Advance your HS Engineering Program with MATLAB

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What is MATLAB?

• Does anyone know what MATLAB stands for?
• Matrix Laboratory
• What is a matrix?
• A matrix is a collection of numbers arranged into a fixed number of rows and columns. Usually the numbers are real numbers.
• The software is developed by a company named Mathworks.
• It is a desktop environment that can perform iterative calculation tasks with matrices and arrays.
What Industries is MATLAB used in?

- Machine Design – stresses in a machine element
- Circuits – simulate electrical circuits
- 3D Modeling – animate, visualize interactive models
- Aerospace – perform analysis of wing performance
- Solar Energy – model and analyze solar electric panels
- Civil Engineering – FEM numerical calculations
- Mechanical – statics, dynamic simulations
- Prosthetics – decode neurologic inputs for devices
- Fire Protection – detect smoke and generate alarm
- Architectural/Structural – load distribution on a structure, load calculations
- Nuclear Power – reaction simulation
- Environmental - evaluate environmental issues
Where is MATLAB used and what for?

- Math...
- Graphics...
- Programming...
  - Signal processing and communications
  - Image and video processing
  - Control systems
  - Test and measurement
  - Computational finance
  - Computational biology
  - Mechatronics and Robotics
  - Simulations
MATLAB Math Operations

Arithmetic

```
>> 2*3+5
ans =
    11

>> (26+53)-(3^4+5)*2/3
ans =
    21.6667
```

```
>> sin(30)
ans =
    -0.9880

>> sin(30*pi/180)
ans =
    0.5000
```

```
>> log(4)
ans =
    1.3863

>> log10(4)
ans =
    0.6021
```
MATLAB Math Operations

• Matrix Operations

```
>> x=[1 2 3; 4 5 6; 7 8 9]

x =

1  2  3
4  5  6
7  8  9

>> y=[1;0;-4];
>> w=x*y

w =
-11
-20
-29

>> x=[1 3 0 5 -2]

x =

1  3  0  5  -2

>> x(2)

ans =

3

>> y=pi*x

y =

3.1416  9.4248  0  15.7080  -6.2832
```
MATLAB Math Operations

Arrays

- These are especially useful if you are calculating or graphing with functions.

```plaintext
>> a=(0:0.2:1)

a =
     0   0.2000   0.4000   0.6000   0.8000   1.0000
```
MATLAB Math Operations

Variables and Solving with Equations

```matlab
>> %define measurements of box
>> length = 11;   >> width = 14;       >> height=2;
>> %formula for surface area
>> surface_area=(length*width*2)+(width*height*2)+(length*height*2)
>> surface_area = 408
>> %use same measurements for volume
>> volume=length*width*height
>> volume = 308

>> % p(x)=2x-3=0 ... what is x?
>> p=[2 -3]

p =
     2   -3

>> roots(p)
ans =
     1.5000
```
MATLAB Graphing Operations – 2 dimensional

• Rough resolution

```
Another graph
>> x=[-3:1:3]  % Create an array of values from -3 to 3
x =  
  -3  -2  -1  0  1  2  3  
>> y=x.^2-3  % Calculate y values
y =  
    6  1  -2  -3  -2  1  6  
>> plot(x,y)  % Plot the graph
>> hold on  % Keep the figure open for additional plots
>> title('another example')  % Set the title
>> xlabel('x-axis')  % Set the x-axis label
>> ylabel('y-axis')  % Set the y-axis label
>>
```

• Improved resolution

```
Let's try changing resolution of values to make the graph smoother
>> x=[-3:0.25:3];  % Create an array of values from -3 to 3 with finer resolution
>> y=x.^2-3;  % Calculate y values
>> plot(x,y)  % Plot the graph
>> hold on  % Keep the figure open for additional plots
>> title('finer resolution')  % Set the title
>> xlabel('x-axis')  % Set the x-axis label
>> ylabel('y-axis')  % Set the y-axis label
>>
```
MATLAB Graphing Operations - Comparative

