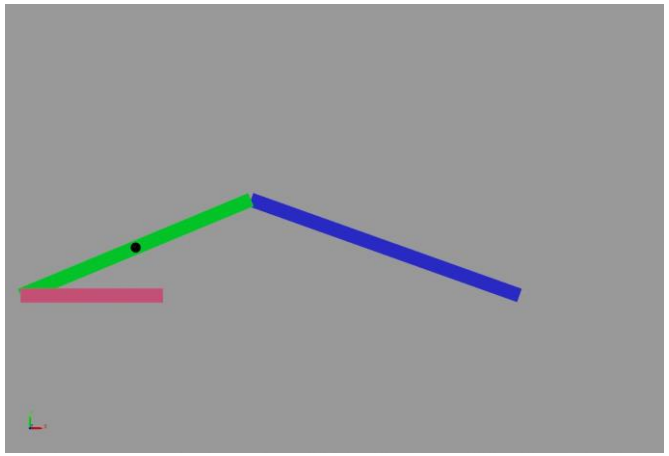


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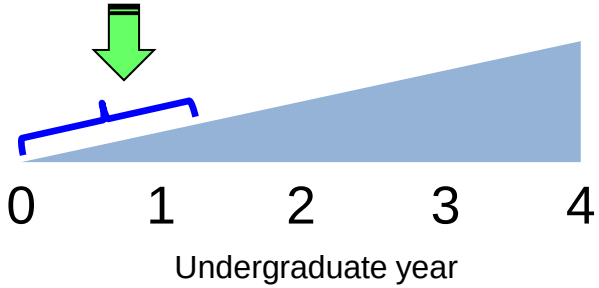
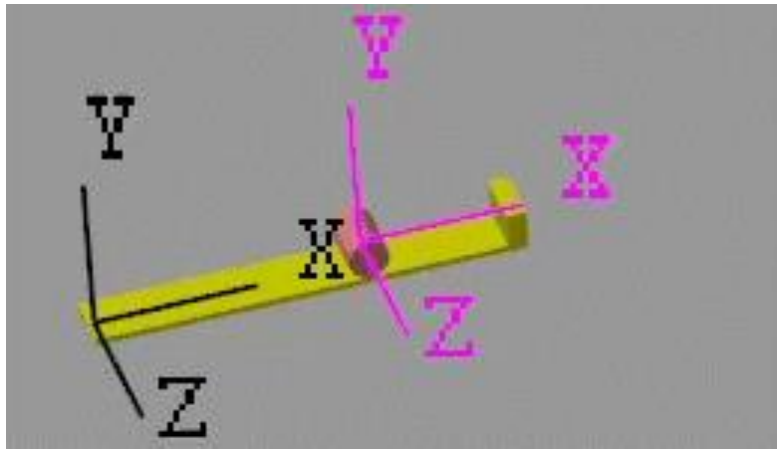
FRICTION

Rolling Pipe on accelerating truck bed

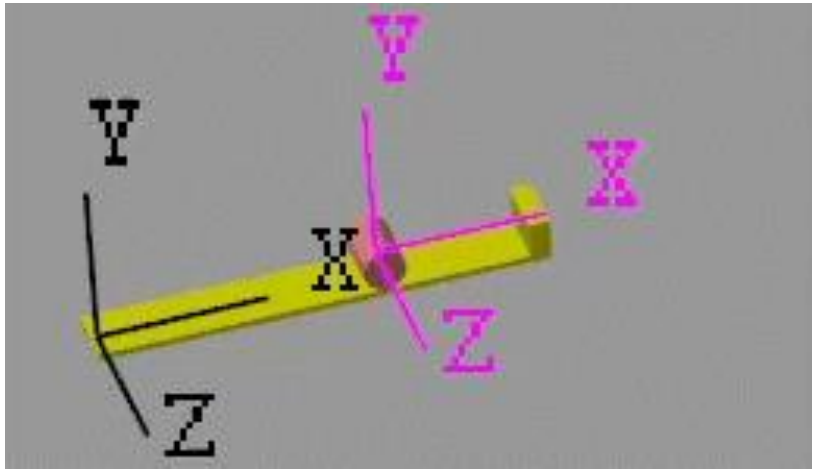


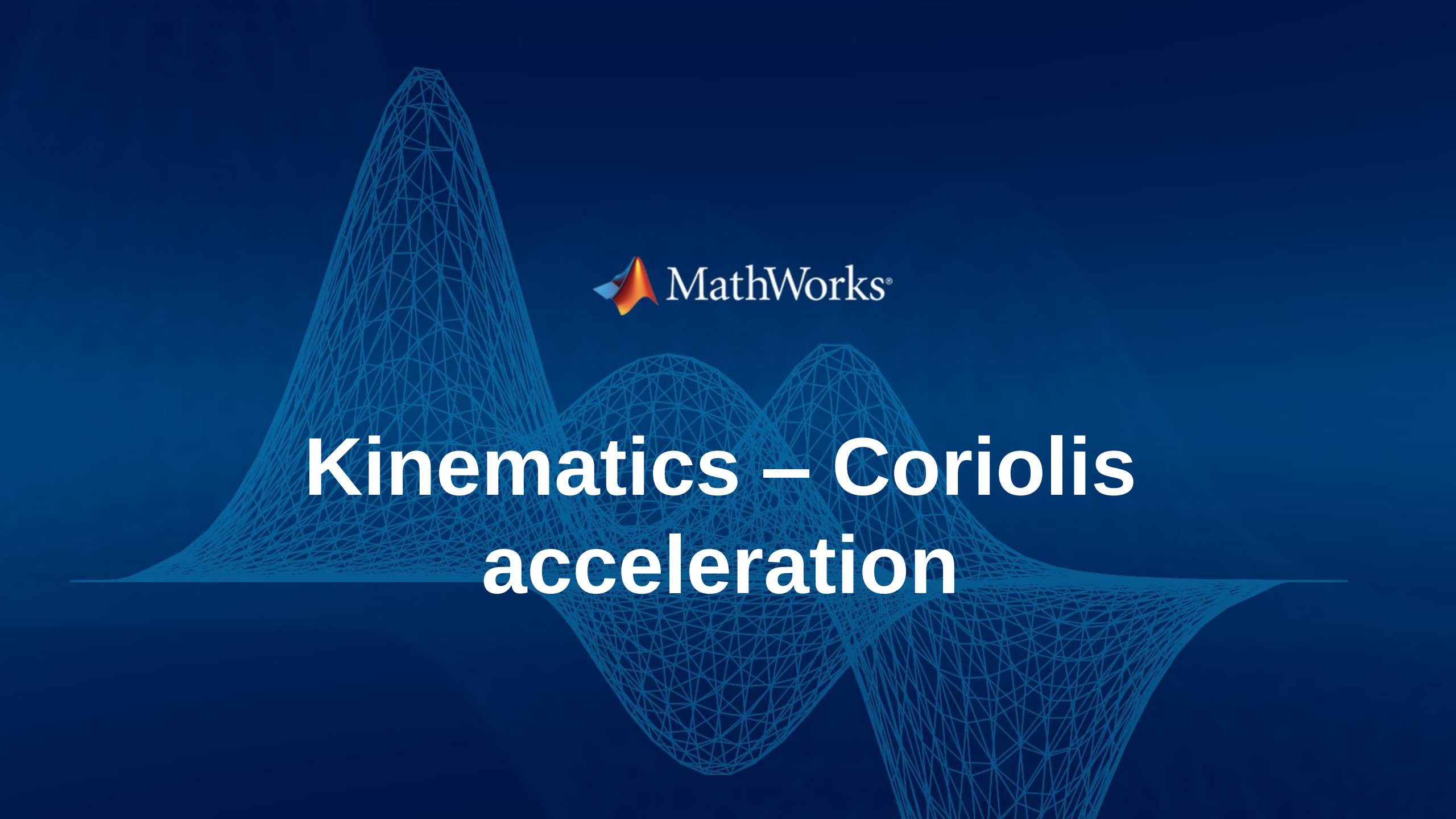
- **Benefits**
  - Validate hand computations
  - Visualize motion of mechanism
- **Concepts**
  - Kinematics: Acceleration Analysis of rolling pipe
  - Kinetics: Newton' 2nd Law
- **Getting started**
  - `>> DEMO_START_HERE_PLEASE.mlx`

Rolling



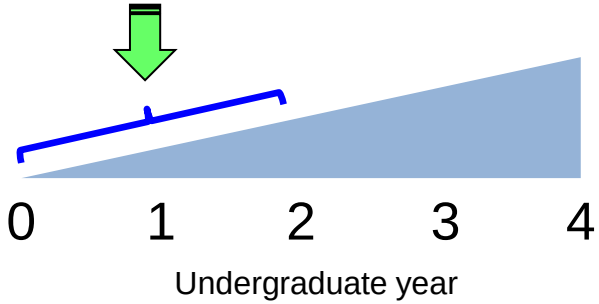
Rolling AND sliding



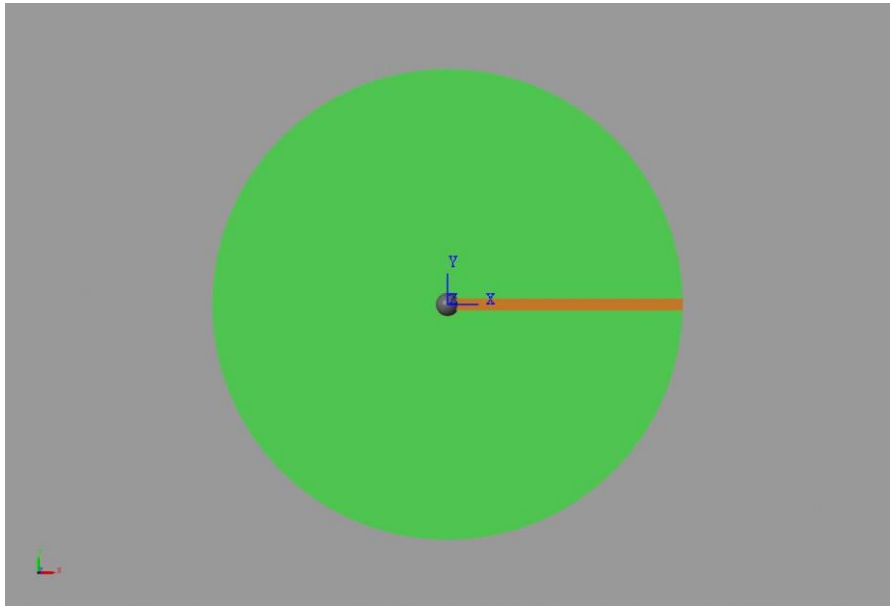


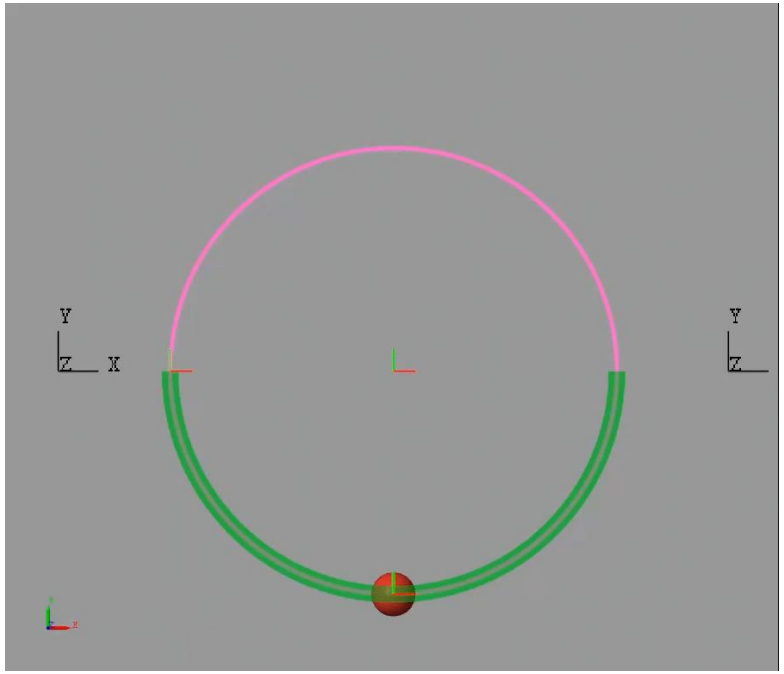
Kinematics – Coriolis acceleration

Coriolis acceleration

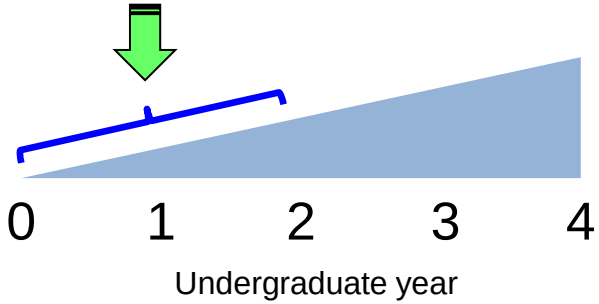


- **Benefits**
  - Validate hand computations
  - Visualize motion of mechanism
- **Concepts**
  - Kinematics: Velocity Analysis of a mechanism
- **Getting started**
  - `>> bh_START_HERE_green_disk.mlx`
  - `>> bh_START_HERE_PLEASE_half_hoop.mlx`

