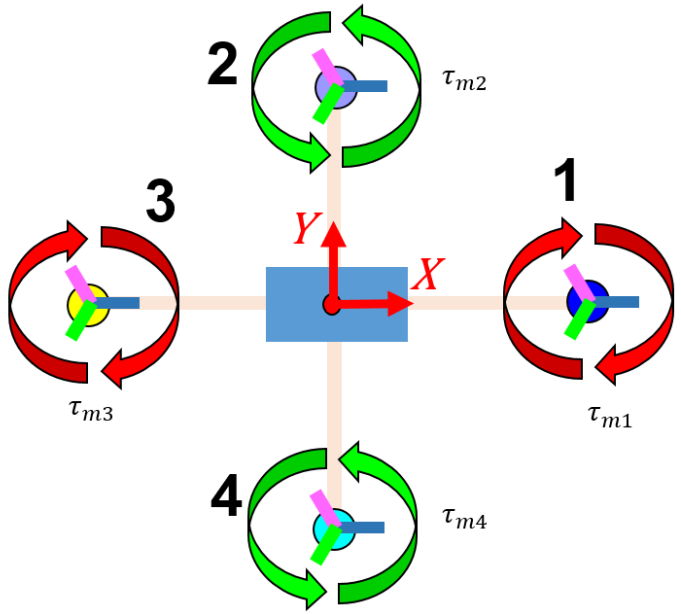
Quadcopter Modelling and simulation

- a case study for encouraging deeper learning engagements with students.



Brad Horton
Engineer
MathWorks

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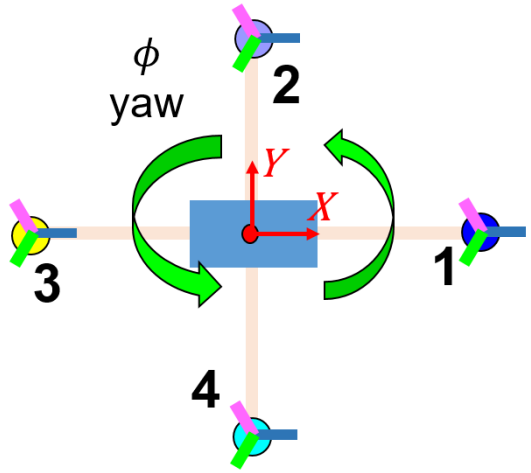
Does it fly ?


ϕ
yaw
2
Y
X
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1
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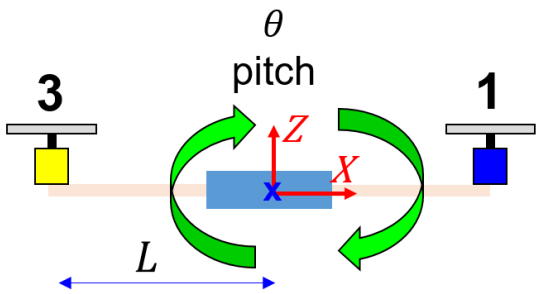
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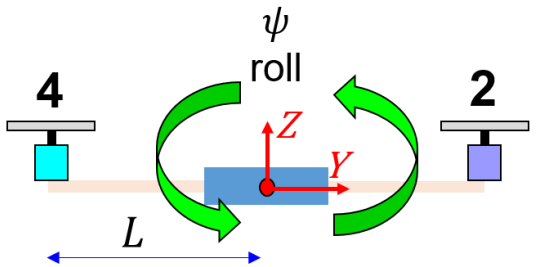
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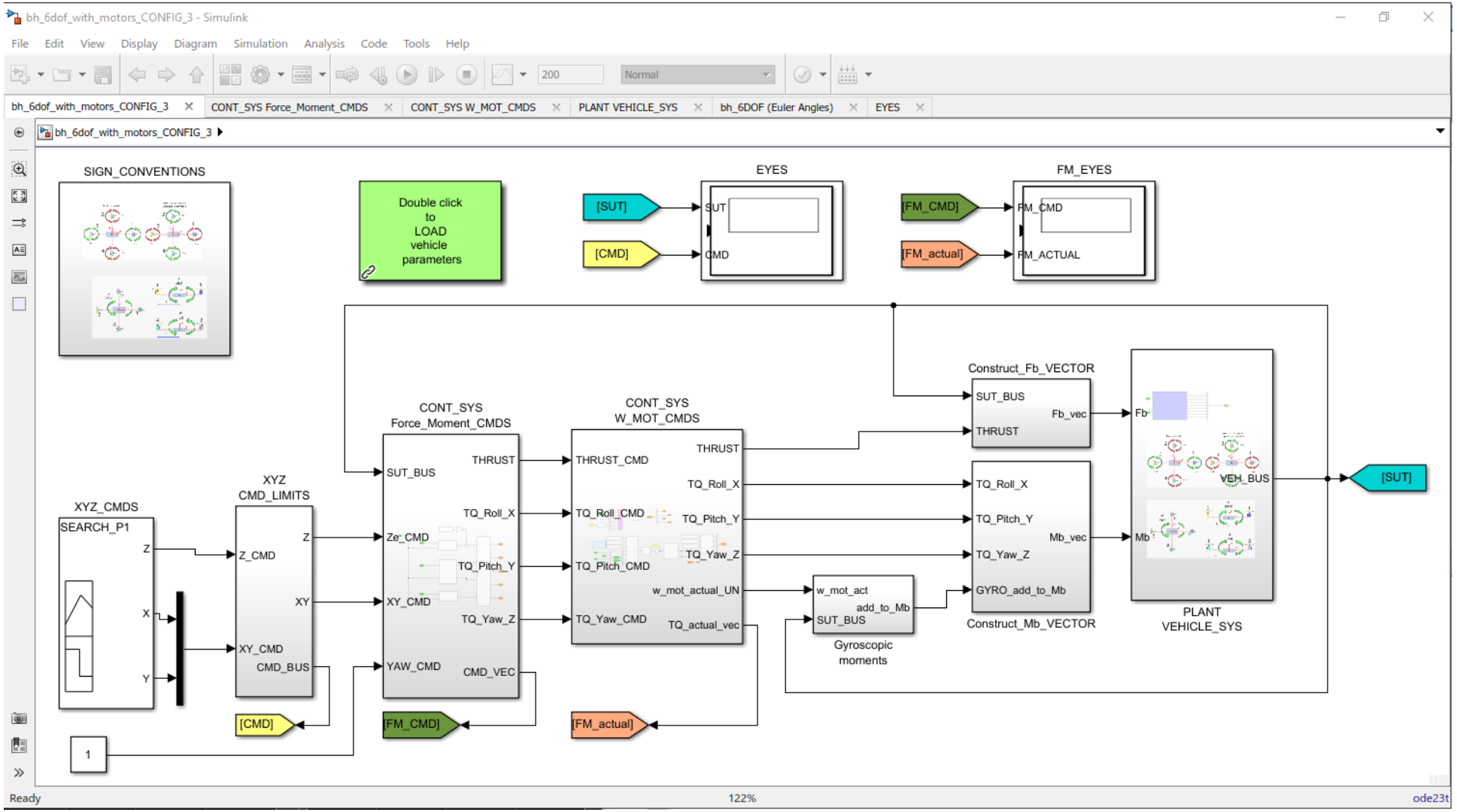
bh_6dof_with_motors_CONFIG_3 - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
bh_6dof_with_motors_CONFIG_3
CONT_SYS Force_Moment_CMDS
CONT_SYS W_MOT_CMDS
PLANT VEHICLE_SYS
bh_6DOF (Euler Angles)
EYES
SIGN_CONVENTIONS
Double click to LOAD vehicle parameters
[SUT]
[CMD]
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FM_ACTUAL
Construct_Fb_VECTOR
SUT_BUS
THRUST
Fb_vec
Fb
VEH_BUS
XYZ_CMDS
SEARCH_P1
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Z_CMD
XY
XY_CMD
CMD_BUS
CONT_SYS Force_Moment_CMDS
SUT_BUS
THRUST
TQ_Roll_X
Ze_CMD
TQ_Pitch_Y
XY_CMD
TQ_Yaw_Z
YAW_CMD
CMD_VEC
CONT_SYS W_MOT_CMDS
THRUST_CMD
TQ_Roll_CMD
TQ_Pitch_CMD
TQ_Yaw_CMD
w_mot_actual_UN
TQ_actual_vec
w_mot_act
add_to_Mb
SUT_BUS
Gyroscopic moments
TQ_Roll_X
TQ_Pitch_Y
TQ_Yaw_Z
GYRO_add_to_Mb
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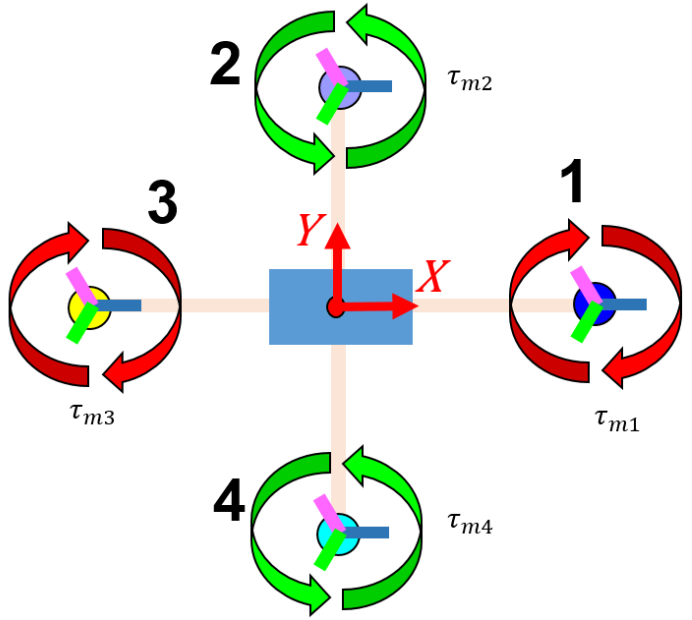
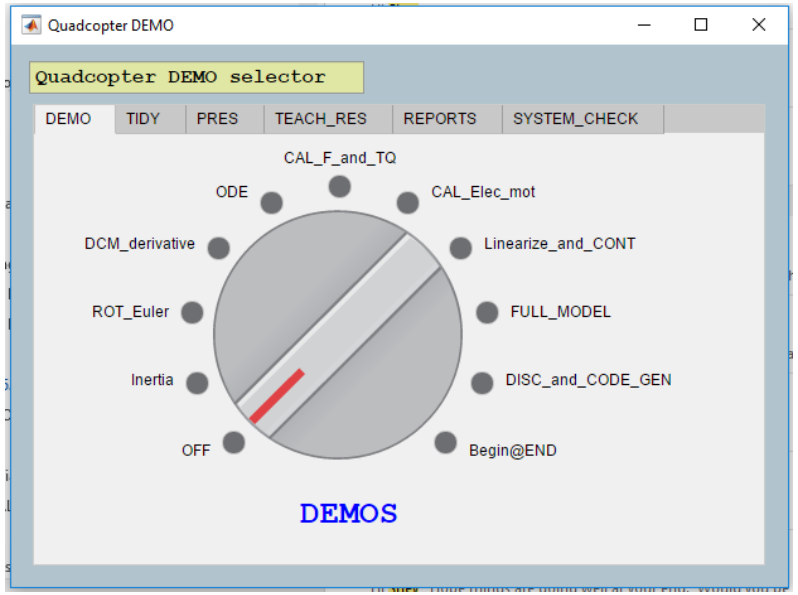
Ready
122%
ode23t