Trigonometric functions... Two on one plot
>> x=0:pi/20:2*pi;
>> y=sin(x);
>> z=cos(x);
>> plot(x,y,'-',x,z,'--')
>> hold on;
>> grid on;
>> title('sine and cosine functions')
>> xlabel('x-axis')
>> ylabel('sine and cosine')
>> legend('sinx','cosx')
>>

Using subplot....
>> x=[1:1:10];
>> y=x.^2;
>> z=sqrt(x);
>> w=2*x-3;
>> v=x.^3;
>> subplot(2,2,1)
>> hold on;
>> plot(x,y)
>> subplot(2,2,2)
>> plot(x,z)
>> subplot(2,2,3)
>> plot(x,w)
>> subplot(2,2,4)
MATLAB Graphing Operation – 3D Dimensional

3 dimensional plots
>> [X,Y] = meshgrid(-2:.5:2);
>> Z = X.* exp(X.^2 - Y.^2);
>> plot3(X,Y,Z)
>> mesh(X,Y,Z)
>> hold on
>> grid on
>> surf(X,Y,Z)

You can also make contours...
>> contour(A)
MATLAB Programming

- FOR Loop
  ```matlab
  >> for n=1:10;
     x(n)=n^2;
   end
  >> % nested loop
  >> for n=1:3
     for m=1:3
        y(m,n)=m^2+m*n+n^2;
     end
  end
  ```

- WHILE Loop
  ```matlab
  >> tol=0.0;
  >> n=0;
  >> while tol<10
     n=n+1
     tol=tol+2
   end
  ```

- IF THEN
  ```matlab
  >> boxes=10;
  >> cost=boxes*3;
  >> if boxes>7
     cost=boxes*2.5;
  end
  ```

- IF ELSE IF
  ```matlab
  >> if boxes>7
     cost=boxes*2.5
     elseif boxes<9
     cost=boxes*2
     elseif boxes>9
     cost=boxes*1.5
   end
  ```

- SWITCH CASE
  ```matlab
  >> % learning?
  >> % award calculator with switch case
  >> function award(grade)
  >>     switch grade
  >>         case 90
  >>             amount=20
  >>         case 80
  >>             amount=15
  >>         case 70
  >>             amount=10
  >>         otherwise
  >>             amount=0
  >>     end
  >> end
  ```
MATLAB Versus Excel

MATLAB
• Great for sophisticated math
• Great for large data sets, matrix algebra, other complex math
• Numbers and data sets can be stored in variables and not seen all the time
• Useful for creating programs for calculations that need choice
• Can perform more complex logical operations

Excel
• Keep a table of your data
• Good for explanations and presentations
• Is very visual, you can see all your numbers
• Useful for simple calculations that do not involve choice
• Can perform simple logical operations (IF command)
MATLAB and Excel

• You can use MATLAB and Excel together…
• Import Excel data into MATLAB
• Use the import tool. Excel data is naturally represented in MATLAB as a table, which organizes tabular data into columns of a single variable.
• Access MATLAB from Excel
• Spreadsheet Link connects Excel with the MATLAB workspace, enabling you to access the MATLAB environment from an Excel spreadsheet. You can exchange data between MATLAB and Excel, taking advantage of the familiar Excel interface while gaining access to MATLAB algorithms in image processing, data analytics, and control engineering.
• Package MATLAB code as Excel add-ins
• With MATLAB Compiler™, you can package math, graphics, and user interfaces created in MATLAB as Excel add-ins to perform analyses with Excel. These Excel add-ins can be distributed royalty-free to users who do not have MATLAB, and require no VBA programming.
MATLAB Versus Python

MATLAB
• Works through simulations
• You can use image processing
• A programming language and a programming interface
• Functionality can be expanded by various toolboxes

Python
• Easy to learn
• Highly Portable
• Extensile and free
• Uses white space to delimit blocks
MATLAB Versus Python

MATLAB
- In use since the 1970s
- Allows matrix manipulations, plotting, creation of interfaces
- Test algorithms w/o compiling
- Developer add-ons needed for improved performance
- Standard library does not contain generic programming functionality
- Generates readable C and C++ code

Python
- Developed in 1991
- Used for web programming
- Extensive support libraries
- High performance linear algebra, graphics, and statistics
- Extensive standard library
- No automatic code generation for embedded systems
MATLAB Desktop

MATLAB Desktop – shows contents of existing folder

Workspace – shows all functions and variables

Command Window – where you enter all your commands

When clicked on, “details” will share information about a file that is highlighted...