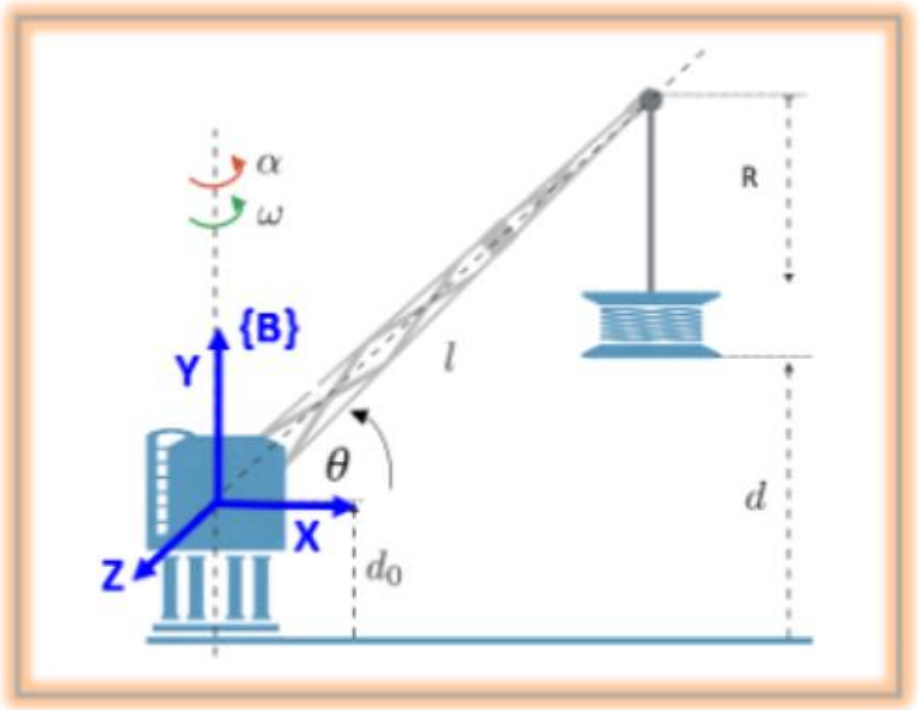


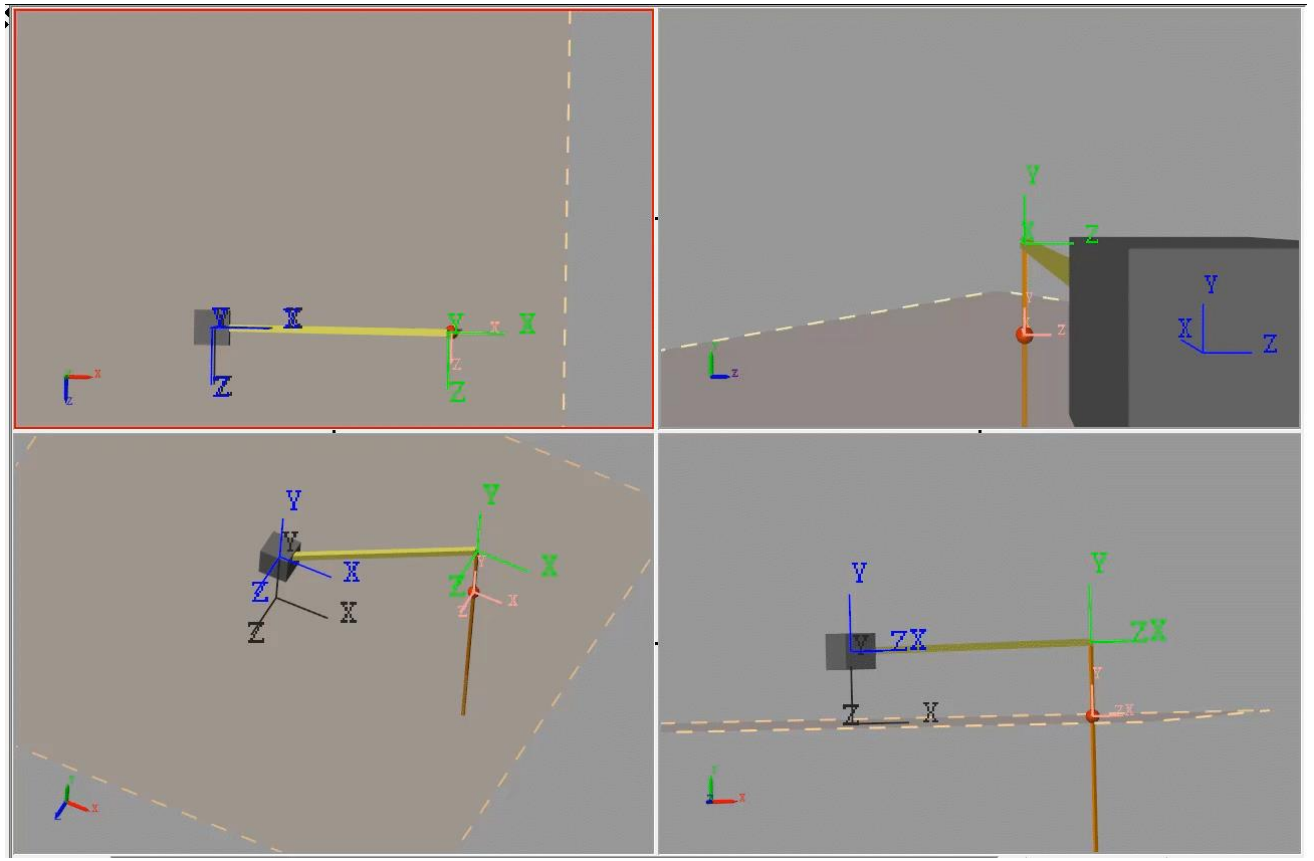


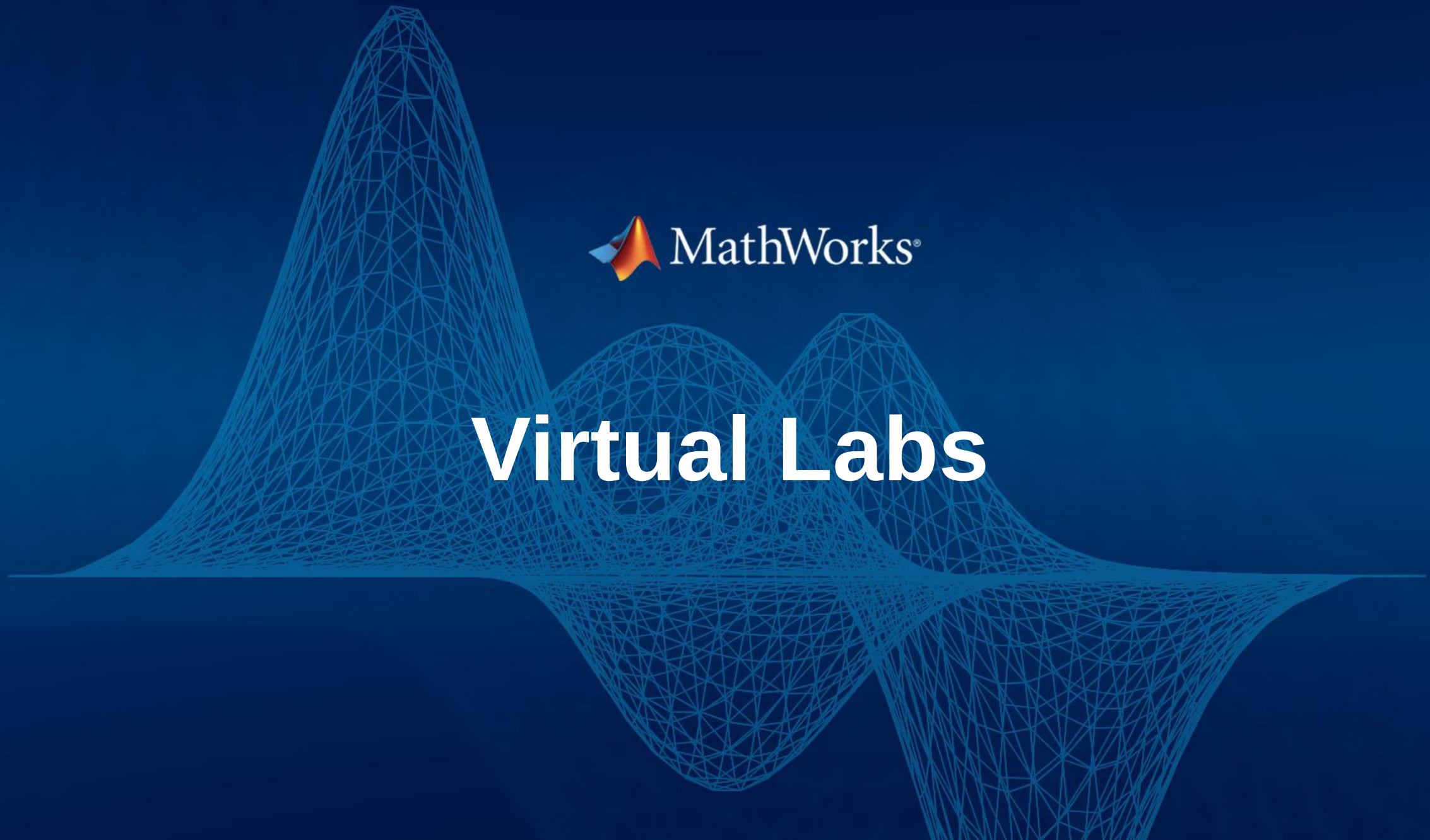
Coriolis acceleration



- **Benefits**
  - Validate hand computations
  - Visualize motion of mechanism
- **Concepts**
  - Kinematics: Velocity Analysis of a mechanism
- **Getting started**
  - `>> bh_START_HERE_PLEASE_crane_analysis`







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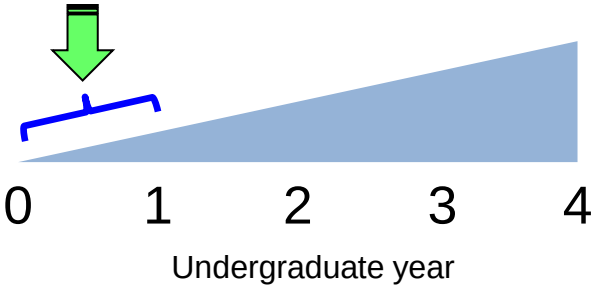
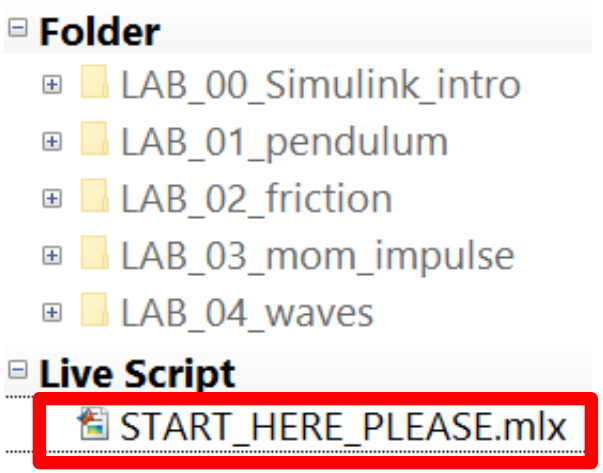
Virtual Labs

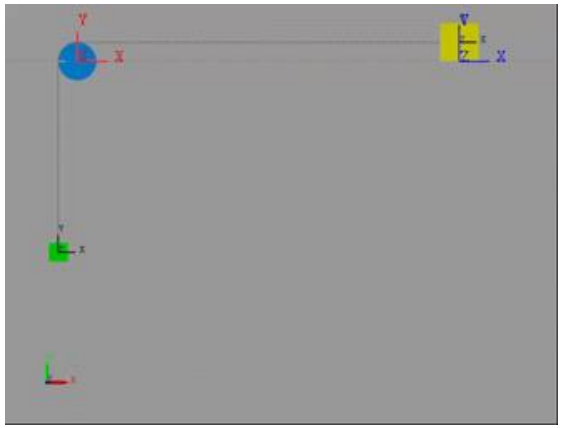
VIRTUAL LAB 1st year Physics Mechanical dynamics

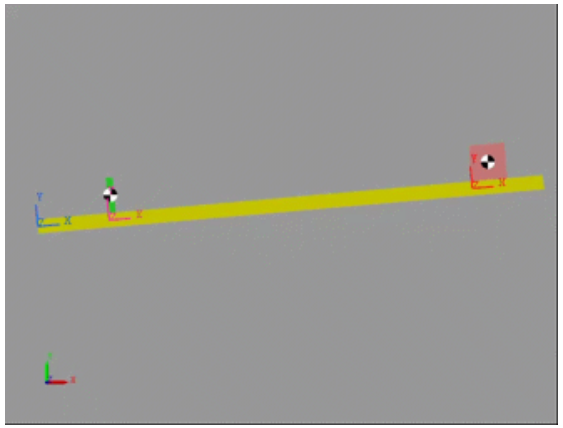


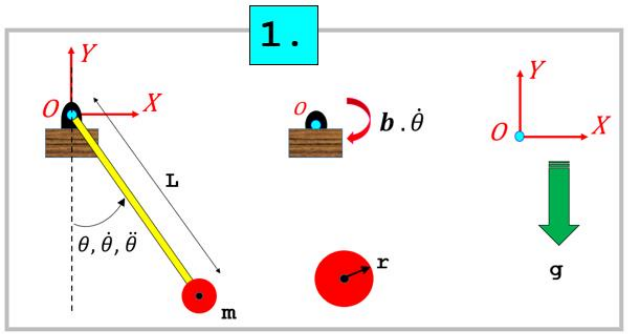
- **Benefits**
  - Visualize motion of mechanism
- **Concepts**
  - Kinetics: Newton's 2nd Law, Friction, Impulse Momentum
- **Getting started**

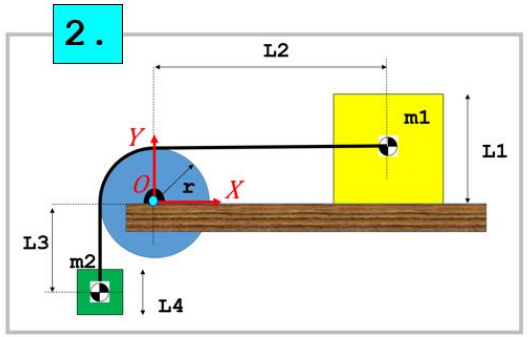
https://insidelabs-git.mathworks.com/ww-edu-technical/coursework/virtual-lab-1st-year-physics-mechanical-dynamics

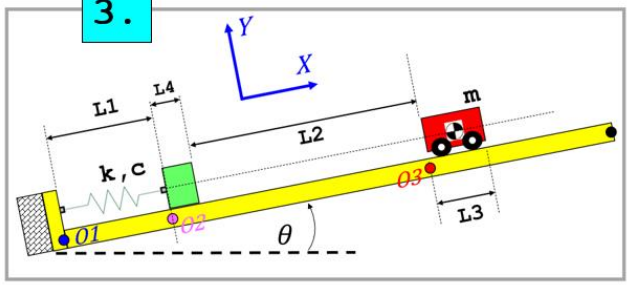


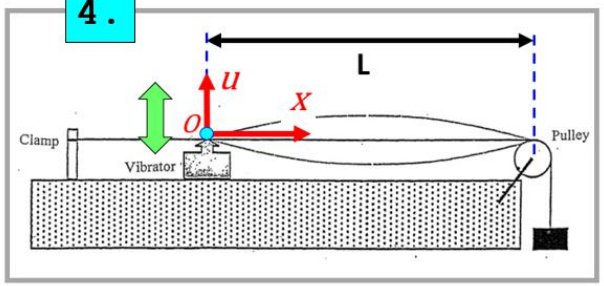




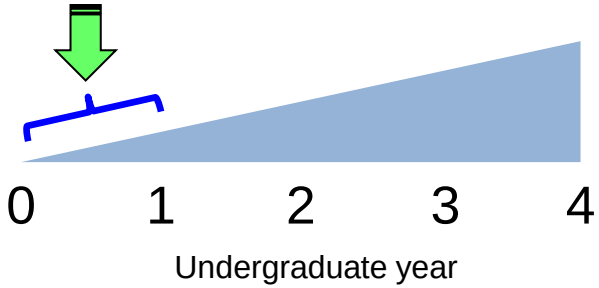






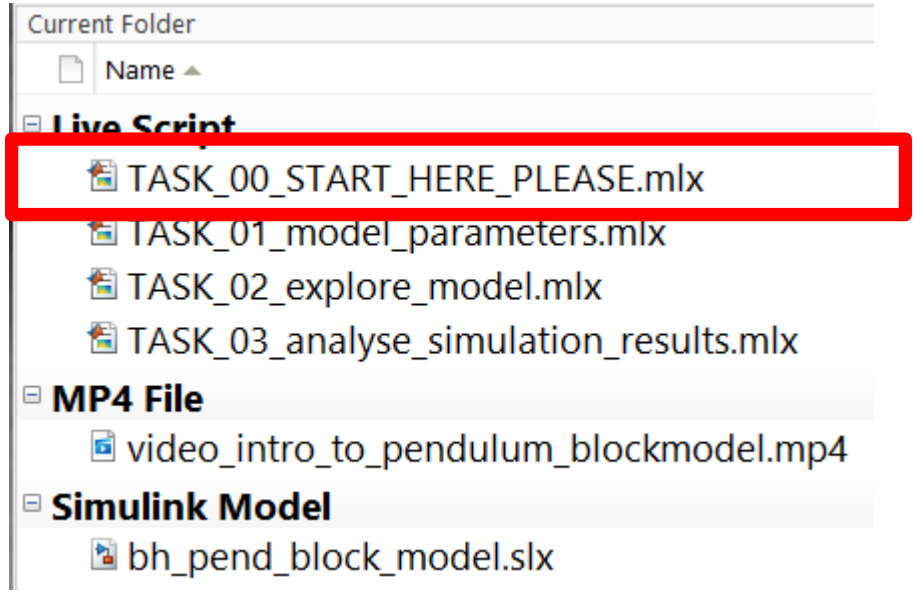


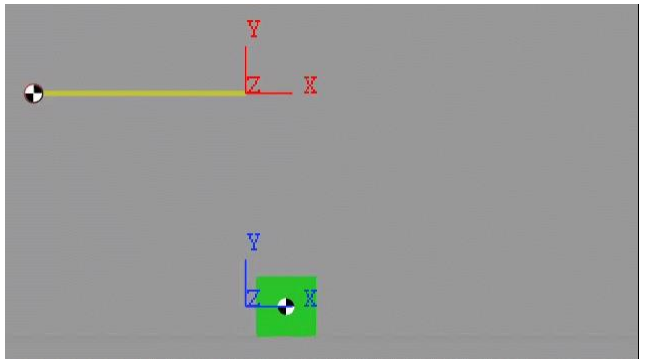
VIRTUAL LAB Pendulum Block and Friction

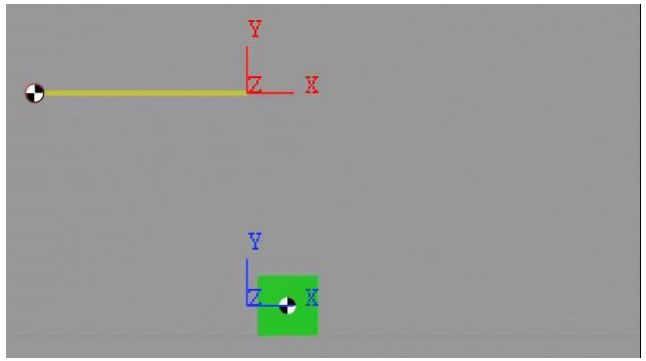


- **Benefits**
  - Visualize motion of mechanism
- **Concepts**
  - Kinetics:
    - Principle of Work and Energy
    - Principle of Impulse and Momentum
    - Newton's 2nd Law
- **Getting started**