Today's Agenda:

- Review Student learning styles
  - Surface learning versus Deep learning
- The MATLAB Technical Computing Environment
  - How can it support/encourage Deep Learning?
- Where can you find teaching resources ?
- Q/A
  - How can you download ALL of the demonstrations shown today ?

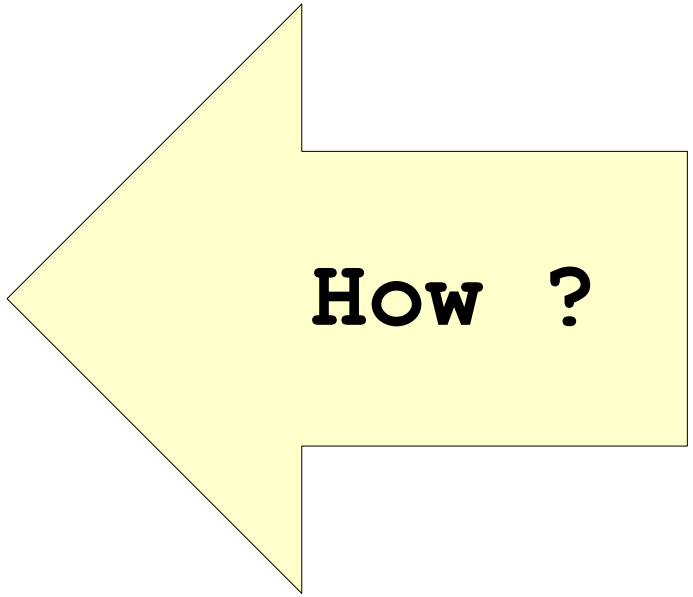




Student Learning styles - Surface versus Deep

Deep approach:

- A desire to understand
- Will take ownership of learning.
- Wants to Link concepts and apply to problem solving.
- Regards learning as a pleasant thing to do



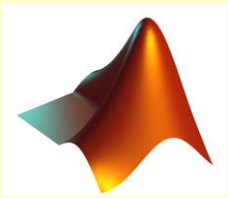
Surface approach

- Learning to pass an exam
- Rote learning
- Disinterest in seeking connections that link concepts
- Learning is UNpleasant

Fostering a Deep Learning approach:

Deep Learning:

- A desire to **understand**
- Will take ownership of learning.
- Wants to Link concepts and apply to problem solving.
- Regards learning as a pleasant thing to do



Technical Computing Environment:

