General Instructions

Due Date: Sunday, September 11th, 2022 by 11:59pm (submit via Zybooks)

Assignment Summary Instructions:
This assignment has one problem, summarized below. You will use MATLAB as a tool to solve the problem for the given test cases, ensuring that your code is flexible for any additional test cases that might be used to evaluate it.

- Metal Forging (Application of Materials Science)

Zybooks Submission Instructions:
After completing this assignment in MATLAB, to receive credit, you must submit your code in Zybooks. The following components must be submitted under the specified chapter of the course Zybooks before the deadline to receive credit.

- Chapter 29.1 MA1: Main Script

To submit your script, copy and paste your code into the submission window, making sure to remove any housekeeping commands. You may submit to Zybooks as many times as you want before the deadline, without any penalty. The highest score attained before the deadline will be graded. All components are due before the due date. No credit will be given if it is not submitted through the Zybooks platform before the deadline. Credit for each component will be awarded based upon the percentage of successfully completed assessments.

Proficiency Time: Times are included with the Background and Task sections. These times are the estimated amount of time it should take you to **redo** an assignment once you are fully proficient in material that it covers. To practice, reread the background in the given Comprehension Time and attempt to complete the problem in the given Proficiency Time.

Academic Honesty Reminder

The work you submit for this assignment should be your work alone. You are encouraged to support one another through collaboration in brainstorming approaches to the problem and troubleshooting. In this capacity, you are permitted to view other students' solutions, however, copying of another student's work is strongly discouraged.

This assignment will be checked for similarity using a MATLAB code. The similarity code will check each submission for likeness between other student submissions, past student submissions, the solution manual, and online resources and postings. If your submission is flagged for an unreasonably high level of similarity, it will be reviewed by the ENGI 1331 faculty, and action will be taken by faculty if deemed appropriate.

NOTE: Since this is an automated system for all sections, if any of your work is not your own, you will be caught. Changing variable names, adding comments, or spacing will not trick the similarity algorithm.

Background: Comprehension Time: 15 – 20 min

In a factory, various metal pieces are forged and then plunged into a liquid to quickly cool the metal. The type of metal as well as each metal's specific heat capacity [J/(g ºC)] and mass [g] are given in the data file **MA1_data.mat** as two different variables. The tables below represent those variables for the data provided:

Table 1: Materials variable saved in **MA1_data.mat**

Material
Aluminum
Cadmium
Iron
Tungsten

Table 2: Data variable saved in **MA1_data.mat**. Information about material. Each row corresponds to the same row in the **Materials**.

Specific Heat (c_p) [J/(g ºC)]	Mass [g]
0.897	4000
0.231	8000
0.450	5000
0.134	12800

The metal pieces vary in mass and are produced at a temperature of 300 ºC. The ideal process lowers the temperature of the material to 50 ºC. The liquid used to cool the metal is glycerol, whose properties are provided in the data file **CoolingLiquid.csv** and shown in the table below.

Table 3: CoolingLiquid.csv provides the data shown in the Value column.

Material Property	Value	Units
Specific Heat	2.4	J/(g ºC)
Specific Gravity	1.261	-
Initial Temperature	25	ºC

It is critical to evaluate the necessary amount of cooling liquid needed for each cooling process (depending on the material and its mass). You will need to use Equation 1 to determine the energy needed to cool the material and the necessary mass of the cooling liquid. Recall that density is mass divided by volume. Careful of units!

$$Q = mc_p\Delta T \qquad \text{Eq. 1}$$

where Q is thermal energy [J], m is mass [g], c_p is specific heat [J/(g ºC)], and ΔT is the change in temperature [ºC].

Your job is to develop a script to determine the thermal energy in joules removed from each rod, cooling the rod from an initial temperature of 300 ºC to a final temperature of 50 ºC. You will then determine the required volume of cooling liquid (in gallons) to properly cool the rod. Your script will accomplish this for a user defined material with given values and for the dataset provided.