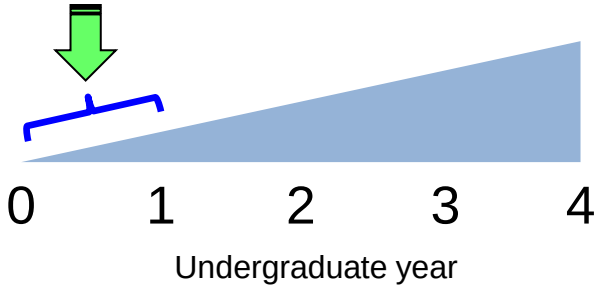
https://insidelabs-git.mathworks.com/ww-edu-technical/coursework/virtual-lab-pendulum-block-and-friction



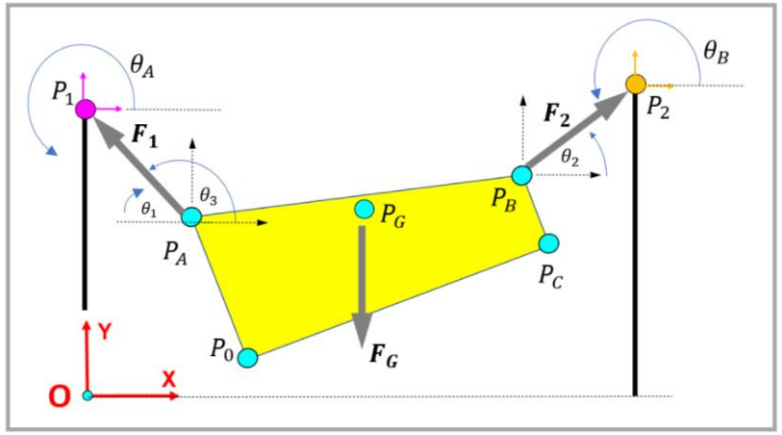




VIRTUAL LAB 3-Forces on a Rigid Body

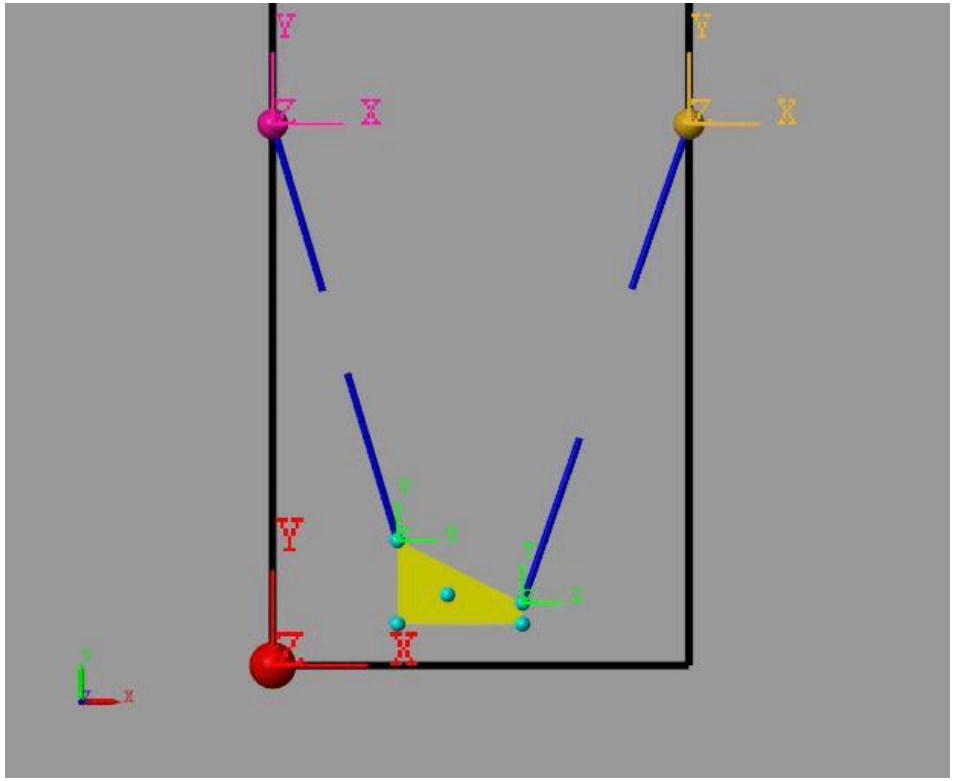


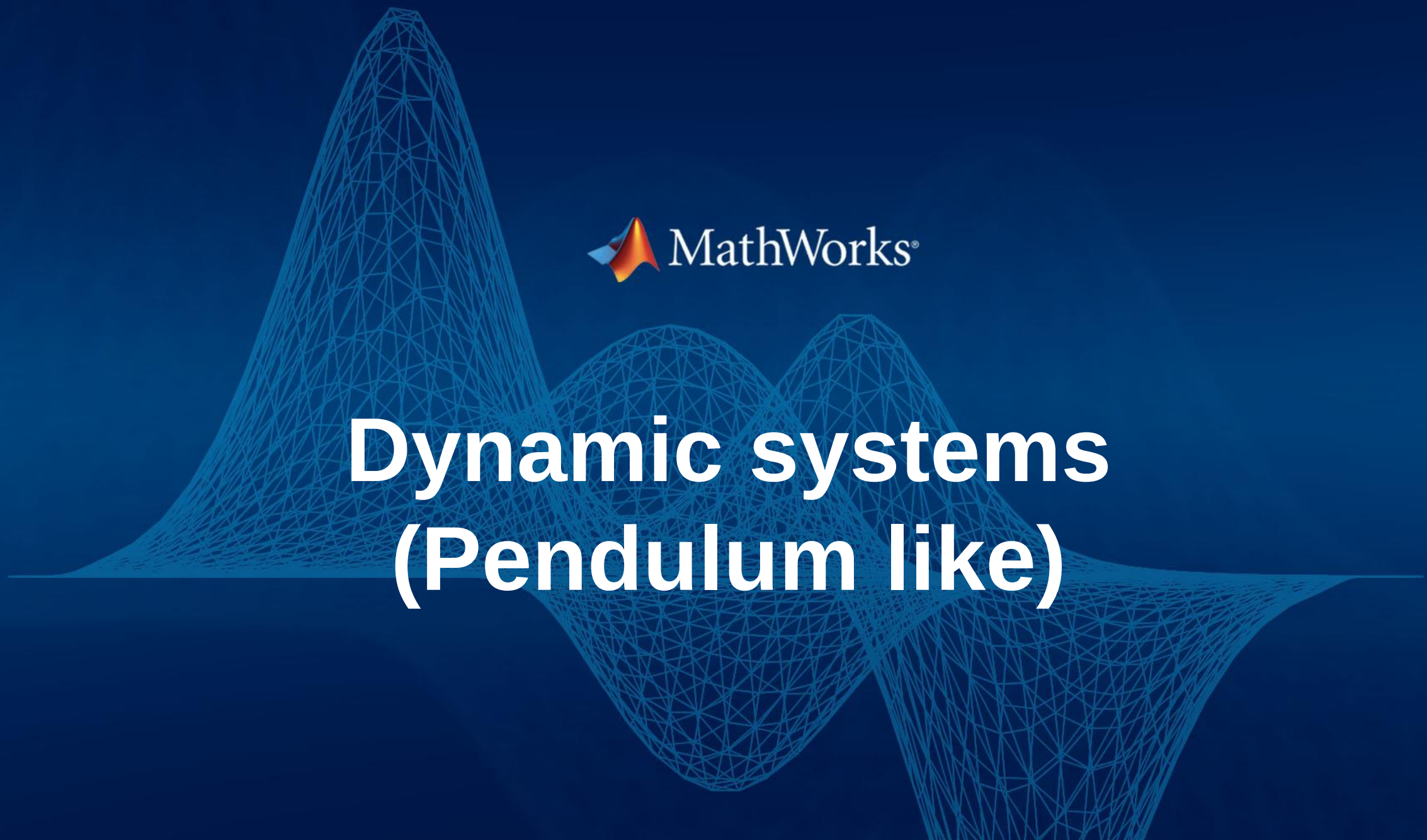
- **Benefits**
  - Visualize motion of mechanism
- **Concepts**
  - Statics:
    - Force Equilibrium
- **Getting started**



Live Script

- bh_PREwork_things.mlx
- TASK_00_START_HERE_PLEASE.mlx
- TASK_01_model_parameters.mlx
- TASK_02_explore_the_model.mlx
- TASK_03_Analyse_Measured_Results.mlx
- TASK_03_Analyse_Measured_Results_SOLUTION.mlx





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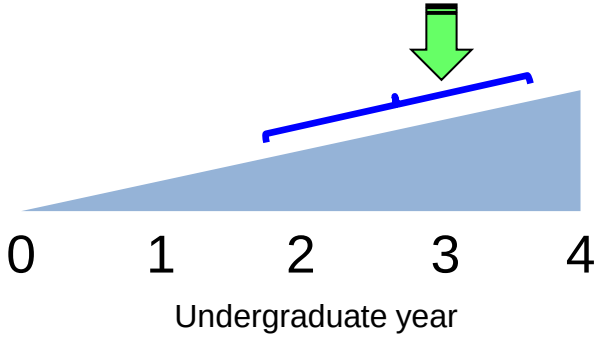
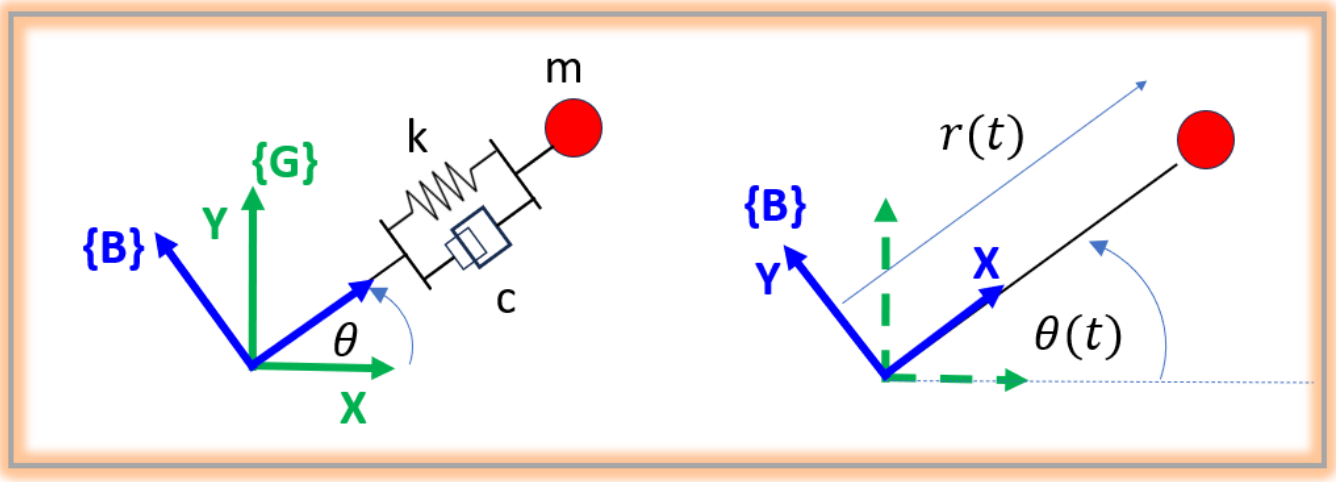
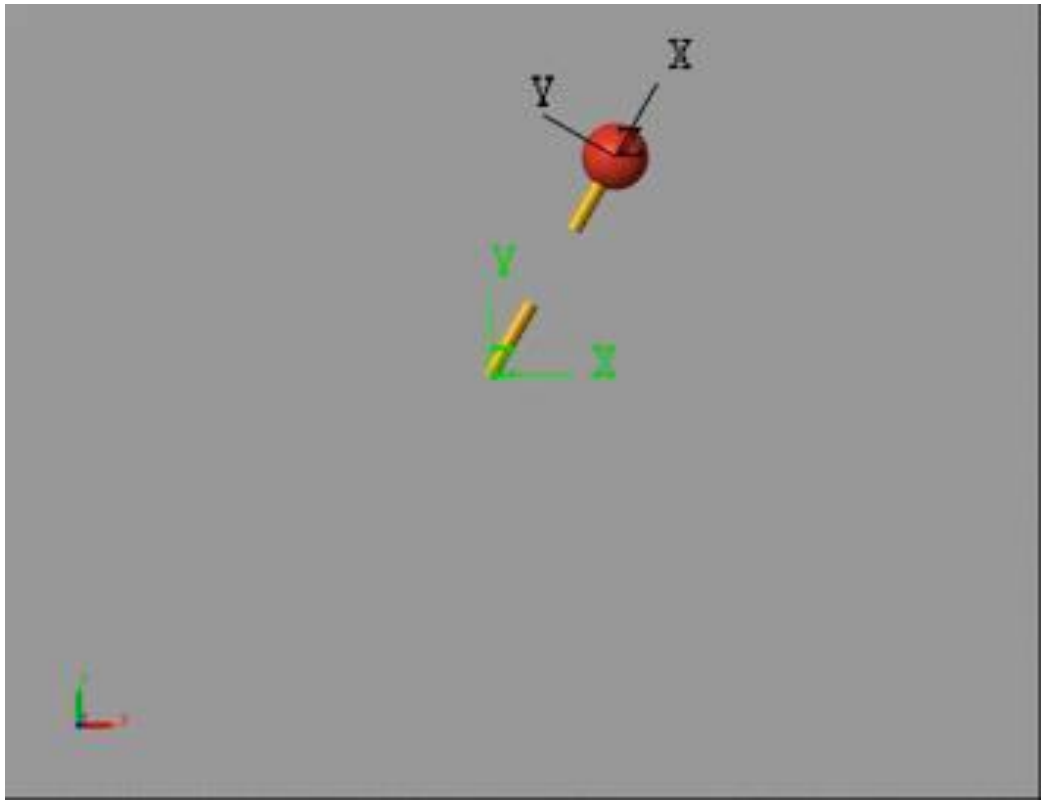
Dynamic systems (Pendulum like)

Extendable Pendulums

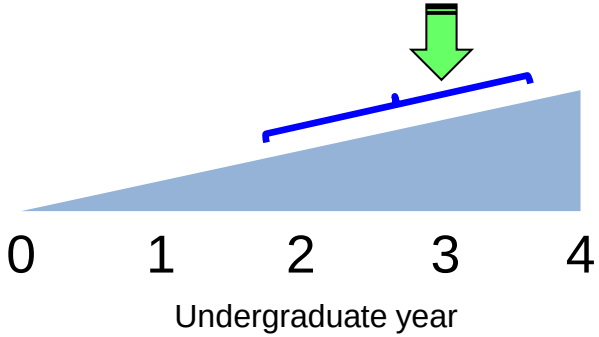


- **Benefits**
  - Validate hand computations
  - Visualize motion of mechanism
- **Concepts**
  - Kinematics: rotating frames
  - Kinetics: Lagrange
- **Getting started**
  - `>> bh_START_HERE_PLEASE`