Contributes towards

Enhancement of understanding

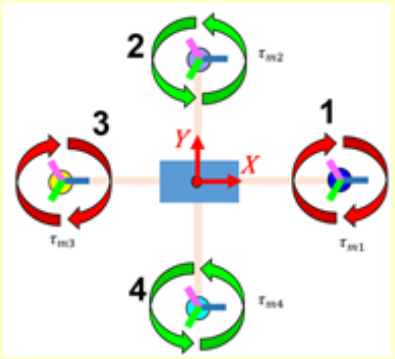
Enhancement of Understanding

- Decompose BIG problems into several smaller problems.
- Provide choices on how to solve.
- Build upon existing skills and experiences
- Provide self serve support

Quadcopter case study

Enhancement Of Understanding:

- Decompose 1 BIG problem into several smaller problems.
- Build upon existing skills and experiences
- Choices on how to solve
- Provide self serve support



Model the vehicle

TASKS CONCEPTS

1st , 2nd, 3rd year

Calibrate the electric motors

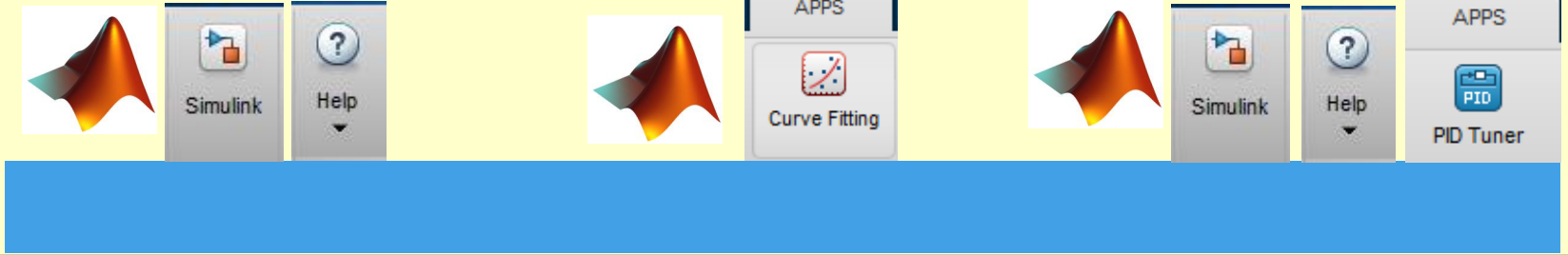
TASKS CONCEPTS

1st , 2nd year

Control the vehicle

TASKS CONCEPTS

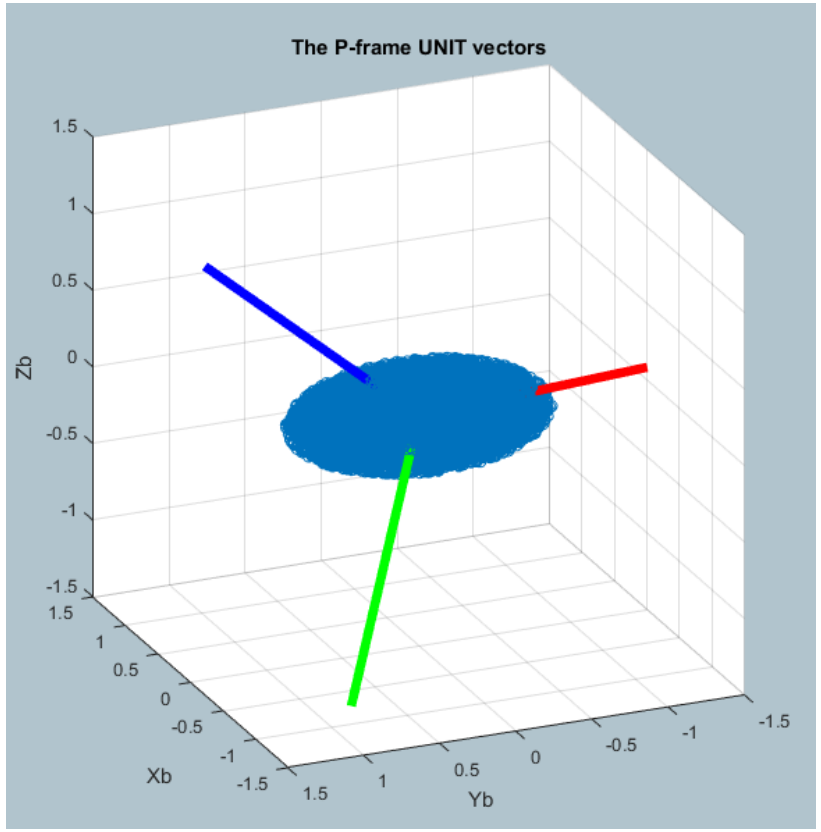
3rd , 4th year



Demo these tasks

Task: Principal moments of Inertia

$$ {}^{P}L = {}^{P}I \times {}^{P}\omega \qquad where \qquad {}^{P}I = \begin{pmatrix} I_1 & 0 & 0 \\ 0 & I_2 & 0 \\ 0 & 0 & I_3 \end{pmatrix} $$



MathWorks

Live Script

bh_task_principal_I.mlx

Help

```
>> doc eig
>> doc Linear Algebra
```

Free MATLAB Courseware

Numerical Computing with MATLAB

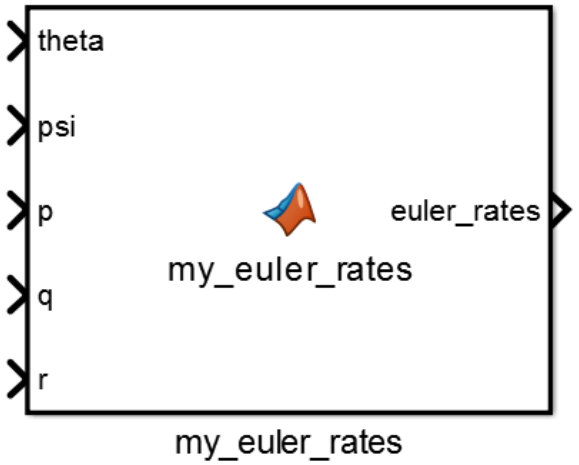
Applied Numerical Methods with MATLAB

Task: Passive Rotations and Euler rates

```
euler_rates = A \ [p; q; r];
euler_rates = simplify(euler_rates)
```

euler_rates =

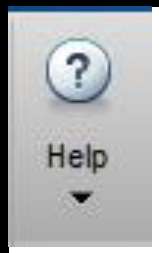
$$\begin{pmatrix} \frac{r\cos(\psi)+q\sin(\psi)}{\cos(\theta)} \\ q\cos(\psi)-r\sin(\psi) \\ \frac{p\cos(\theta)+r\cos(\psi)\sin(\theta)+q\sin(\psi)\sin(\theta)}{\cos(\theta)} \end{pmatrix}$$



MathWorks

Live Script

bh_task_explore_euler_rates_CONCEPT.mlx




```
>> doc live scripts
>> doc matlabFunction
>> doc matlabFunctionBlock
```