Tasks: Proficiency Time: 1 hr – 1 hr 25 min

TASK 1: (15 – 20 min)

Load in the provided data file **CoolingLiquid.csv** in Table 3. Prompt the user to enter a new material name, and prompt the user to enter the specific heat [J/(g ºC)] and the mass [grams] of that new rod material. Calculate

- The thermal energy [joules] that must be removed from each rod to cool it from 300 ºC to 50 ºC
- The volume of cooling liquid [gallons] needed to properly cool the rod for the new material

Output the results of the thermal energy [joules] and volume of cooling liquid [gallons] to the command window.

NOTE (avoid hardcoding): Your code should produce different results if the data for the cooling liquid is changed or there are changes in the user inputs.

TASK 2: (20 – 25 min)
Load in the provided data file **MA1_data.mat** which contains the additional materials and masses from Tables 1 & 2. Using the cooling liquid properties, calculate

- The thermal energy [joules] that must be removed from each material to cool it from 300 ºC to 50 ºC
- The volume of cooling liquid [gallons] needed to properly cool each material

Store these results as well as the results from Task 1 into a matrix which contains, for each material, specific heat [J/(gºC)] in column 1, mass [grams] in column 2, thermal energy [joules] in column 3, and volume of cooling liquid [gallons] in column 4. Refer to the sample output on the next page for a visual representation of the expected results.

The data from Task 1 should be appended to the bottom of this matrix, and the name of the new material should be appended to the end of the Materials string array. Save the matrix and updated string array as two separate variables within a .mat file named **MA1_Task2.mat**. Output to the command window the total number of materials in the updated material list.

NOTE (avoid hardcoding): Your code should produce different results if the data values for the material and masses change or if there are changes in the user inputs from Task 1. The number of material names in the string array should equal the number of rows in your matrix.

TASK 3: (15 – 25 min)
You would like to approximate the thermal energy loss and volume of cooling liquid needed for a rod that is an alloy of two materials. The alloy will have properties based on the average thermal energy of the two materials. The alloy will require a volume of cooling liquid equal to the sum of the volumes of cooling liquid needed for the two materials. Prompt the user to select (with a menu) the first material. Then, prompt the user to select the second material. Prevent the user from selecting the same material twice by removing the first selected material from the second list of materials. Output to the command window

- The thermal energy [joules] that must be removed from the alloy to cool it from 300 ºC to 50 ºC
- The volume of cooling liquid [gallons] needed to properly cool the alloy

NOTE (avoid hardcoding): The number of menu options should be equal to the number of rows in the **Materials** variable (including the user entered material). The second menu should have all options minus the option that was chosen in the first menu. The menus should update if different material names are provided in the **Materials** variable or if the user enters a different material name in Task 1.

TASK 4: (10 – 15 min)
Create two simple plots that display the results with the mass on the x-axis. The first plot (Figure 1) should use thermal energy [joules] as the y-axis. The second plot (Figure 2) should use cooling liquid volume [gallons] as the y-axis. These should be separate plots shown as points (experimental data), both using the results from **Task 2**.

Additionally, include the following formatting on your plots:

- X-axis label
- Y-axis label
- Title
- Gridlines

NOTE (avoid hardcoding): The result of your code should produce different plots if the data values for the material and masses change or if there are changes in the user inputs from Task 1. The number of material names in the string array should equal the number of points in your plot.

Sample Output:

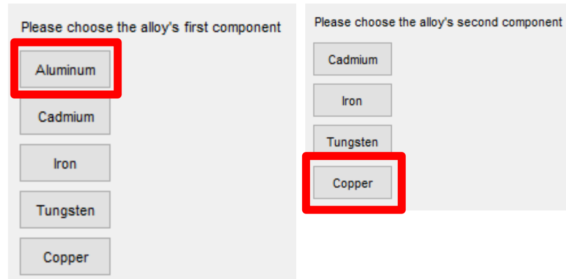
<u>Sample output for given data:</u>

- Additional test case scenarios are described in the Additional Resources folder accompanying this prompt.