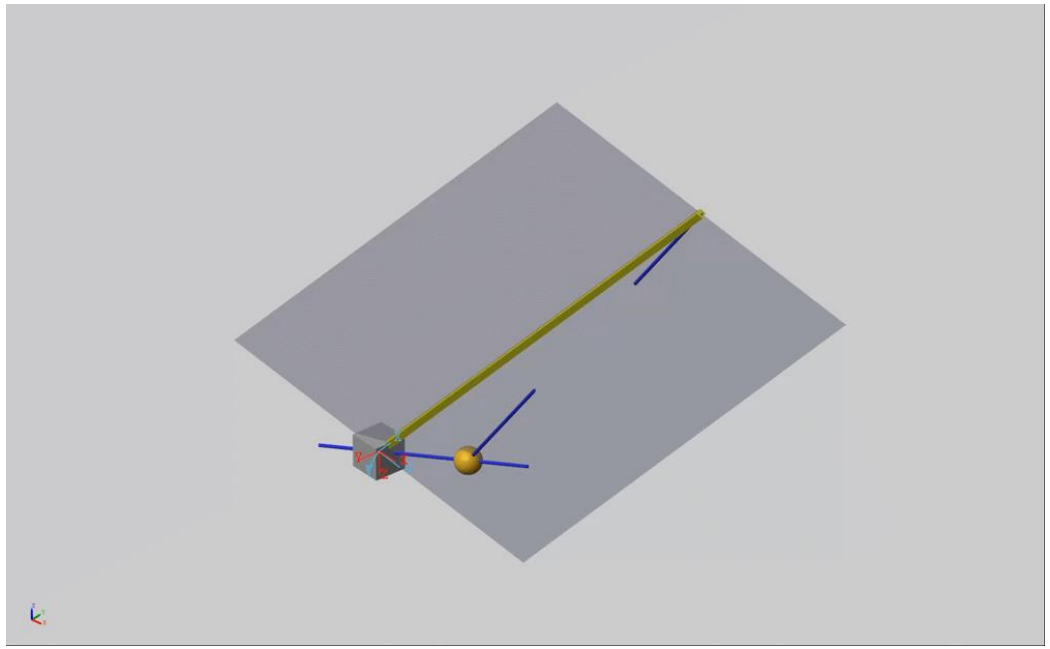


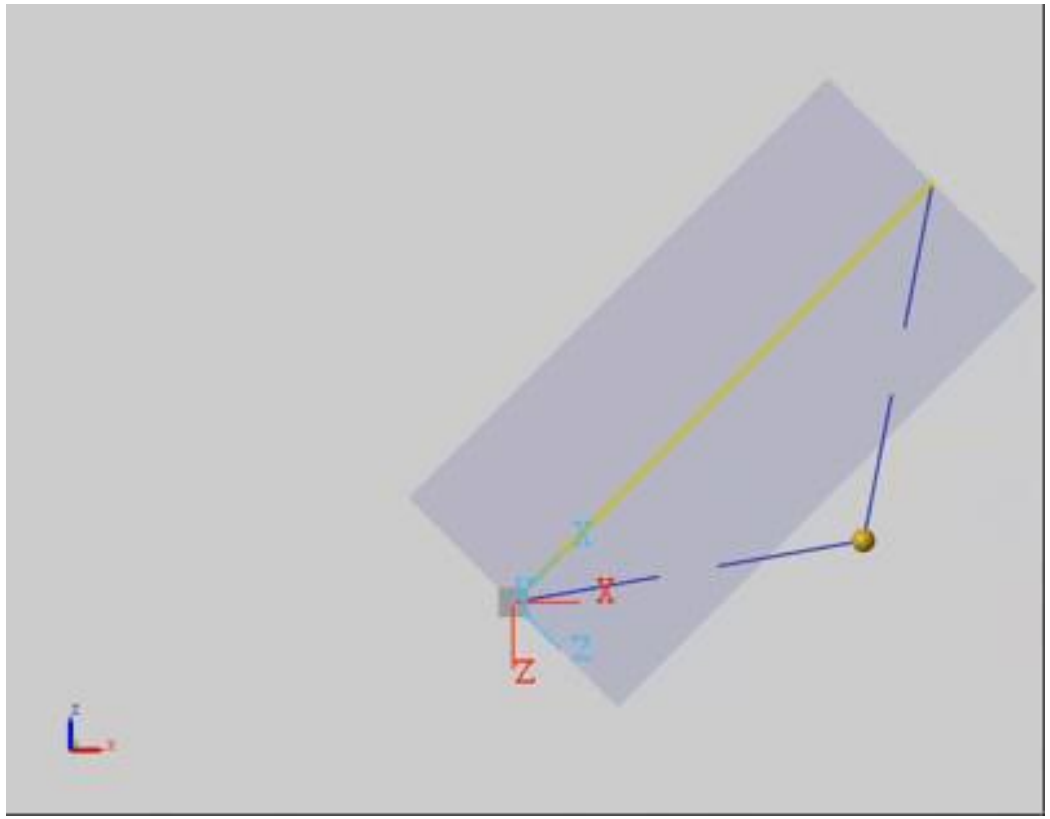


Dragline

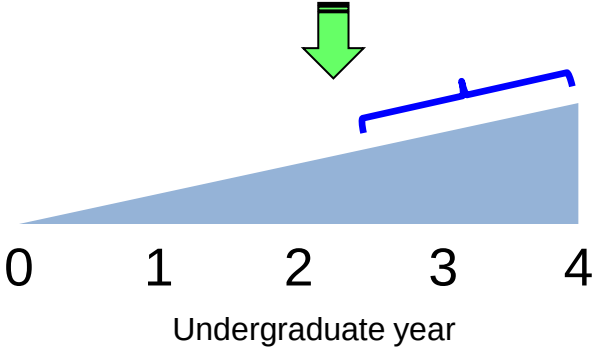


- **Benefits**
  - Validate hand computations
  - Visualize motion of mechanism
- **Concepts**
  - Kinematics: rotating frames
  - Kinetics: Lagrange
- **Getting started**
  - `>> bh_START_HERE_PLEASE`

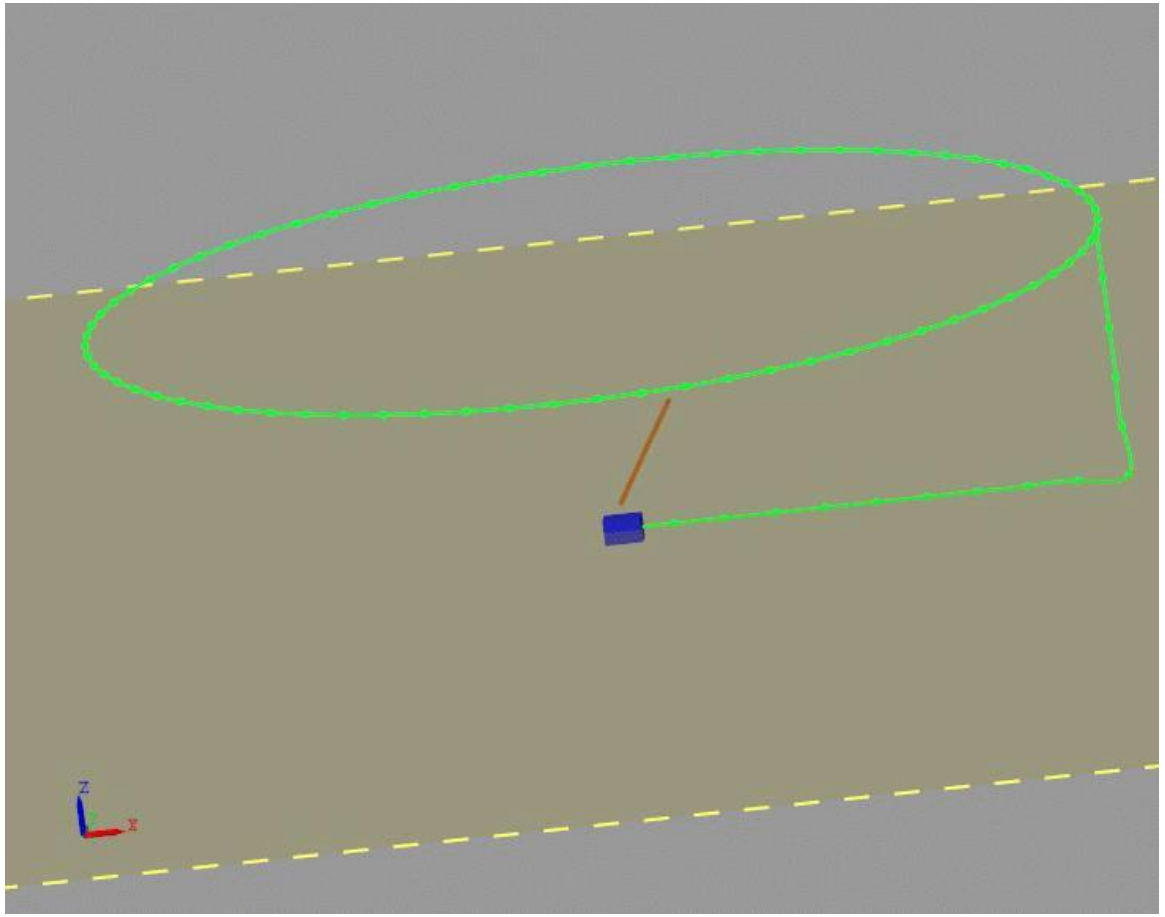




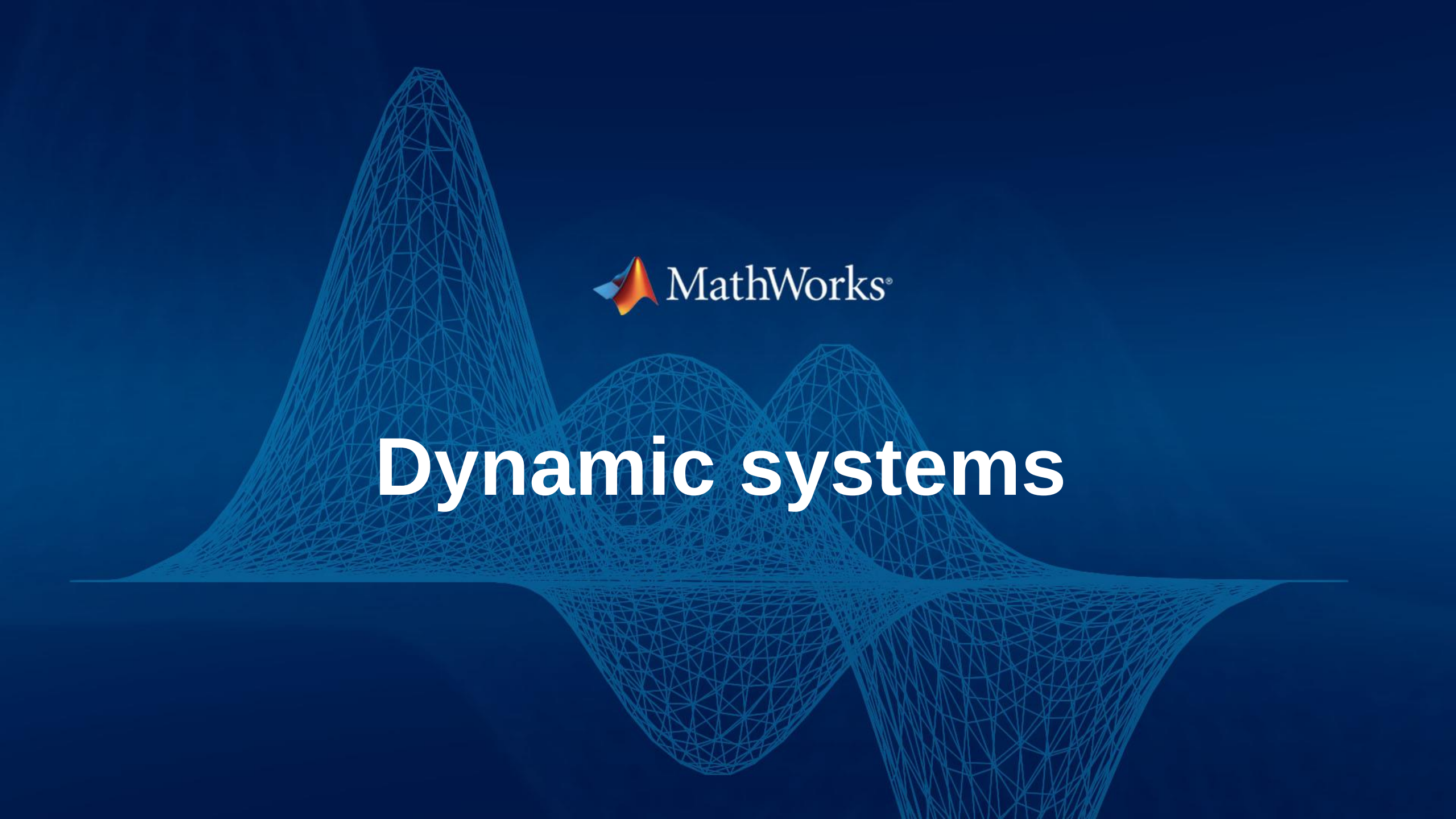
Floating Pendulums – 2D and 3D



- **Benefits**
  - Validate hand computations
  - Visualize motion of mechanism
- **Concepts**
  - Kinetics: Newton's 2nd Law and Lagrange
- **Getting started**
  - `>> bh_START_HERE_PLEASE (2D)`
  - `>> bh_START_HERE_PLEASE (3D)`

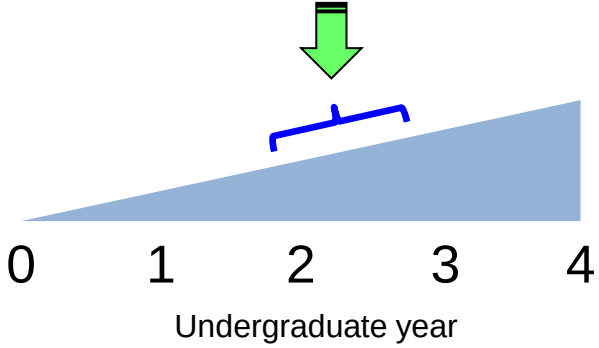


https://insidelabs-git.mathworks.com/ww-edu-technical/demos/demo-extracting-linear-plants-from-non-linear-mechanical-system-models

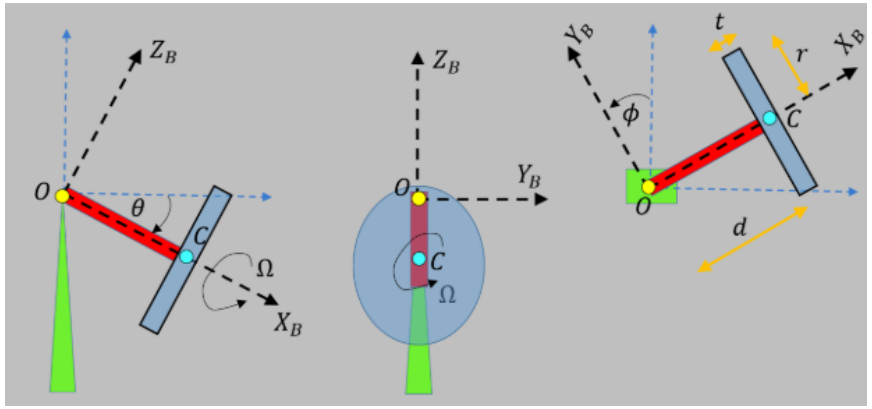


Dynamic systems

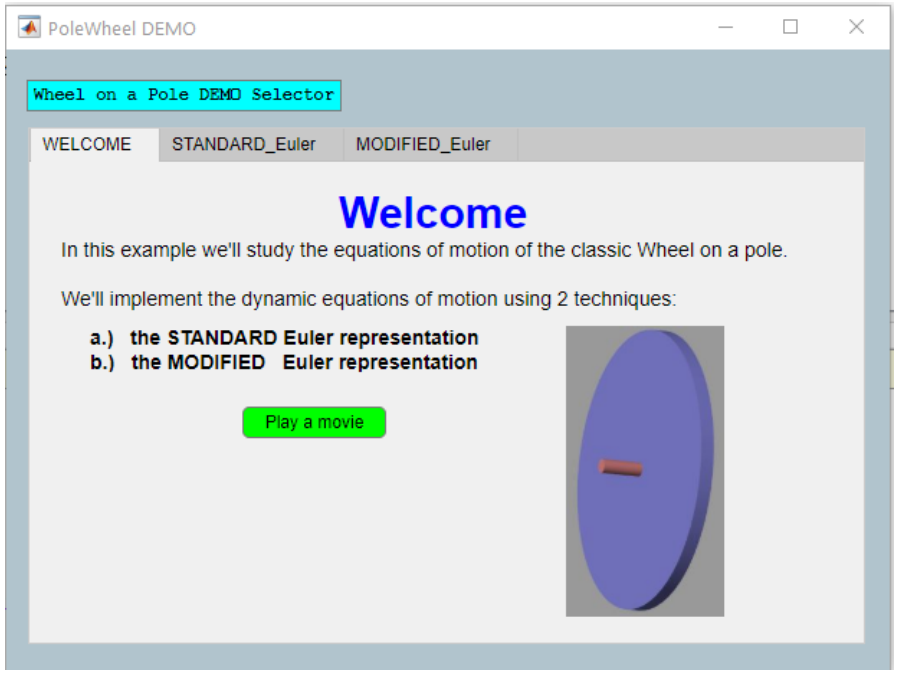
Gyroscope



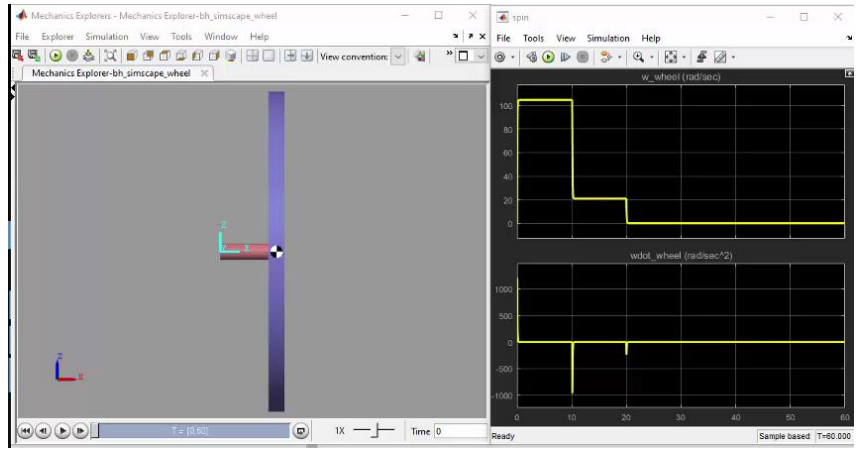
- **Benefits**
  - Validate hand computations
  - Visualize motion of mechanism
- **Concepts**
  - Kinetics: Newton's 2nd Law
- **Getting started**
  - `>> bh_wheel_on_pole_startup`



$$M_O - ({}^B_C I.\dot{\Omega} + \omega \times ({}^B_C I.\Omega)) = {}^B_O I.\dot{\omega} + \omega \times ({}^B_O I.\omega)$$