Free MATLAB Courseware

Introduction to MATLAB

Aeronautical Systems-Guidance and Control

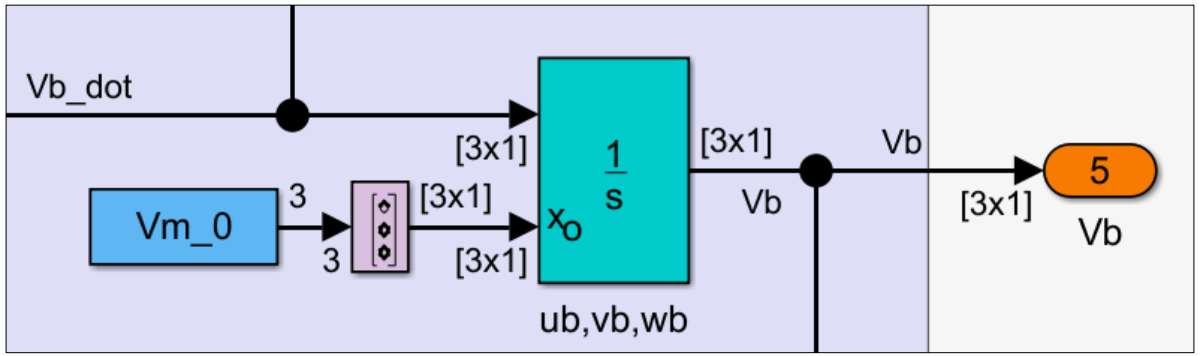
Task: Solving ODEs

$$ {}^{B}F = m.({}^{B}\dot{v} + {}^{B}\omega \times {}^{B}v) $$

$$ {}^{B}M = {}^{B}I.{}^{B}\dot{\omega} + {}^{B}\omega \times ({}^{B}I.{}^{B}\omega) $$

```
%   F = m*(vDOT + w_x_v)
vDOT = F/m - cross(w,vB);

% M   = I*wDOT + w_x_(I*w)
wDOT = inv(I) * (M - cross(w, I*w));
```



MathWorks

Live Script

bh_task_integrate_6dof_MATLAB.mlx

Help

```
>> doc ODE solver
>> doc ode45
>> doc table
>> doc readtable
```

Free MATLAB Courseware

Numerical Computing with MATLAB

Applied Numerical Methods with MATLAB

Differential Equations and Linear Algebra

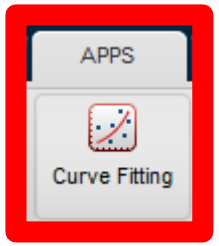
Task: calibrate Thrust,Torque with speed

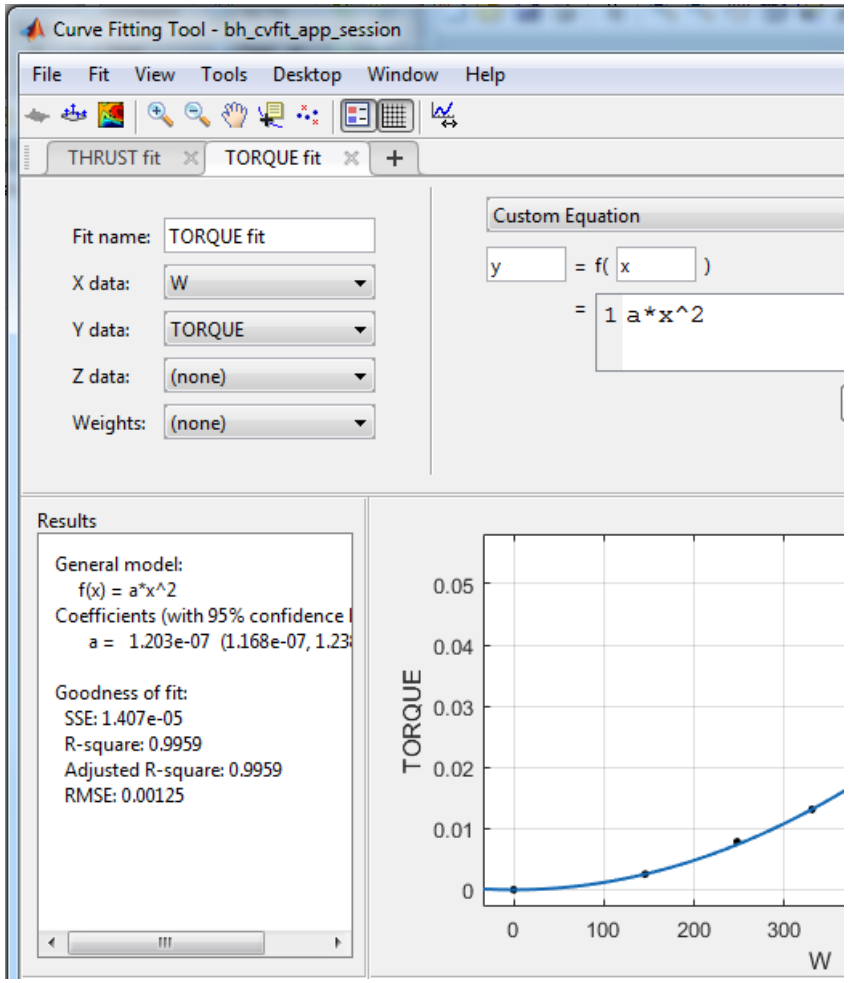
$$THRUST = k_F \times \omega^2$$

$$TORQUE = k_M \times \omega^2$$

```
A  = W.^2;
b  = TORQUE;

kM = A\b
```





MathWorks

Live Script

bh_task_do_F_and_TQ_calibration.mlx

Help

```
>> doc curve fitting
>> doc cvfit
>> doc linear equations
>> doc readtable
```

Free MATLAB Courseware

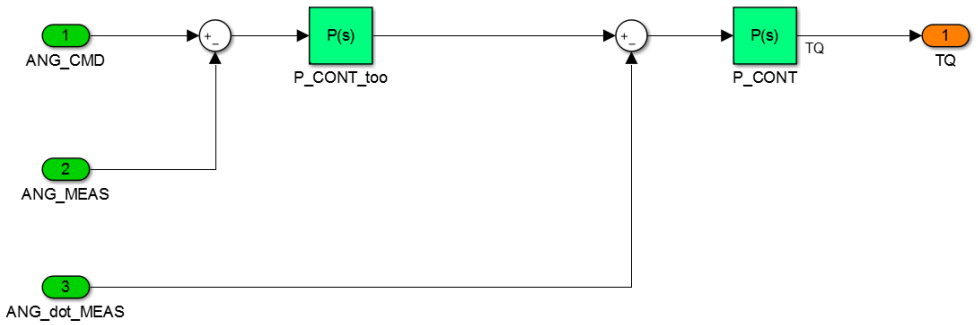
[Numerical Computing with MATLAB]