Pressing this will open the editor, which is where you can create programs
• Just like every programming software, MATLAB has some basic syntax rules that need to be followed.
• Once these are understood, it is fairly easy to use.
• Also, there is a MATLAB “helper” that may tell you where your syntax errors occur.
• This gives you a chance to fix what you need and re-enter your task in your command window.
• Or, it tells you what line has your error in your program. You can go back to your editor window to fix and run your program again.
MATLAB Syntax Part 2

• MATLAB is case sensitive. It is recommended that you type in everything in lower case.
• “ans” is the default variable storage for operations. This will be overwritten as necessary.
• ALL variables must start with a letter, can use up to 63 characters, cannot have punctuation, can have underscores, and can be a mix of letters and numbers
• Text can be assigned to a variable
• “clear” will erase all variables
• “clc” will clear the command window
• Graphics window – will launch automatically when a plot or graph is requested in the command window or a program
• You can copy and paste text and commands ...
• Use of the semi-colon: It suppresses output if it is placed at the end of the line. Or, it starts a new row in a matrix.
• Matrix inversion – to invert a matrix, use the apostrophe
• format for a matrix: \[ z=[1 \ 2;3 \ 4] \text{ OR } z = [1,2;3,4] \]
• You can create incremented arrays using the colon key \[ t=(0:1:50) \]
• format: variable=(begin:increment:end) ← this is similar to Autofill in Excel
• To start a comment, use the % symbol (shift 5)
• Any text that should be printed must be enclosed inside of apostrophes
Basic MATLAB Programs

MATLAB programs can be created using various programming concepts
• Scripts – simple programs that perform and operation with NO input
• Functions – simple programs that require input variables with the calling of the program
• For Loops – useful for repetition for a certain number of times
• While Loops – useful for repetition while a condition is true
• If then – useful for when a choice must be made (best used for 2 choices)
• If else if – useful for when a choice must be made (best for a multitude of choices – good for inequalities)
• Switch case – useful for when a choice must be made to a finite number of choices
Pre-existing MATLAB Programs

- There are some fun and interesting programs that already exist and are available in MATLAB
- Vibes
- Teapotdemo
- Makevase
- Xpbombs
- Step
- Earthmap
- Truss
- Wrldtrv
- Xpsound
- Eml_asteroids
- Rlc_gui
Example Programs Created by Students

Solving Simultaneous Equations...

• In Statics, students will come up with two equations that have two unknowns that need to be solved...

• Here is a program developed by a student:

```
% Introduce program to the user
display('Welcome to the simultaneous equation calculator!');
display('This program can solve any simultaneous equation for you. ');

display(' ');

% Asking the user for the variables for 1st equation
display('EQUATION 1: ');
ax_1= input('What is the x-intercept? ');
by_1= input('What is the y-intercept? ');
c_1= input('What is the equation equal to? ');

display(' ');

% Asking the user for the variables for 2nd equation
display('EQUATION 2: ');
ax_2= input('What is the x-intercept? ');
by_2= input('What is the y-intercept? ');
c_2= input('What is the equation equal to? ');

display(' ');

%Solving the equation
a=[ax_1 by_1;ax_2 by_2];
b=[c_1;c_2];

c=a

display('Your results will be shown with your x value on top and your y value on the bottom.');
display('It will be equal to c.');
```
Example Programs Created by Students

Solving Simultaneous Equations...

• Here is that program as it is executed:

```
COMAND WINDOW:

>> SimEquations
Welcome to the simultaneous equation calculator!
This program can solve any simultaneous equation for you.

EQUATION 1:
What is the x-intercept? 4
What is the y-intercept? 1
What is the equation equal to? -1

EQUATION 2:
What is the x-intercept? 1
What is the y-intercept? 3
What is the equation equal to? 19

Your results will be shown with your x value on top and your y value on the bottom.
It will be equal to c.

Q =
-2.0000
7.0000
```
Example Programs Created by Students

Friction...