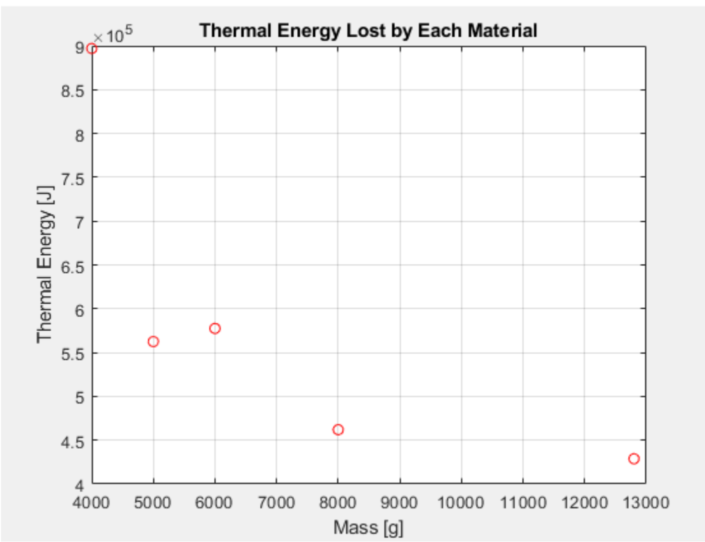
<u>Sample Output to Command Window (Aluminum and Copper were chosen in Task 3)</u>

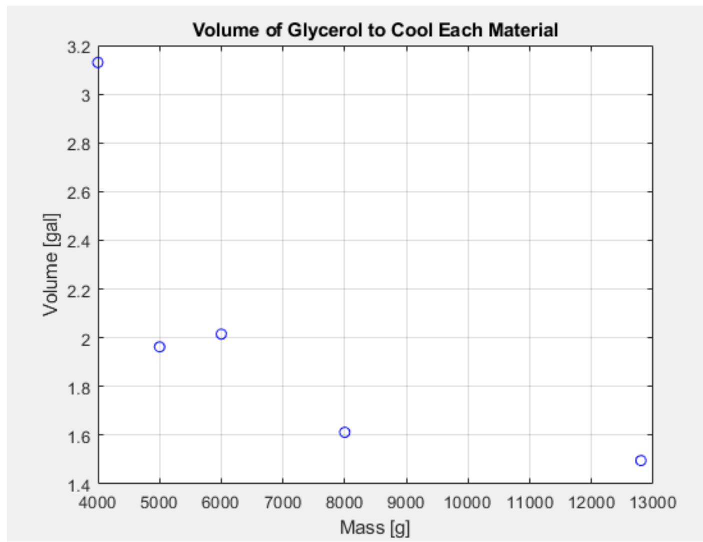
Command Window

```
Please enter a new material: Copper
Please enter the specific heat for the new material [J/(g degC)]: 0.385
Please enter the mass of the new material: 6000
The thermal energy removed from the material during cooling is 577500 [J],
which requires at least 2.02 gallons of glycerol.

5 materials have been analyzed. See Problem1_Task2.mat.

The thermal energy lost by the alloy is 737250 [J].
The volume of glycerol required to cool the alloy is 5.14 [gal].
```



Note the absence of the first choice in the second menu





Sample MA1_Task2.mat:

<u>Materials:</u>

	1
1	Aluminum
2	Cadmium
3	Iron
4	Tungsten
5	Copper

<u>Results:</u>

	1	2	3	4
1	0.8970	4000	897000	3.1299
2	0.2310	8000	462000	1.6121
3	0.4500	5000	562500	1.9627
4	0.1340	12800	428800	1.4962
5	0.3850	6000	577500	2.0151