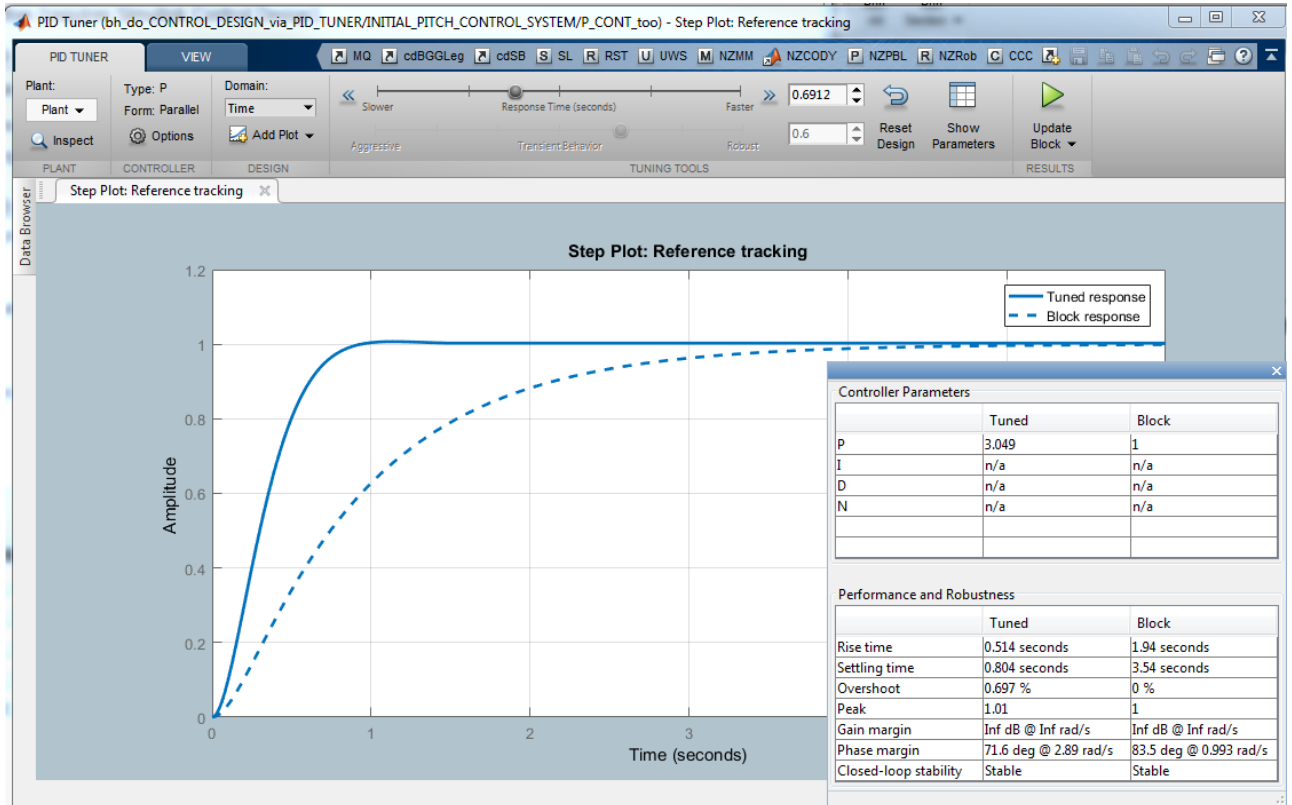
[Engineering Models I]

[Engineering Models II]

[Introduction to Engineering Analysis]

Task: Linearise and Control design





MathWorks

Live Script

bh_task_find_trim_and_linearise.mlx

bh_task_siso_control_design.mlx

Help

```
>> doc findop
>> doc linearize
>> doc pidTuner
>> doc controlSystemDesigner
```

Free MATLAB Courseware

[Control Tutorials for MATLAB and Simulink]

[Aeronautical Systems-Guidance and Control]

[Embedded Control and Mechatronics]

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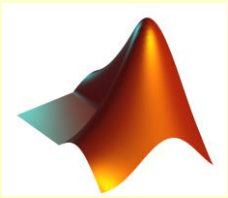

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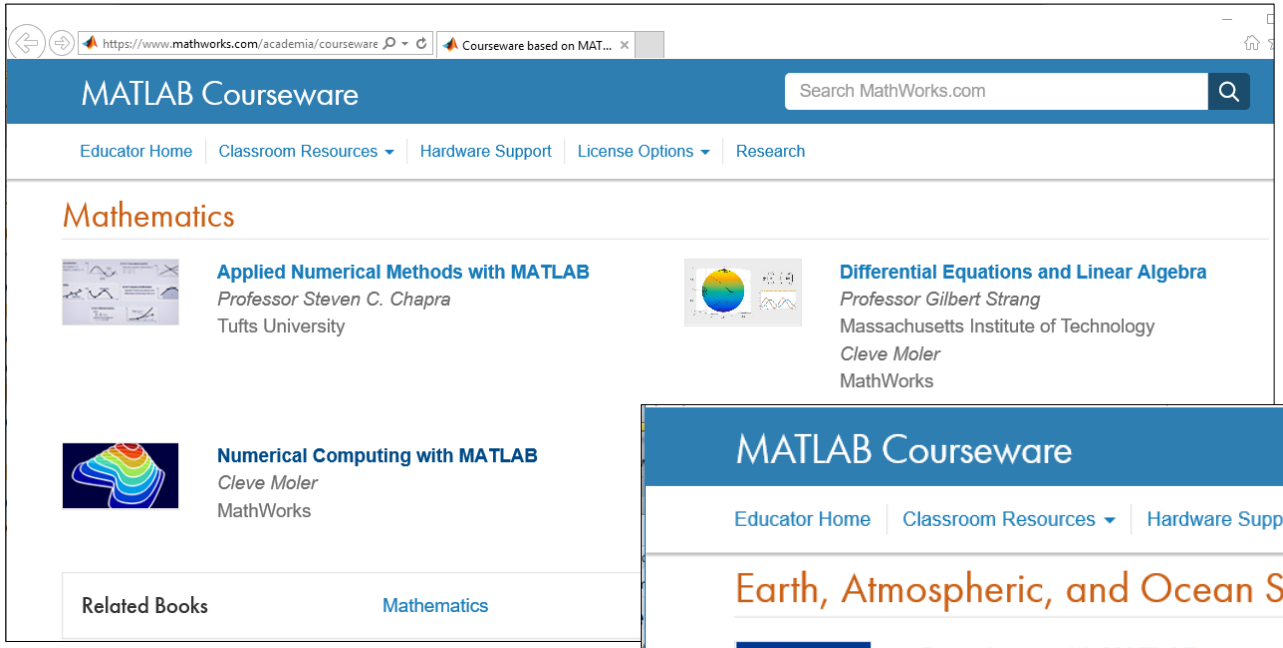
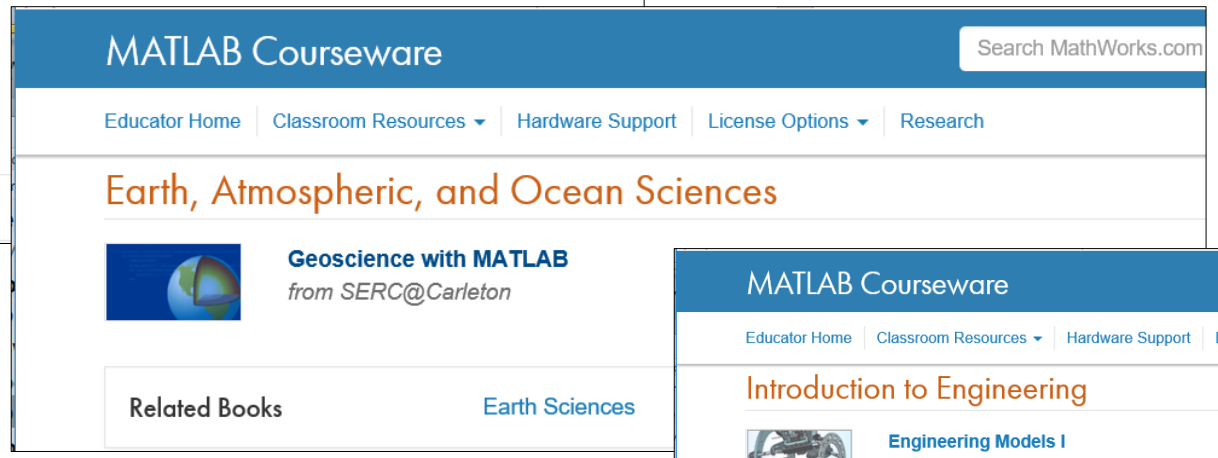
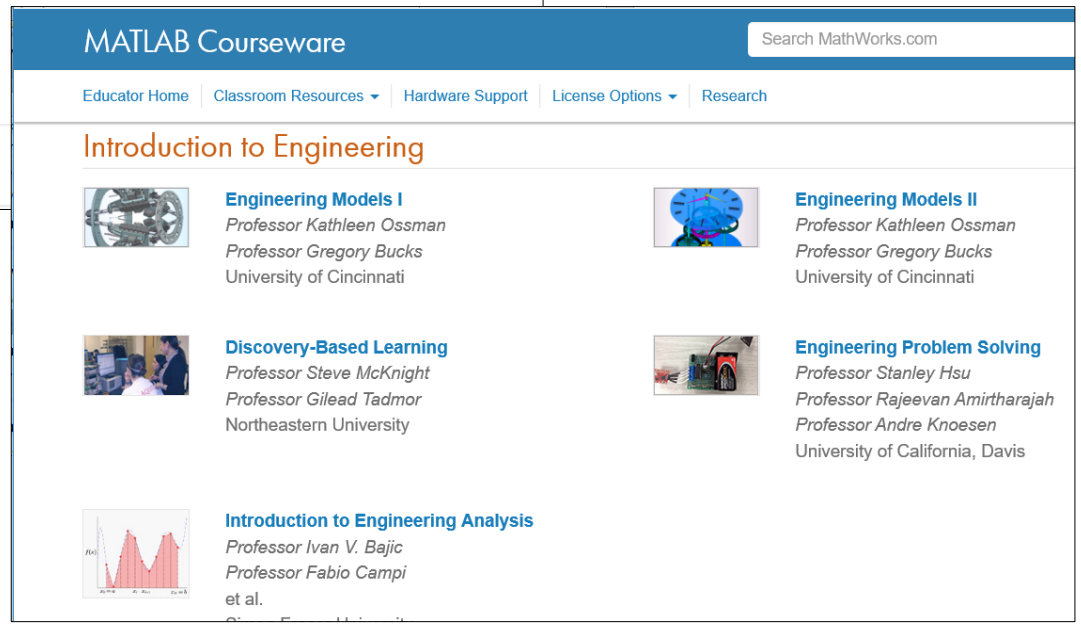
Teaching and Learning Resources.