• When working with friction, in some cases, we need to determine if something will slip or remain stationary OR if something will slip or tip...

• Here is a program developed by a student:

```matlab
%This program is designed to determine if a block is stationary or moving
disp('this program will determine if this block is stationary or moving')
weight=input('what is the weight of the block? ');
angle=input('what is the angle of the block? ');
coefficient=input('what is the coefficient of friction? ');
%This program requires each input such as weight in order to work
wx=weight*sin(angle)
f=coefficient*weight*cosd(angle)
%This equation calculates whether it is stationary or moving based on f>wx
if f>wx disp('The block is stationary because f>wx')
else disp('The block is moving because f<wx')
end
```
Example Programs Created by Students

Friction...

• Here is the program as it is executed:

```python
>> block_program
this program will determine if this block is stationary or moving
what is the weight of the block? 75
what is the angle of the block? 17
what is the coefficient of friction? 0.3

wx =
   21.9279
f =
   21.5169
The block is moving because f<wx
```

```python
>> block_program
this program will determine if this block is stationary or moving
what is the weight of the block? 100
what is the angle of the block? 10
what is the coefficient of friction? 0.25

wx =
   17.3648
f =
   24.6202
The block is stationary because f>wx
```
Coordination with NGSS

• Below are the NGSS standards that are met with MATLAB usage.

• HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

• HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

• Other standards may apply depending upon the problems and programs that are assigned with MATLAB.
Coordination with Math Common Core

• Below are the Common Core standards that are met with MATLAB usage.

• CCSS.MATH.PRACTICE.MP4 Model with mathematics. Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace.

• CCSS.MATH.PRACTICE.MP5 Use appropriate tools strategically. Mathematically proficient students consider the available tools when solving a mathematical problem. These tools might include pencil and paper, concrete models, a ruler, a protractor, a calculator, a spreadsheet, a computer algebra system, a statistical package, or dynamic geometry software.

• Other standards will apply depending upon the problems and programs that are assigned with MATLAB.
Coordination with ITEEA Standards

Below are the ITEEA Standards that are met with MATLAB usage

• 3J – Technological progress promotes the advancement of science and mathematics

• 8H – The design process includes ...

• 8I – Design problems are seldom presented in a clearly defined form.

• 8J – The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

• 10I – Research and development is a specific problem solving process that is used intensively in business and industry to prepare devices and systems for the marketplace.
Coordination with ITEEA Standards

• 10L – Many technological problems require a multidisciplinary approach.

• 11P – Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process...

• 12M – Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.

• 12P – Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.
Coordination with ITEEA Standards

• 17L – Information and communication technologies include the inputs, processes, and outputs associated with sending and receiving information.

• Other standards will apply as various problems and programs are assigned
Coordination with AEEE Learning Progressions

Engineering Knowledge – Quantitative Analysis – Modeling & Simulation:

• Level 1: I can identify and explain the objectives and plans of engineering calculations for design validation.

• Level 2: I can apply engineering calculation procedures to validate a certain solution or idea.

• Level 3: I can predict and refine my solution or decide the final solution among possible ideas through testing my solutions or ideas with engineering calculations.

• Level 4: I can successfully develop and use a variety of models to simulate, evaluate, and validate my ideas or solutions.
Engineering Knowledge – Quantitative Analysis – Computational Tools

• 1: I can explain and demonstrate how to display, manipulate, and solve matrices, arrays, and variables through MATLAB desktop or LabView.

• 2: I can explain and demonstrate how to create functions, call functions, and create various plots of data entered or imported through MATLAB desktop or LabView.

• 3: I can explain and demonstrate how to create programs and scripts that will utilize various types of programs components or loops (for, while, if then, if else if, and/or switch case) through MATLAB desktop or LabView.

• 4: I can successfully create a solution to an engineering problem through the application of an appropriate computational tool.
Coordination with AEEE Learning Progressions

Engineering Knowledge – Technical – Computer Architecture:

• Level 1: I can write pseudo-code for a simple process to run on a microprocessor.

• Level 2: I can write code (any language) for a simple process to run on a microprocessor.