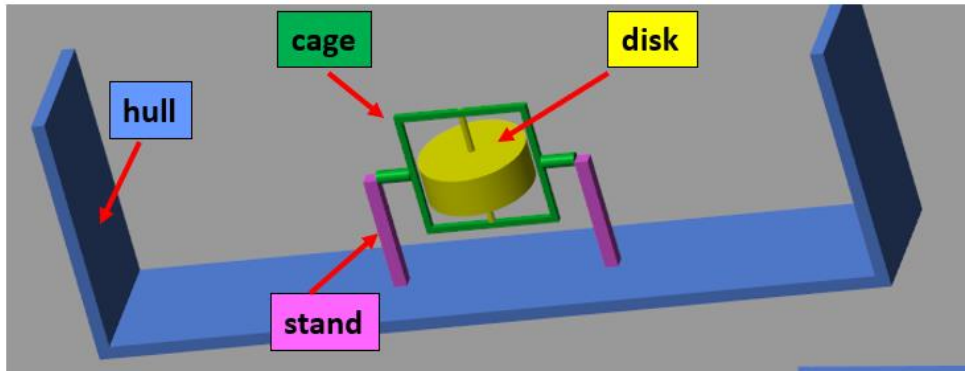


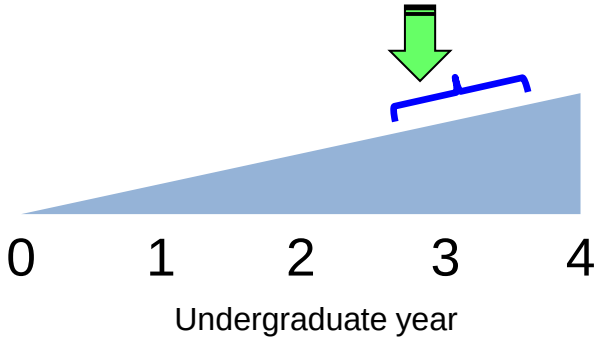
https://insidelabs-git.mathworks.com/ww-edu-technical/demos/demo-wheel-on-a-pole



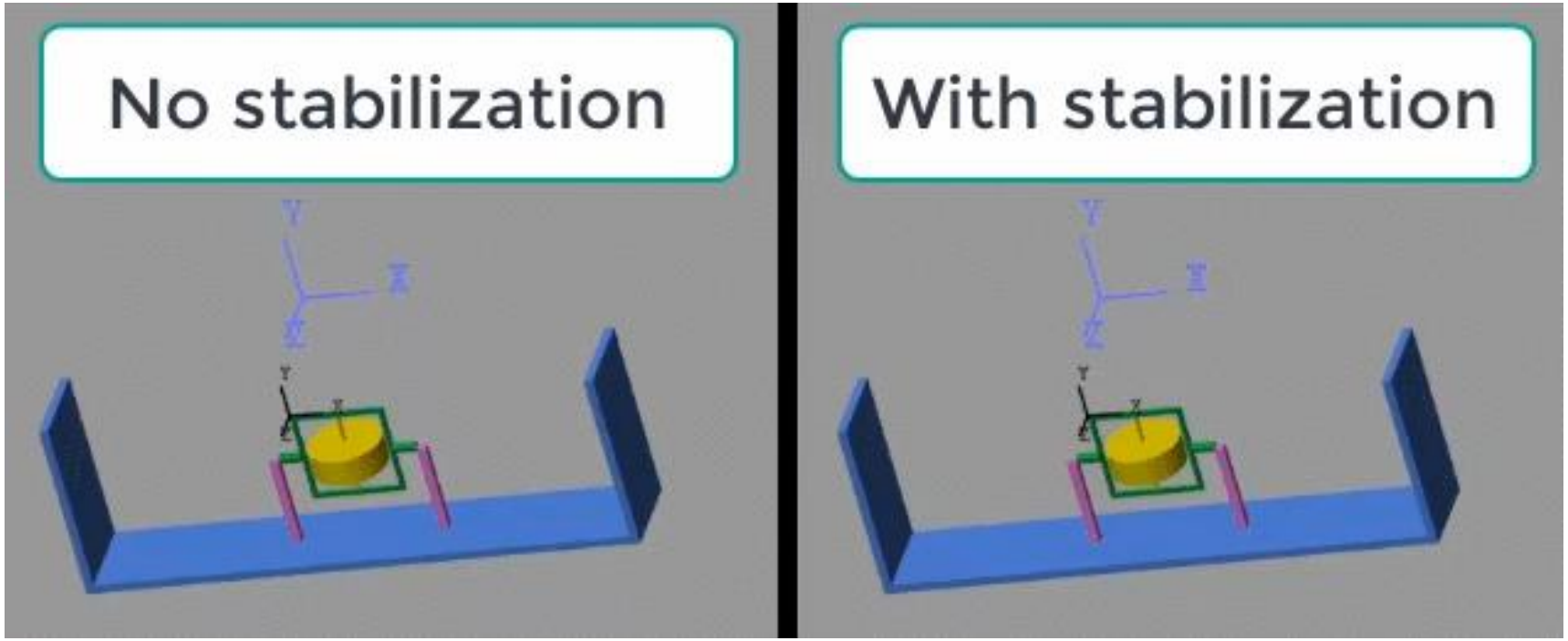
Gyroscopic Boat Stabilization

- **Benefits**
  - Validate hand computations
  - Visualize motion of mechanism
- **Concepts**
  - Kinetics: Lagrange
- **Getting started**
  - `>> DEMO_START_HERE_PLEASE`

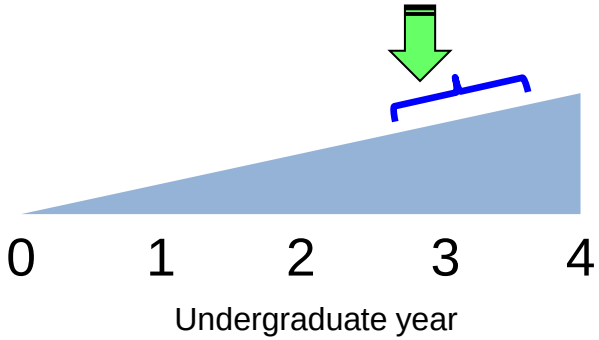




https://insidelabs-git.mathworks.com/ww-edu-technical/demos/gyroscopic-boat-stabilization



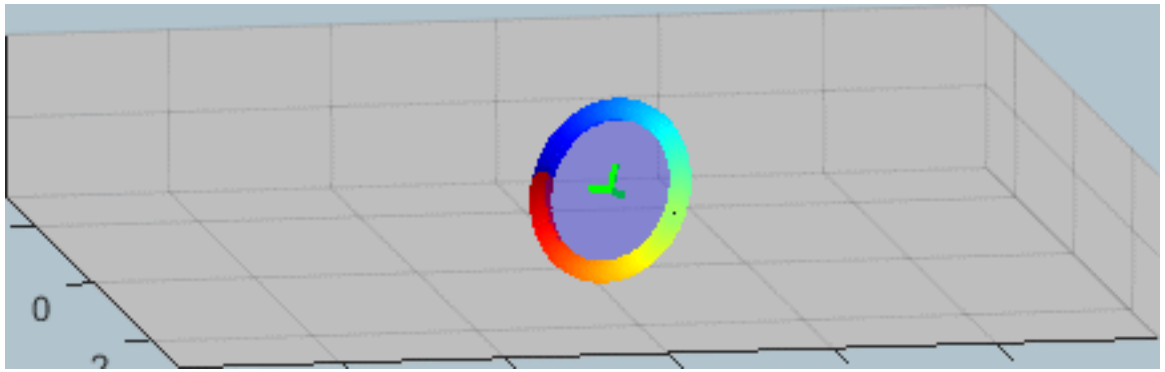
A rolling wheel



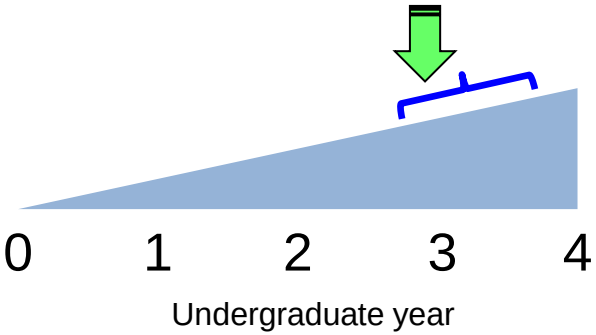
- **Benefits**
  - Validate hand computations
  - Visualize motion of mechanism
- **Concepts**
  - Kinetics: Newton
  - Kinetics: Lagrange (NON-holonomic constraints)
- **Getting started**
  - `>> DEMO_START_HERE_PLEASE`

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_k}\right) - \frac{\partial L}{\partial q_k} = Q_k + \sum_{j=1}^{P} \lambda_j . A_{jk}$$

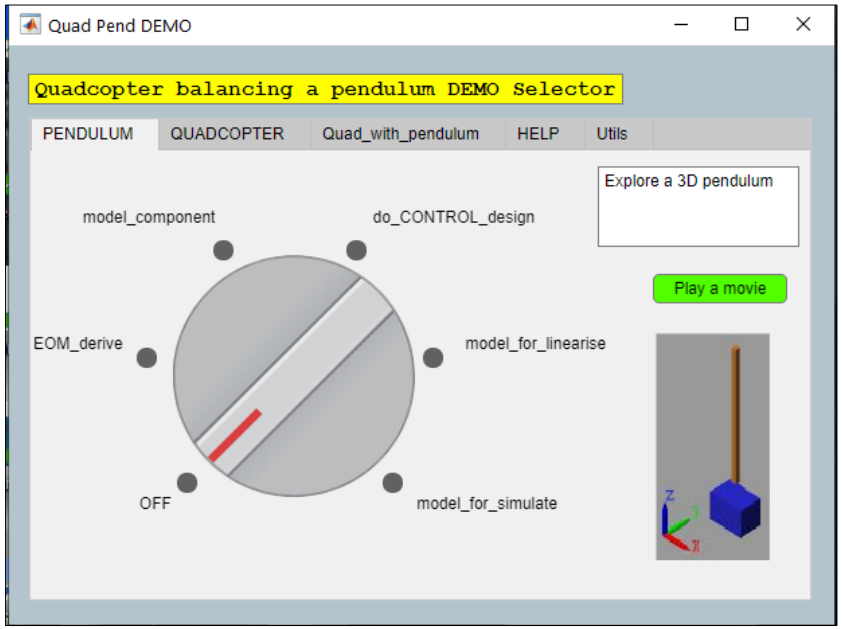
https://insidelabs-git.mathworks.com/ww-edu-technical/demos/a-rolling-wheel-gathers-no-moss



Quadcopter balancing a pendulum



- **Benefits**
  - Validate hand computations
  - Visualize motion of mechanism
- **Concepts**
  - Kinetics: Newton's 2nd Law
  - Kinetics: Lagrange
- **Getting started**
  - `>> bh_startup_quad_and_pendulum`



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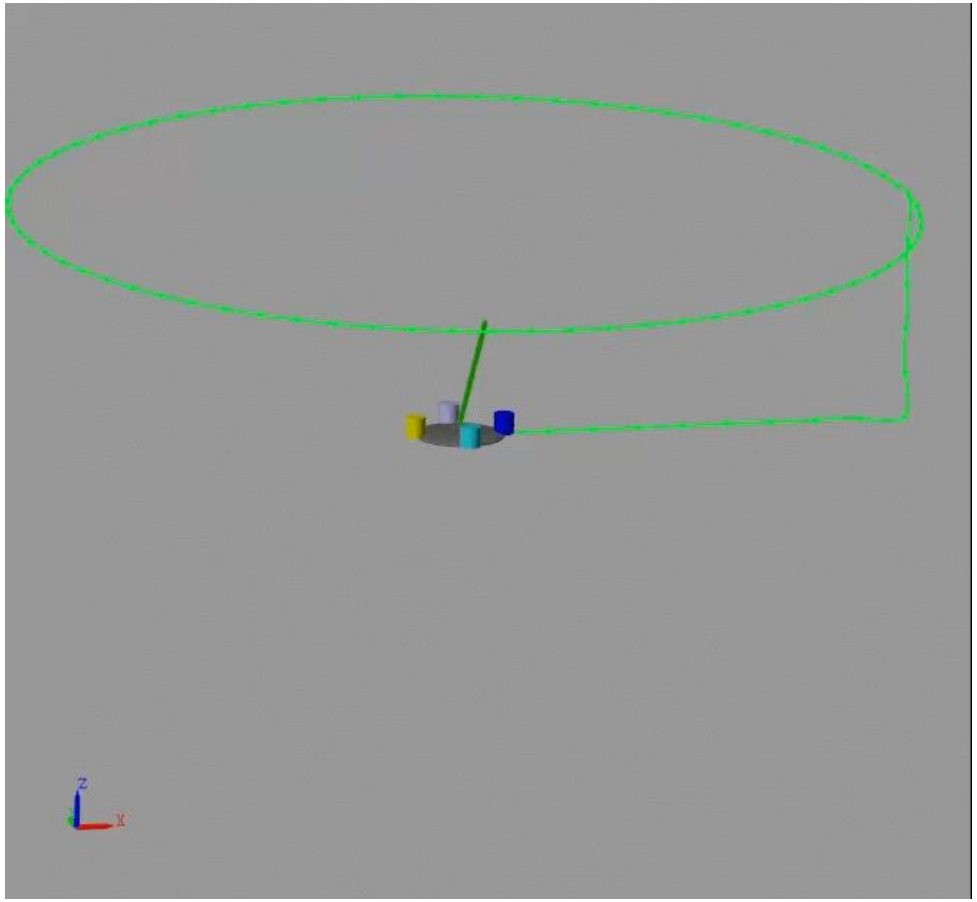
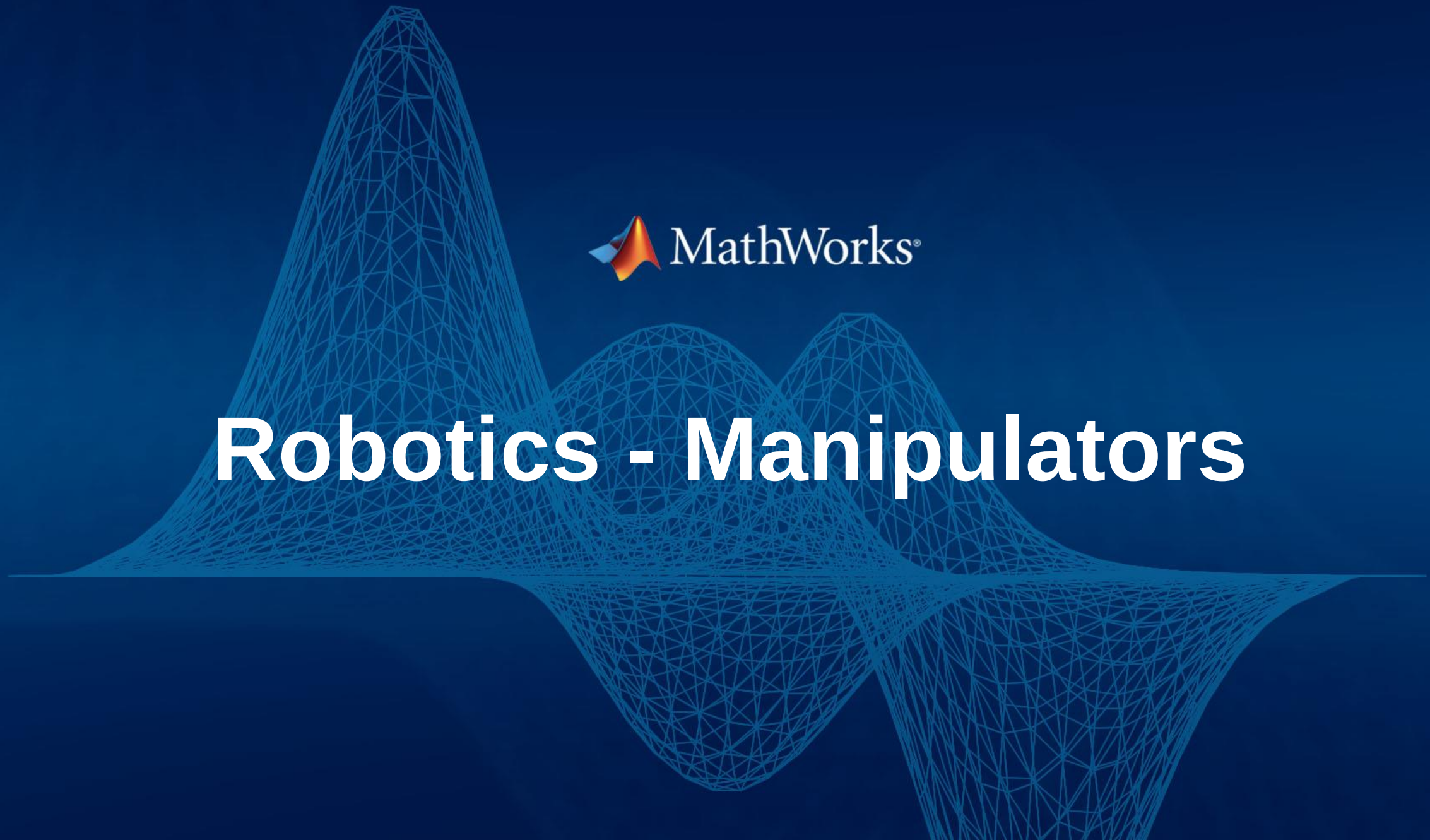
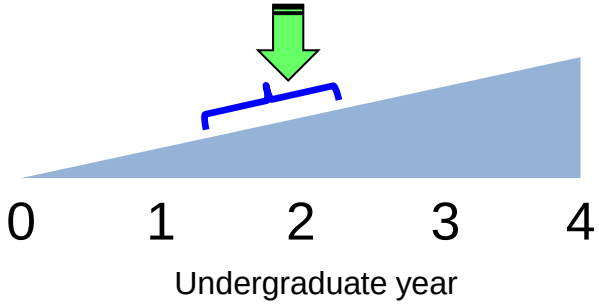