http://www.mathworks.com/academia/courseware

Curriculum materials:

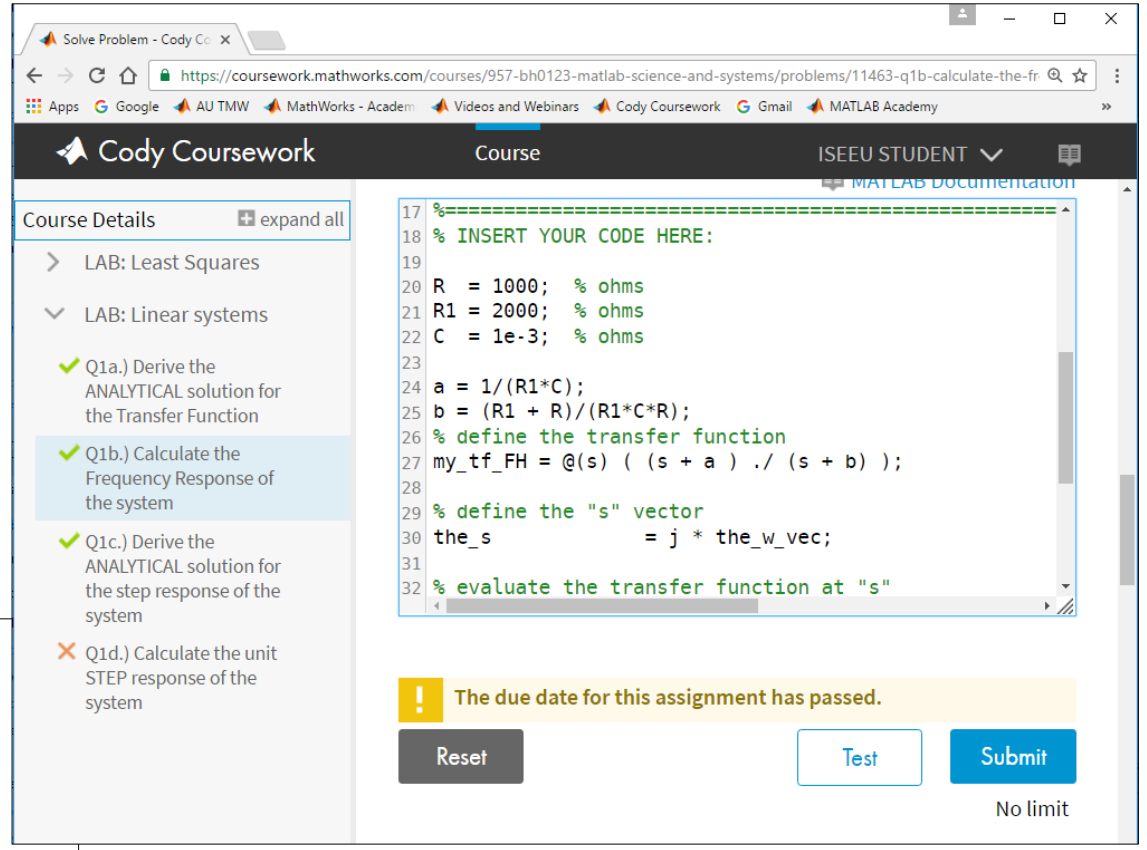
MATLAB Courseware

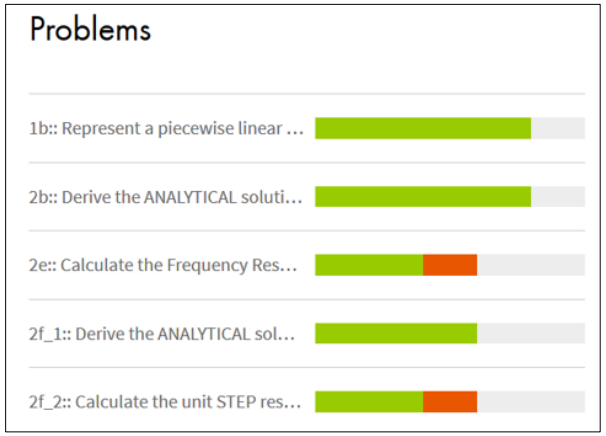
Cody Coursework™

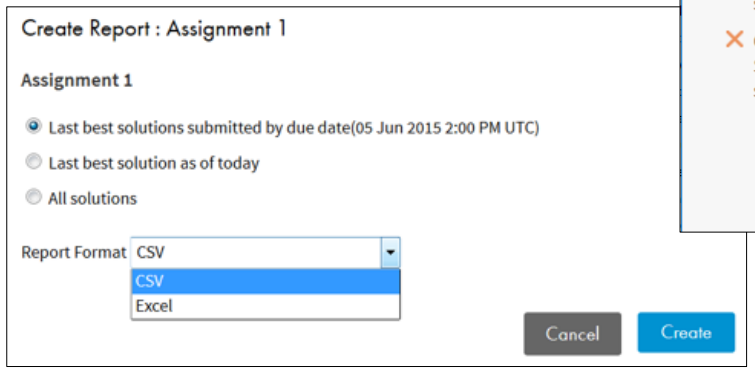
Online automated grading system for MATLAB assignments

http://mathworks.com/help/coursework/cody-coursework-for-instructors.html