• Level 3: I can write pseudo-code (and then run-able code) for more complex processes to run on a microprocessor.

• Level 4: I can successfully solve a design problem involving a computer system.
Engineering Knowledge – Quantitative Analysis – Computational Thinking

• 1: I can develop basic programs using correct syntax and logical organization.

• 2: I can develop programs using more advanced programming techniques, such as loops, conditional structures, and variables.

• 3: I can develop programs using highly advanced techniques, such as writing external functions and calling them from a program.

• 4: I can successfully develop and implement algorithms and programs to solve an engineering design problem through the use of Computational Thinking.
MATLAB Software Use in High School or College

- The first stage of assignments should be just using the command window to do basic mathematical operations, using matrices, and assigning values to simple variables. This will get students familiar with the syntax.
- The next stage of assignments should be graphing exercises. You can use functions, trigonometry, and/or matrices for assignments.
- The next stage of assignments should be about basic programming functions. Students should learn how to use the different constructs.
  - This could come after students obtain some basic programming skills in their computer science classes.
- The remaining assignments should relate to content.
Eastern Technical High School Engineering Careers Program

• Engineering Careers is a Career and Technology Education program offered through a magnet school in the Baltimore County Public Schools system.

• Each year, students take one credit of Engineering and will end up with a 4-credit completer certificate for the program.

• Each year focuses on different aspects or types of engineering.

• Students utilize various types of software in this program: Excel, MATLAB, Inventor, AutoCAD.

• Students work individually and in groups to solve Engineering problems and design solutions to issues that are presented.

• Students will be compiling a portfolio of their work throughout their career.
Eastern Technical High School Engineering Careers Program

<table>
<thead>
<tr>
<th>Grade</th>
<th>Exploring Engineering</th>
<th>Engineering Design Process</th>
<th>2D and 3D Modeling</th>
<th>Materials Science and Engineering</th>
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<tbody>
<tr>
<td>9th</td>
<td>1st 9 Weeks</td>
<td>2nd 9 Weeks</td>
<td>3rd 9 Weeks</td>
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<td>Introduction to</td>
<td>Engineering Design</td>
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<th>Grade</th>
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<td>Ocean Engineering</td>
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<td>Tribology</td>
<td>Signal Processing</td>
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<td>Systems and Communications</td>
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<td>VLSI and circuits: Embedded/Hardware Systems</td>
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<th>Grade</th>
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<th>Grade</th>
<th>Excel in Engineering</th>
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<td>12th</td>
<td>Capstone Experience: Design Challenges that are authentic, connected to Grand Challenges for Engineering, and build upon the previous 4 years and cornerstone project experiences.</td>
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Example MATLAB Programs and Assignments @ Eastern Technical High School

- Freshman year – introductory assignments (basic operations, basic plotting, basic programming)
- Sophomore year – solving a system of simultaneous equations (for Statics), friction calculations (slip or tip & moving or stationary), material science calculations (choice of various equations), voltage storage in a capacitor, gear train calculations (speed, torque, number of teeth)
- Junior year – Storm Water management calculations (rainfall, pond volume), Structural Beam Calculations, Air mixture calculations for HVAC, Boundary Layer generation in fluid mechanics
- Senior – Various assignments based on senior projects
MATLAB Website and Training

• [www.mathworks.com](http://www.mathworks.com)

• This site is the main site for Mathworks, the company that makes MATLAB.

• Click on “Explore MATLAB” to learn more...

• [www.matlabacademy.mathworks.com](http://www.matlabacademy.mathworks.com)

• This site has free courses that you can take to learn how to use MATLAB. You do not need MATLAB software to learn, you can access this from any computer.
Who To Contact?

If you are interested in pursuing the usage of MATLAB in your classroom, in your school, or in your school system, please contact the following person:

Mary Dzaugis  mdzaugis@mathworks.com
Excellent Book Resources

- MATLAB for Beginners: A Gentle Approach by Peter I. Kattan
  ISBN # 9781438203096

- Essential MATLAB 5th Edition by Brian H. Hahn & Daniel T. Valentine
  ISBN # 9780123943989