MathWorks®

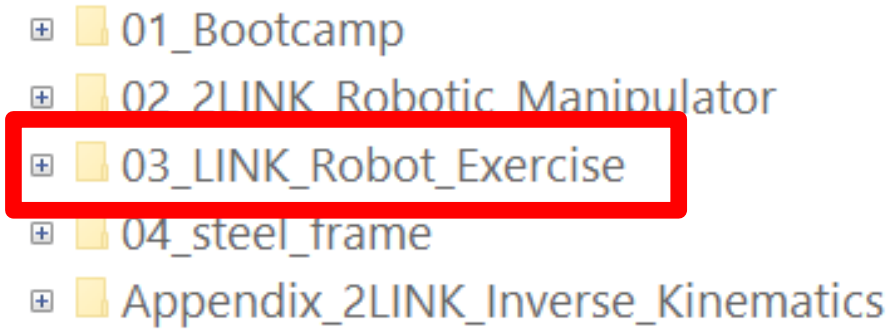
Robotics - Manipulators

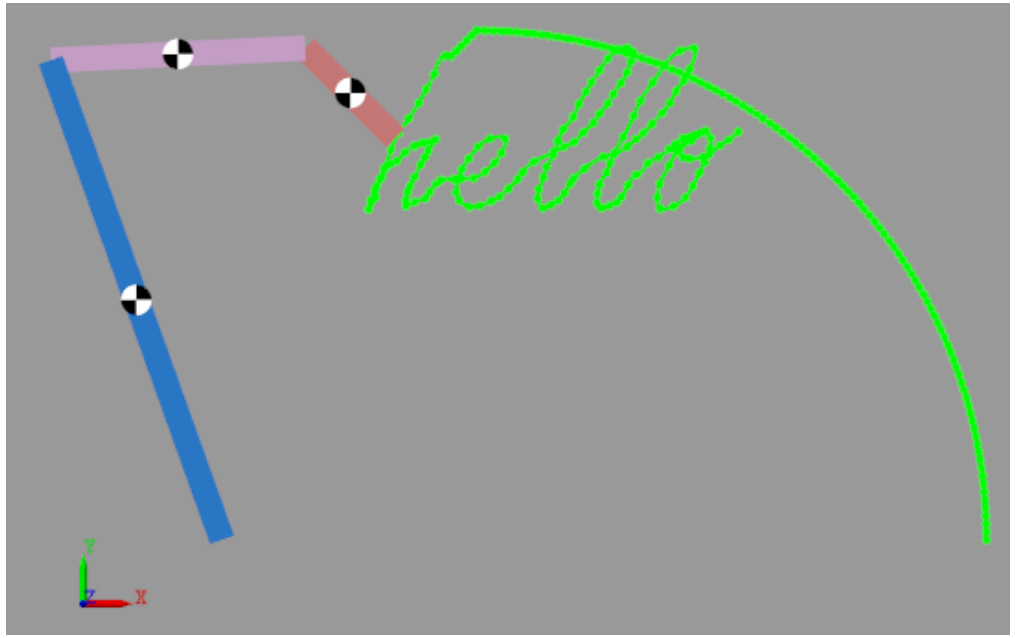
3-LINK Robot



- **Benefits**
  - Validate hand computations
  - Visualize motion of mechanism
- **Concepts**
  - Kinetics: Newton's 2nd Law
  - Kinetics: Lagrange
- **Getting started**
  - `>> bh_3LINK_NEWTON_derivation`
  - `>> bh_3LINK_NEWTON_simulation`
  - `>> bh_3LINK_LAGRANGE_derivation_AND_simulation`

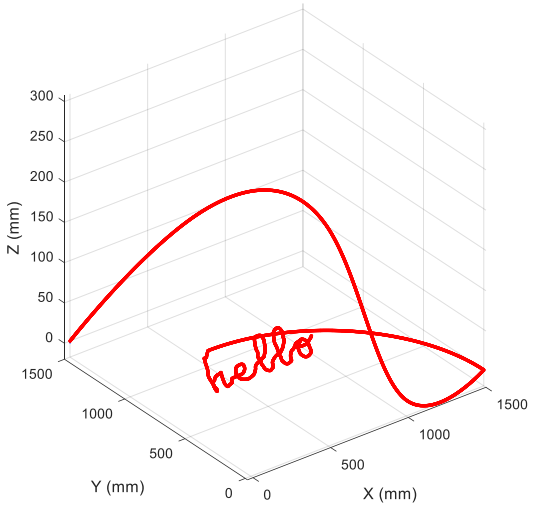
https://insidelabs-git.mathworks.com/ww-edu-technical/seminars/modern-matlab-for-curriculum-delivery-the-disruption-we-had-to-have

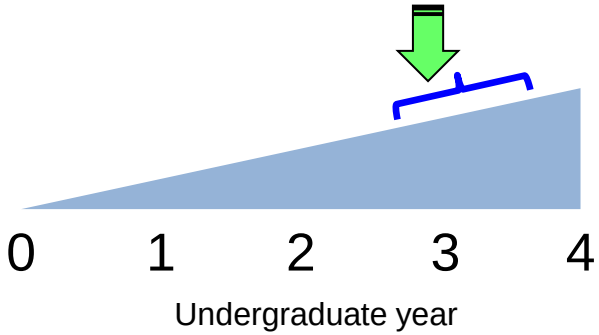




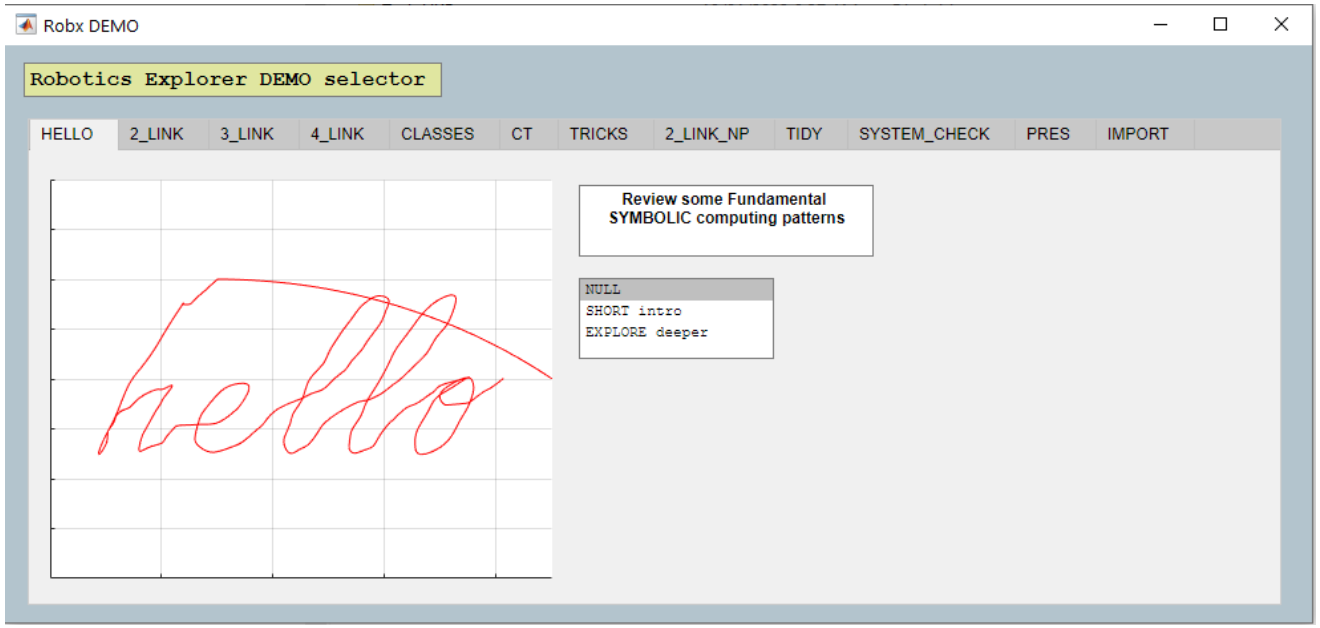
Robot that writes hello

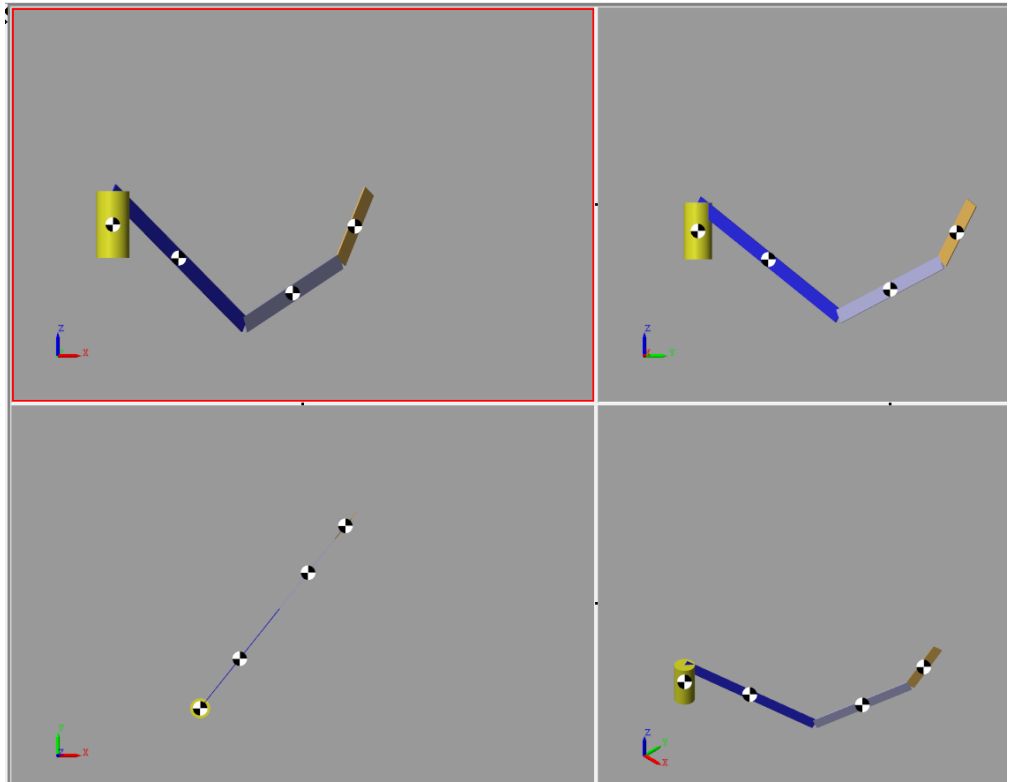
- **Benefits**
  - Visualize motion of mechanism
- **Concepts**
  - Kinetics: Lagrange
- **Getting started**
  - `>> bh_robx_startup`





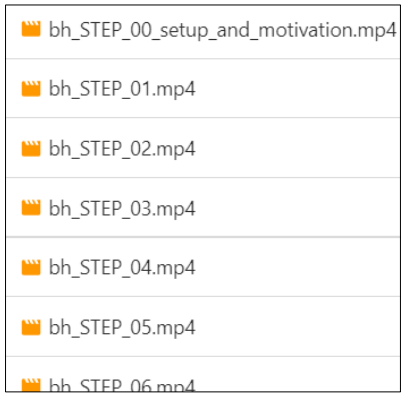
https://insidelabs-git.mathworks.com/ww-edu-technical/seminars/seminar-computational-thinking-and-robots-that-can-write

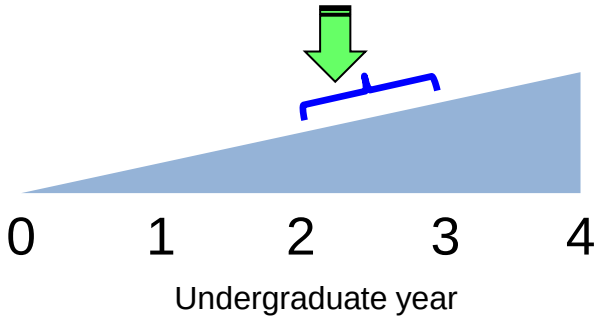




2-dof non planar robot – Hands on **WORKSHOP**

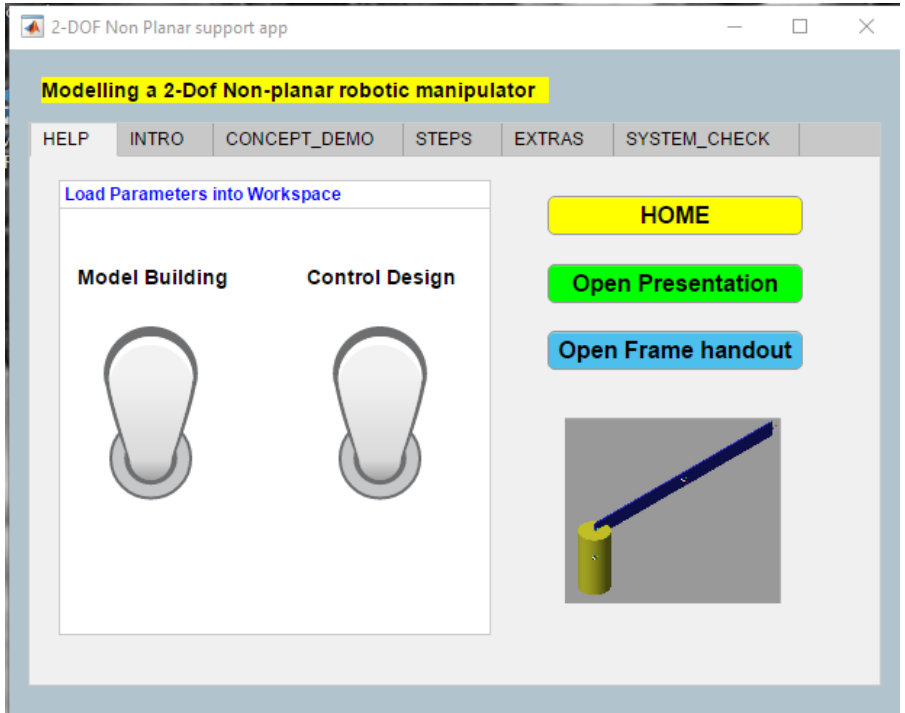
- **Benefits**
  - Visualize motion of mechanism
- **Concepts**
  - Kinetics: Lagrange
- **Getting started**
  - `>> bh_2dofnp_startup`