- 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
- Download all student attempts and report on grading data



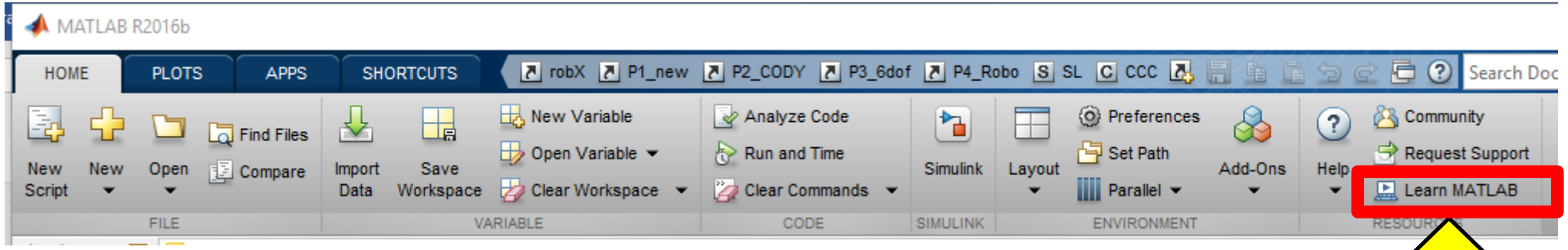




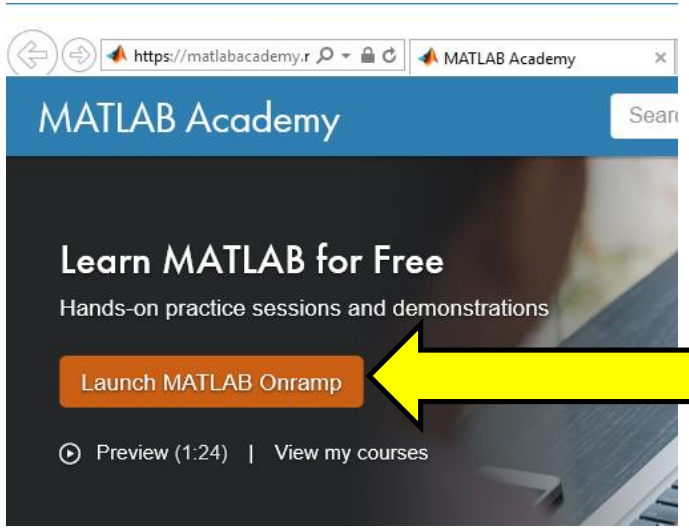
The 1st Stop: …. For students

For Students

- **MATLAB ACADEMY (the portal)**
  - Access a free interactive training course called **MATLAB Onramp**



1.)

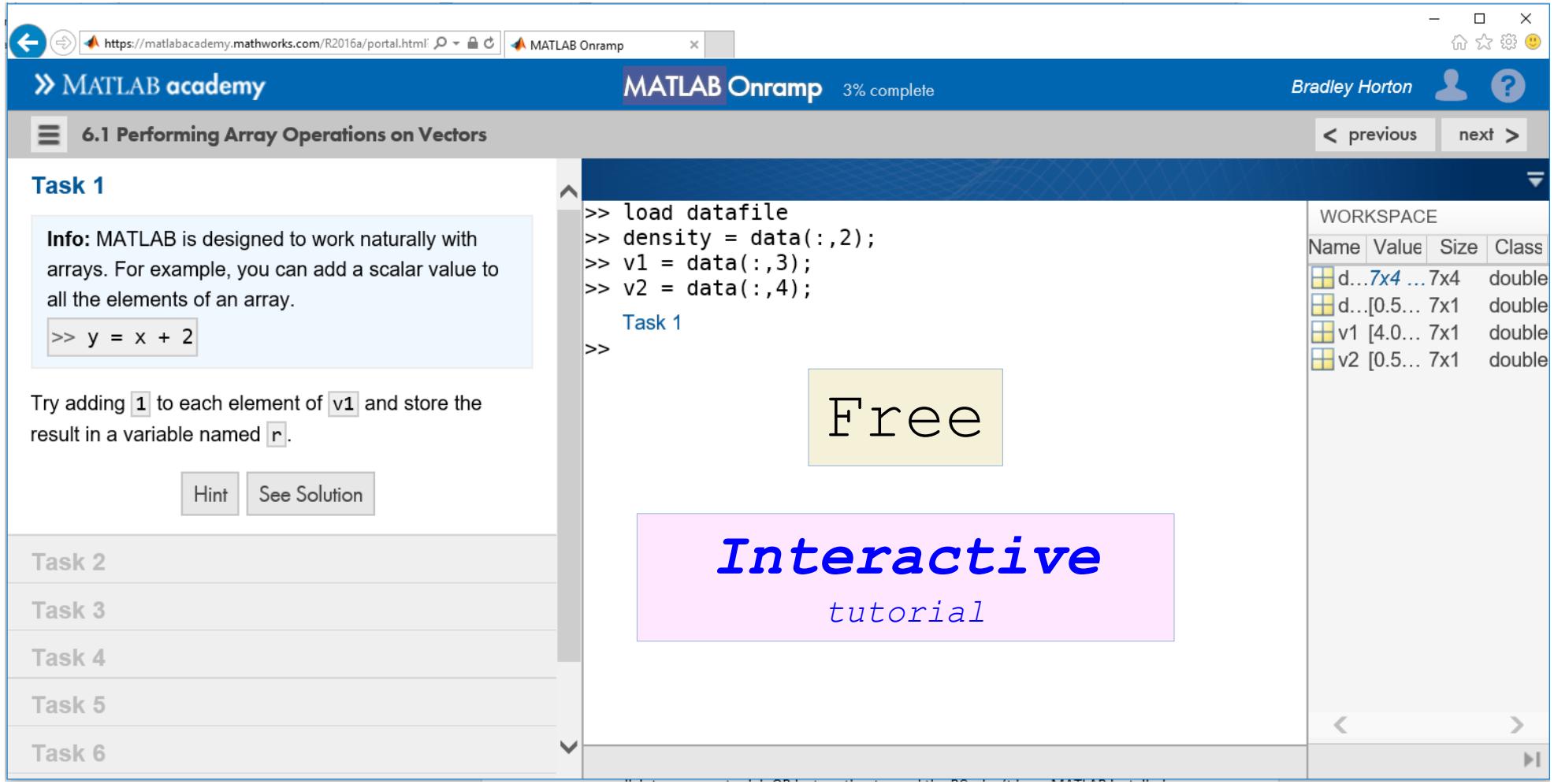


2.)

Launch the FREE course called **MATLAB OnRamp**

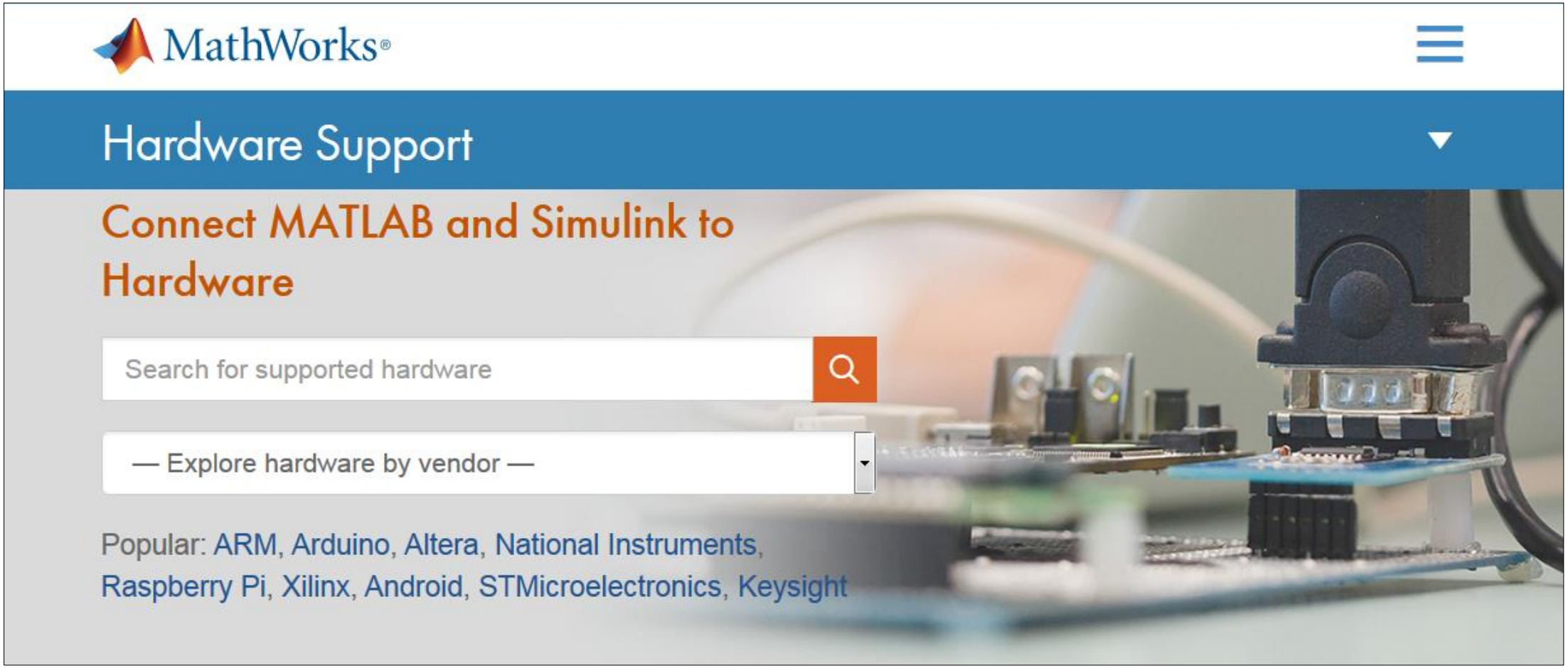
The 1st Stop: …. For students

- **MATLAB Onramp**
  - Provided through your web browser
  - Introduction of programming concepts
  - Students answer questions … and get IMMEDIATE feedback



Connecting to Hardware

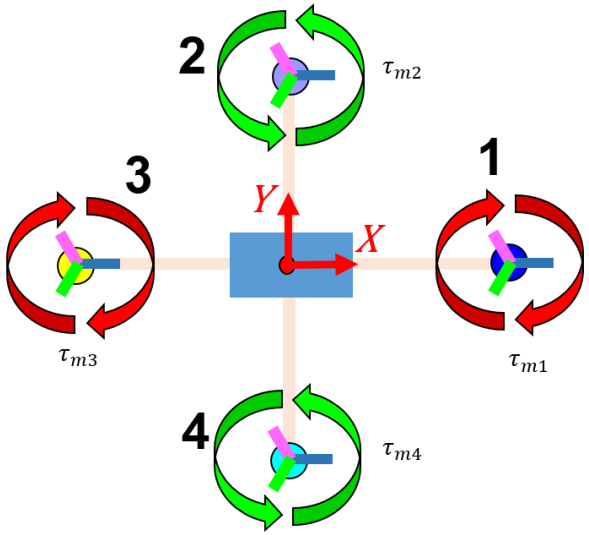
http://www.mathworks.com/hardware-support/home.html



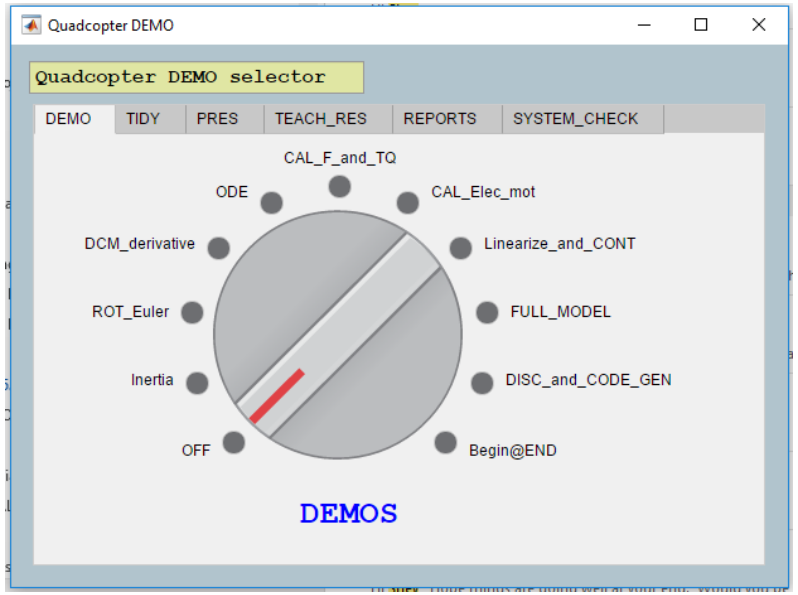
Wrap up

Q/A:

- Are there some questions please ?
- Download the examples that you saw today … and more that you didn't !



R2016b




```
>> bh_startup_6dof
```