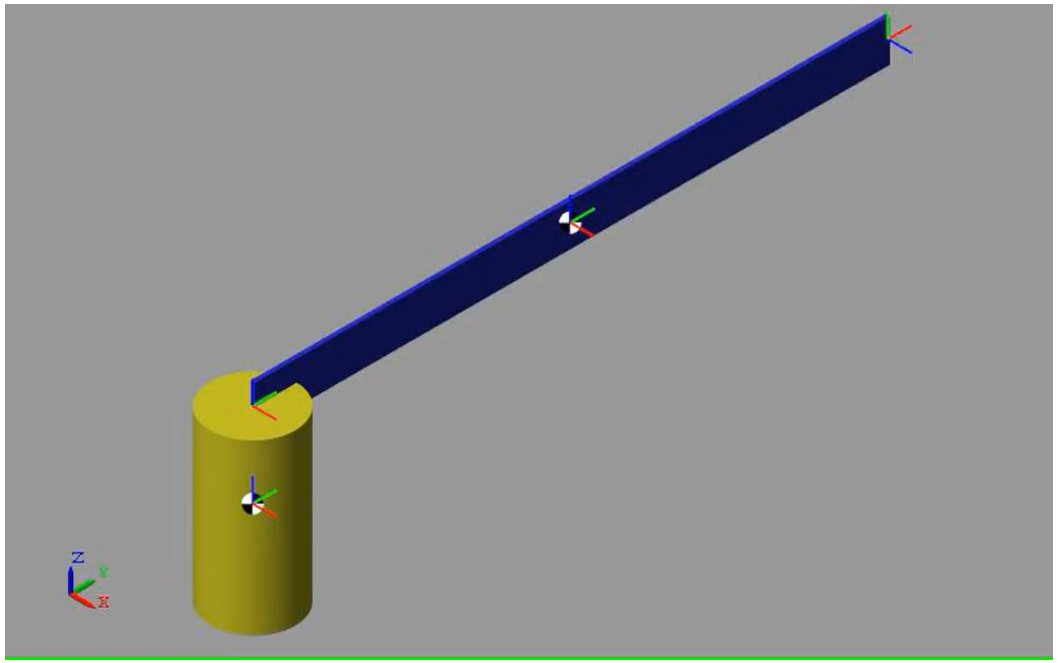




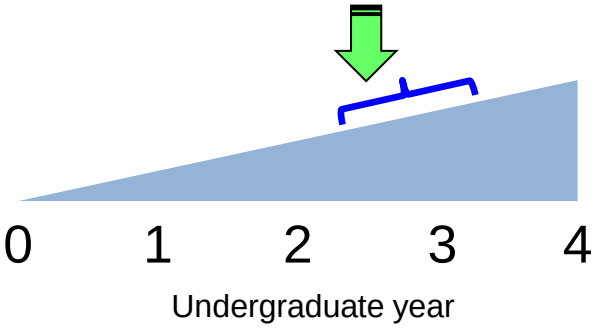
VIDEOS of steps
To create Simscape
Multibody model

https://insidelabs-git.mathworks.com/ww-edu-technical/workshops/workshop-2dof-non-planar-robot

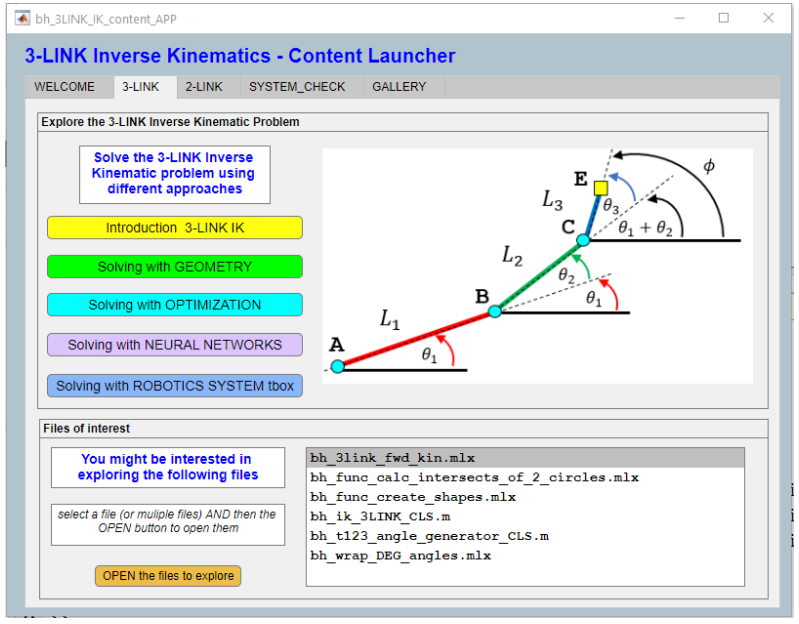




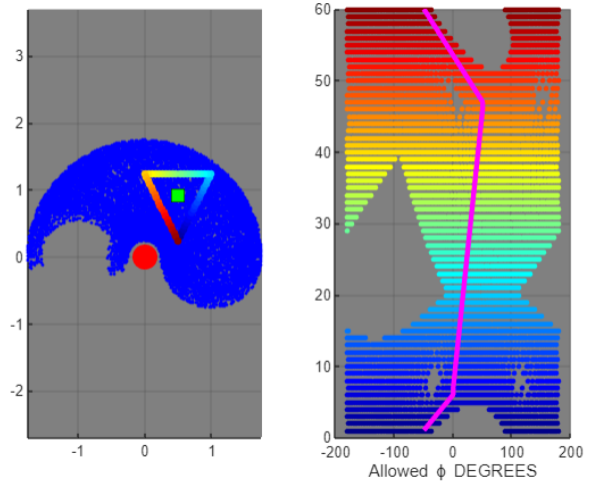
3-LINK Robot Inverse kinematics

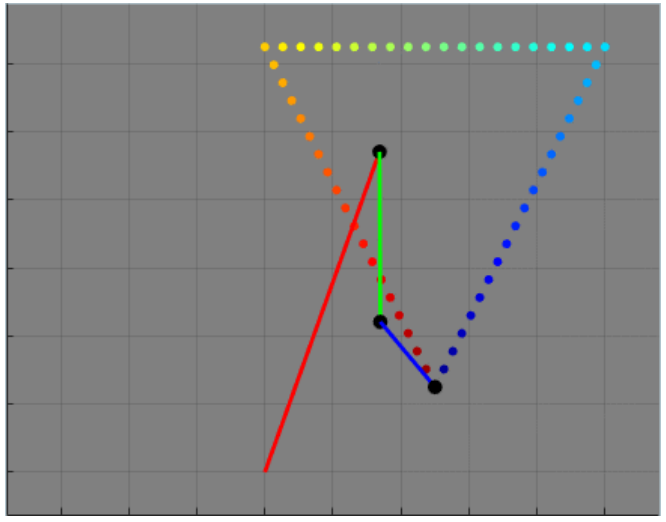


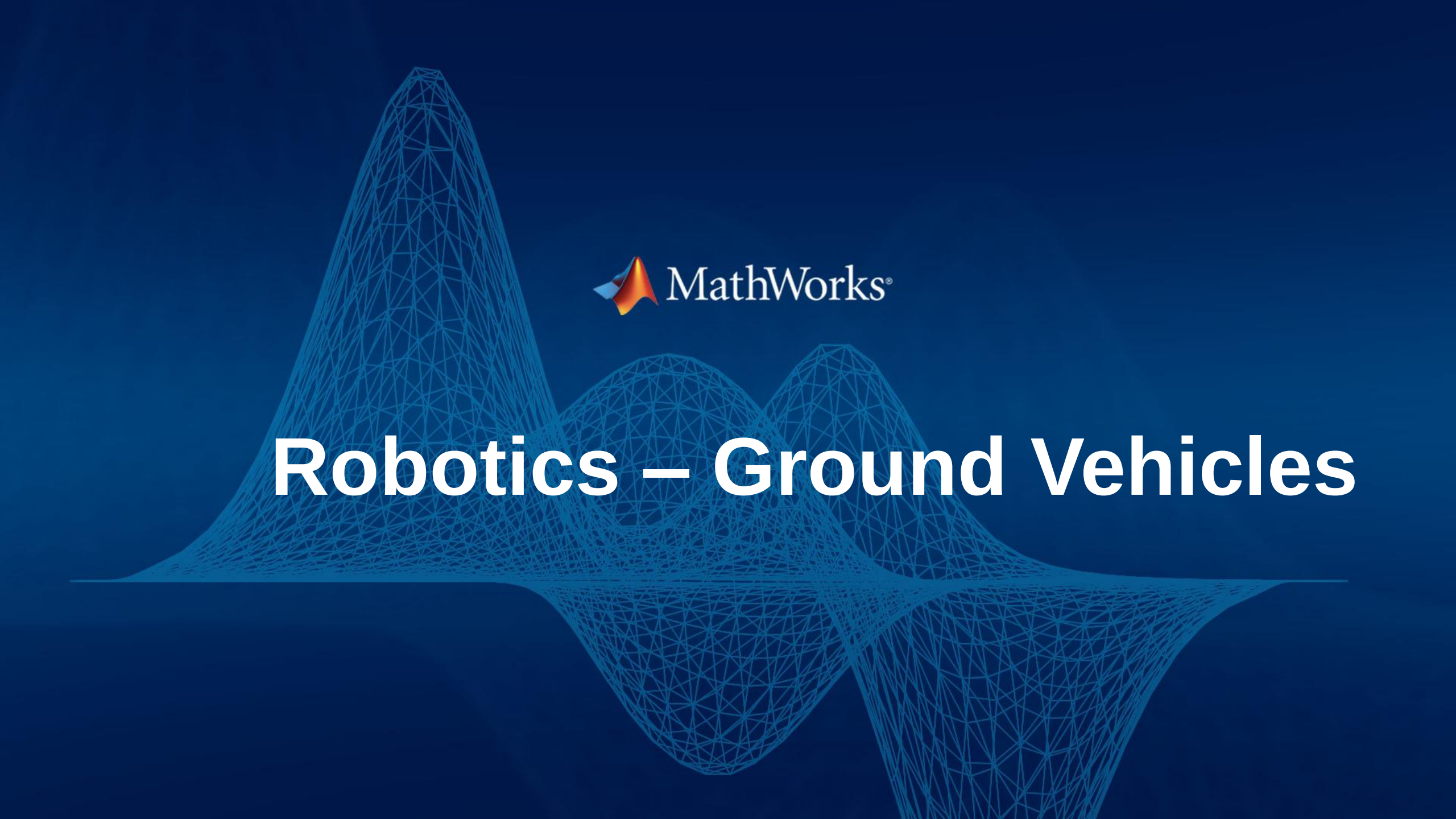
- **Benefits**
  - Solve the Inverse Kinematics problems using different approaches
    - Geometric, optimization, Neural nets, Robotics systems toolbox
- **Concepts**
  - Inverse Kinematics
  - Solving nonlinear optimization problems
  - Shallow Neural Networks
- **Getting started**
  - `>>  bh_3LINK_IK_startup`



https://insidelabs-git.mathworks.com/ww-edu-technical/demos/demo-3-link-inverse-kinematics

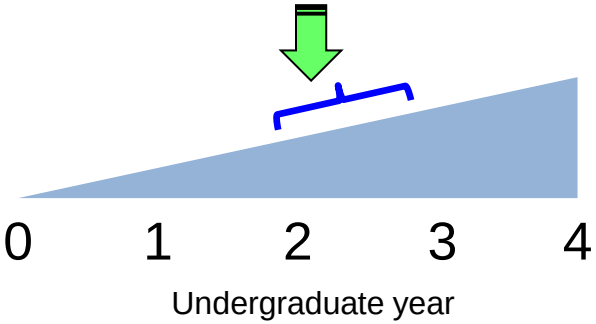






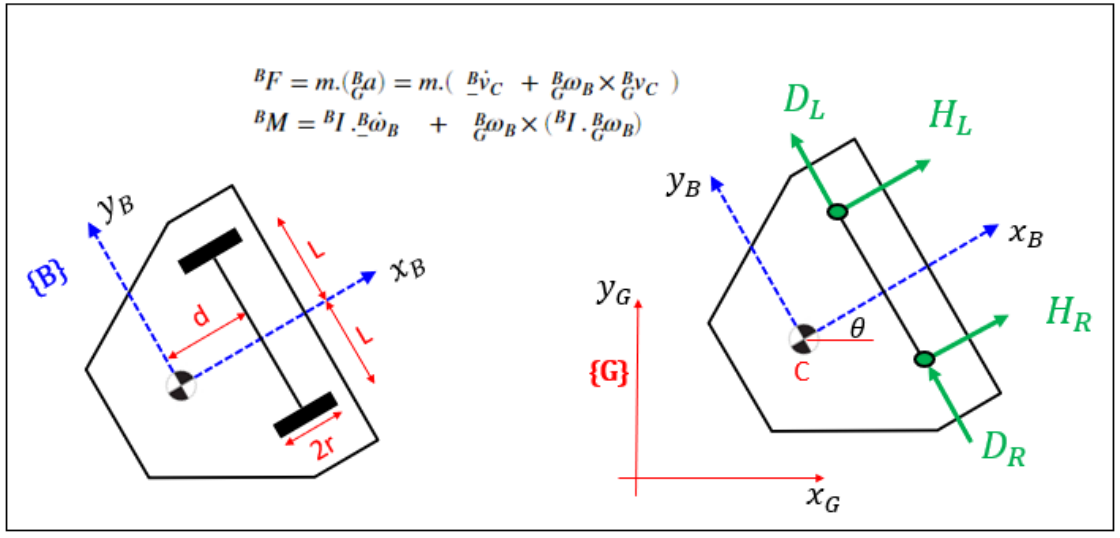
Robotics – Ground Vehicles

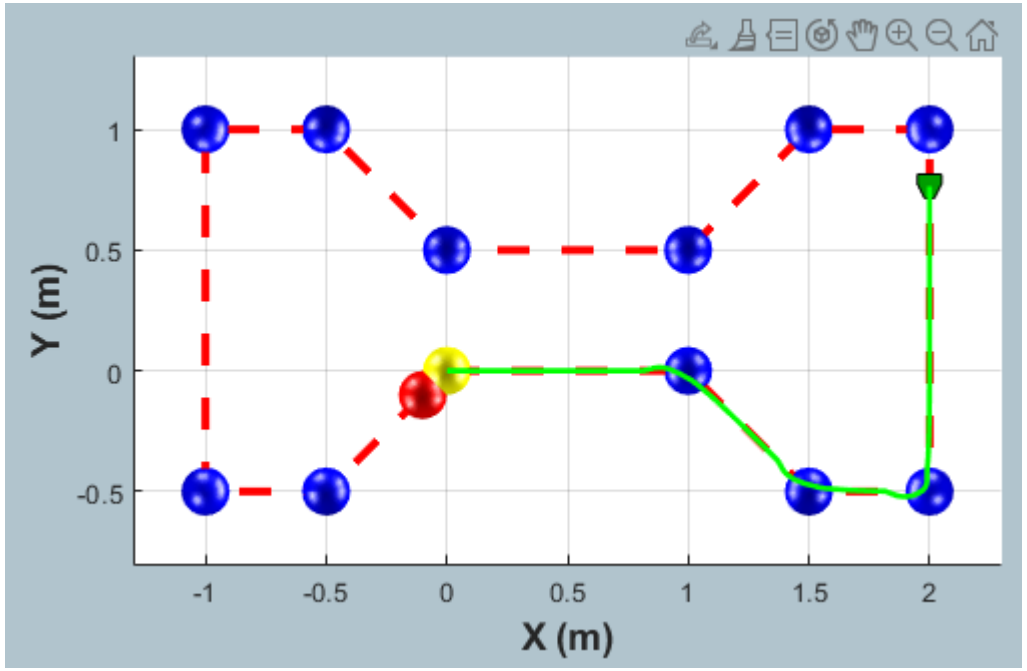
Differential Drive Robot (DDR)



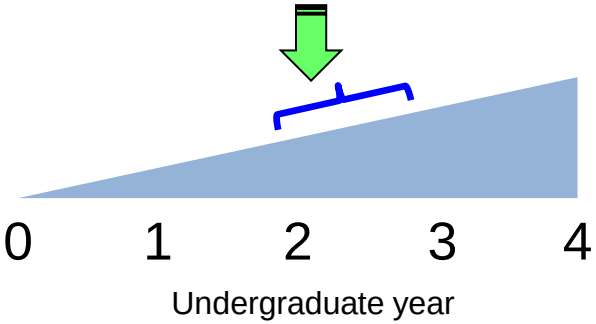
- **Benefits**
  - Explore cause and effect
    - Derive Equations of motion … and then SIMULATE
  - Visualize motion of ground vehicle
- **Concepts**
  - Kinetics: Newton's 2nd Law
  - Control: Pure Pursuit
- **Getting started**
  - `>> DEMO_START_HERE_PLEASE`

https://insidelabs-git.mathworks.com/ww-edu-technical/demos/demo-differential-drive-robot

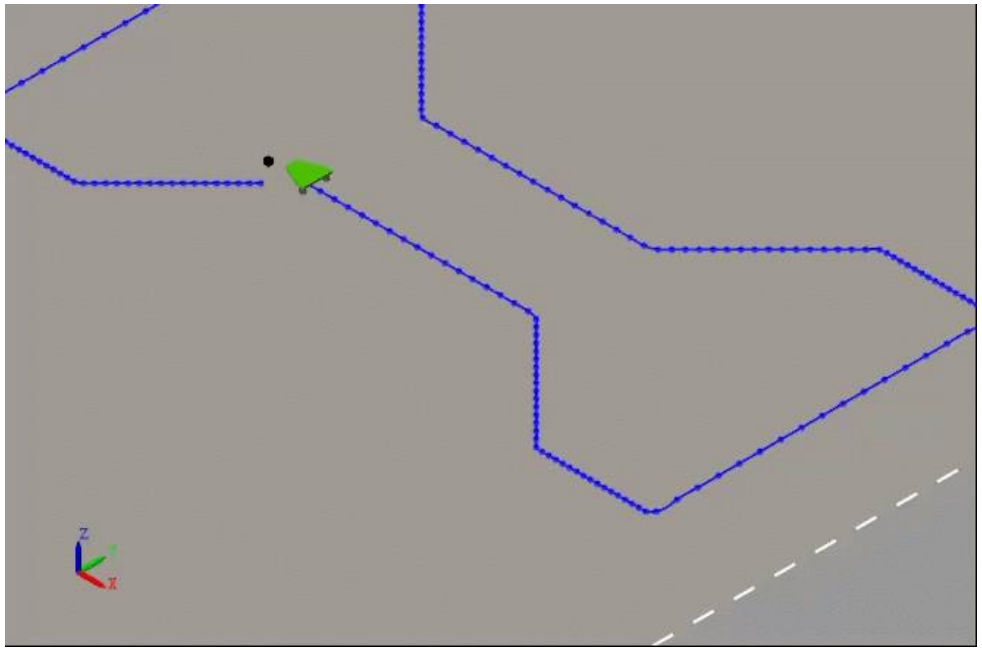


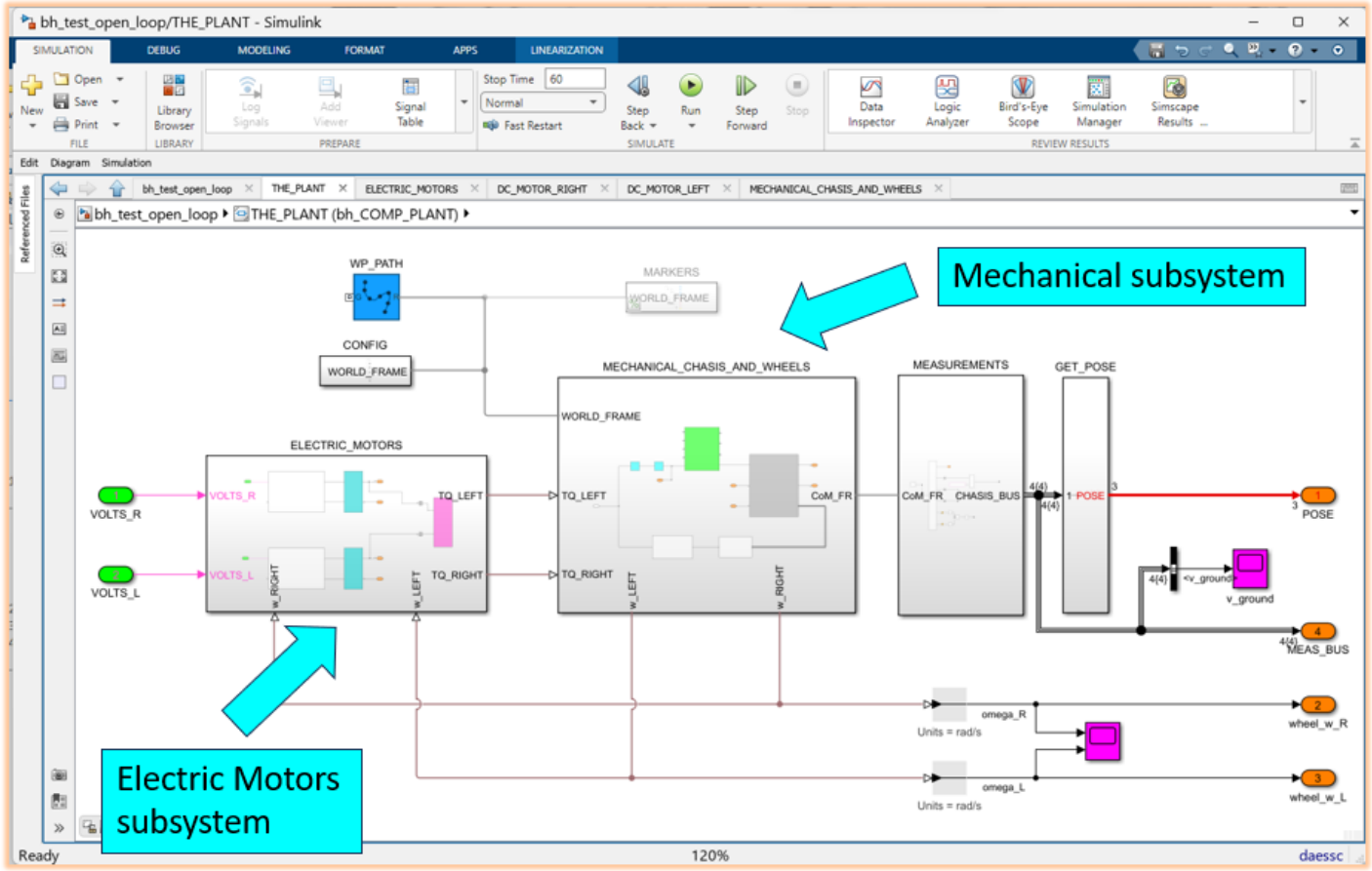


Differential Drive Mobile Robot (DDMR)



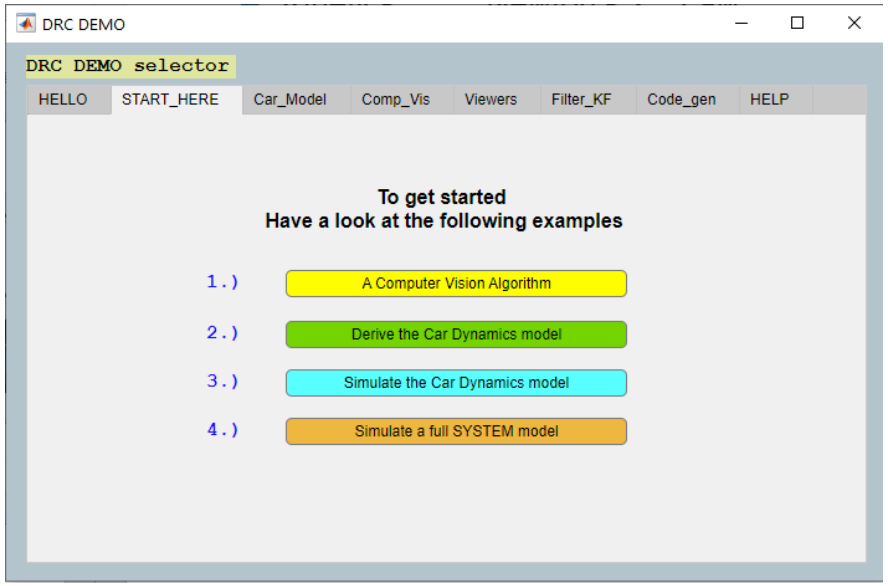
- **Benefits**
  - Explore cause and effect
    - Multi domain model: **Electro Mechanical**
  - Visualize motion of ground vehicle
- **Concepts**
  - Control: Linearise plant, speed controllers
  - Control: Pure Pursuit
- **Getting started**
  - `>> bh_START_HERE_PLEASE`



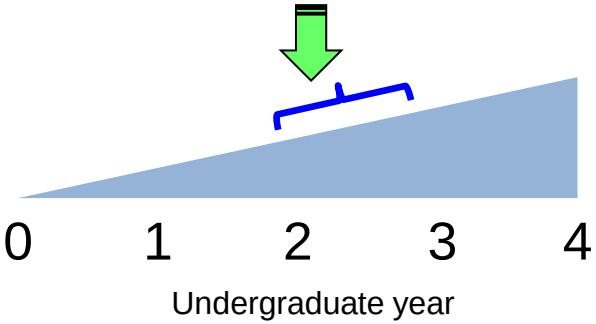


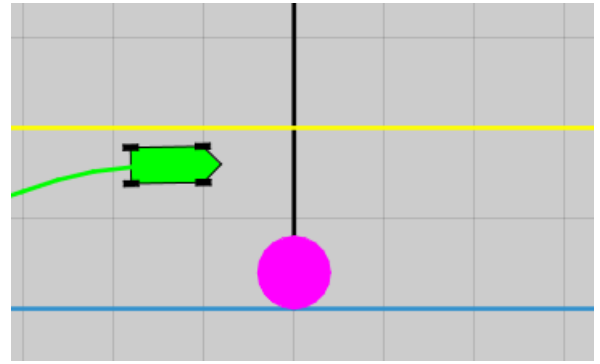
Droid Racing Challenge(DRC)

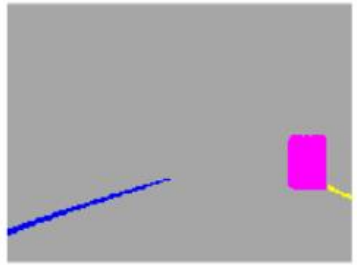
- **Benefits**
  - Explore cause and effect
    - Derive Equations of motion … and then SIMULATE
  - Visualize motion of ground vehicle
- **Concepts**
  - Kinetics: Newton's 2nd Law
  - Computer Vision
  - Finite State Machines
- **Getting started**
  - `>> bh_car_startup.m`

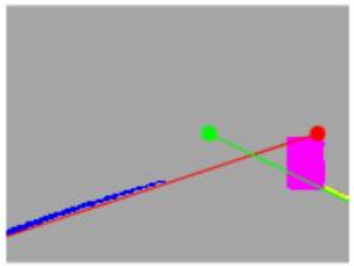


https://insidelabs-git.mathworks.com/ww-edu-technical/demos/demo-droid-racing-challenge---student-competition



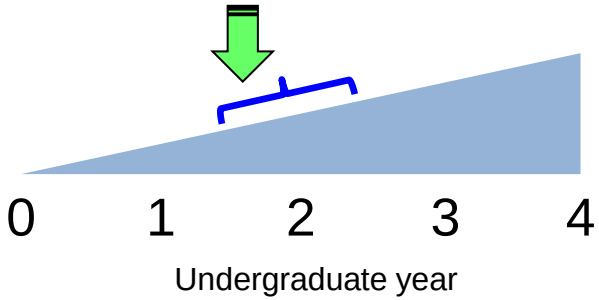






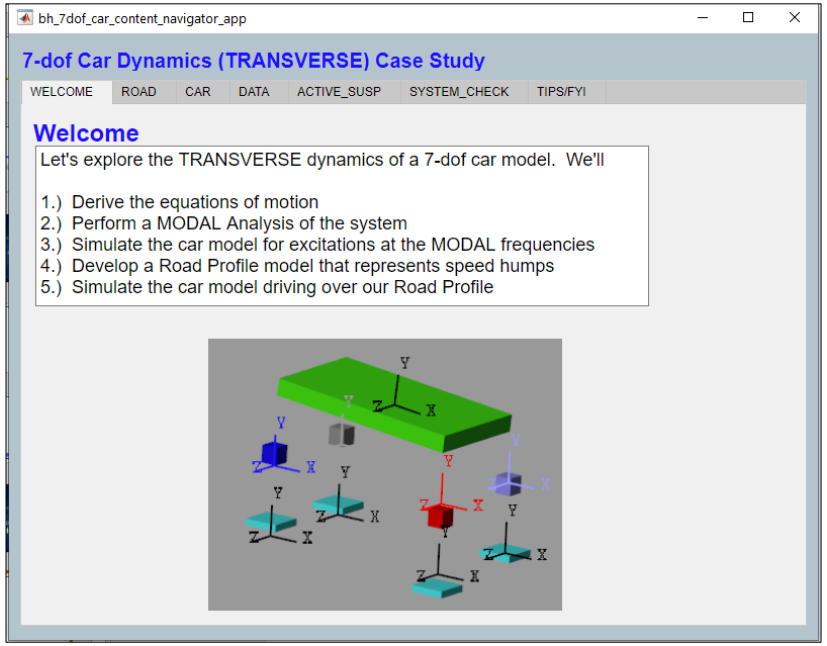
Spring Mass Damper systems

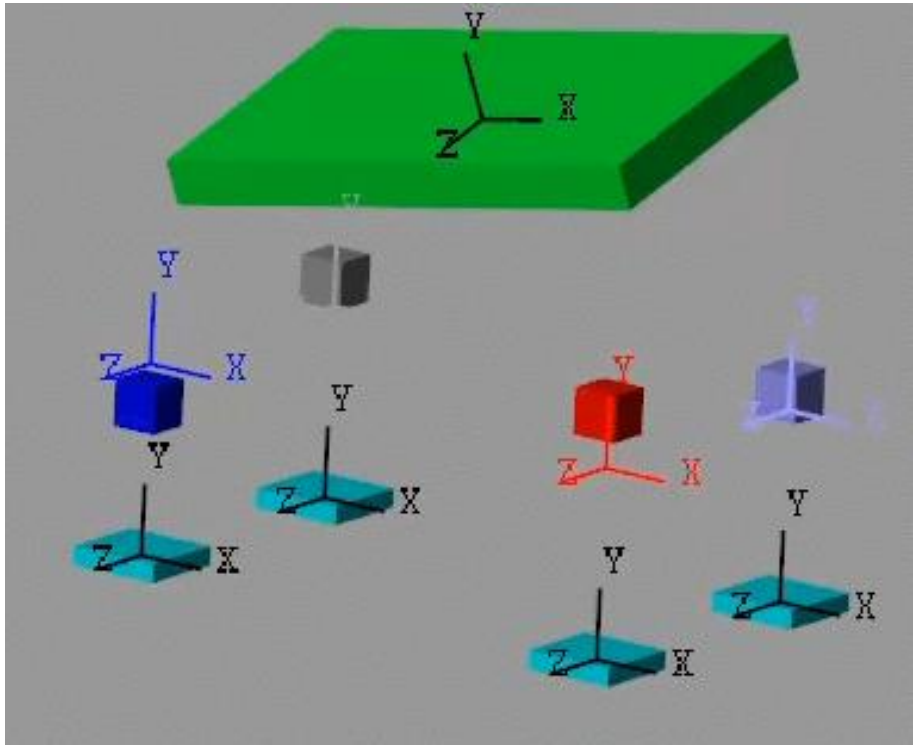
7-dof Transverse car dynamics



- **Benefits**
  - Validate hand computations
  - Visualize motion of mechanism
- **Concepts**
  - Kinetics: Newton's 2nd Law
  - Modal Analysis
- **Getting started**
  - `>> DEMO_START_HERE_PLEASE`

https://insidelabs-git.mathworks.com/ww-edu-technical/demos/car-dynamics-7dof-transverse





MATLAB + Computational Thinking

Decomposition

- Break 1 complex problem into a collection of smaller/simpler problems

Abstraction

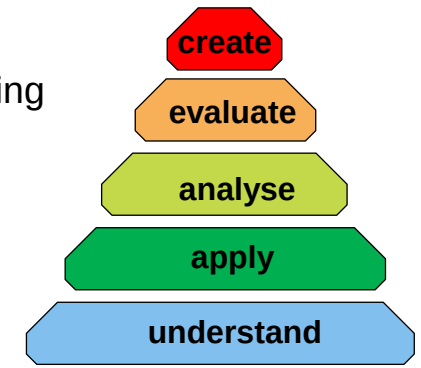
Mathematical modelling
- Symbolic representation
- Block diagrams

Algorithms + Automation

- Formulating solution as a series of steps
- Transforming between Modelling paradigms

Simulation

- What happens when ?



Blooms revised taxonomy: https://tips.uark.edu/using-blooms-taxonomy/