OLLSCOIL NA GAILLIMHE
UNIVERSITY OF GALWAY

Semester 2 2022 / 2023

Exam Code(s)	2BCT/2BSE
Exam(s)	2nd BSc (CS&IT), 2nd BE ESE
Module Code(s)	CT248
Module(s)	Introduction to Modelling
Paper No.	I
External Examiner(s)	Dr. Ramona Trestian
Internal Examiner(s)	Prof. Michael Madden
	*Prof. Jim Duggan

Instructions:

Answer any 3 questions.

Duration	2hrs
No. of Pages	6 (Including Cover Page)
Discipline	Computer Science
Course Co-ordinator	Dr. Colm O'Riordan

Requirements:

Release in Exam Venue	No[]	Yes [☑]
MCQ Answer sheet	No [☑]	Yes [ ]
Handout	No [☑]	Yes [ ]
Formulae & Tables*	No [ ]	Yes [☑]
Cambridge Tables 2nd Edition**	No [☑]	Yes [ ]
Graph Paper*** A4 Graph Paper 1mm 0.1cm Squared (Standard)	No []	Yes [☑]
Other Materials	No [☑]	Yes [ ]
Graphic material in colour	No []	Yes [☑]

1. (a) Given the following array M, write a command that displays only those values that are less than the mean of the array. Note that the MATLAB function mean(M,'all') will return the average of all the array elements.

```
M =

    54    12    90    98    43
    28    67    21    81    94
    42    83    18    17    82
    85    13    10    82    33
     0    58    22    27    17
```

What results would be returned if a call was made to mean(M)?

[9 marks]

(b) Given the following matrices A and B, calculate results for the following operations in MATLAB, and explain the basis for your results.

```
A =                          B =

     5     1     3                1     1     1
     6     7     9                2     2     2
     0     9     7                3     3     3
```

A .^ B;

A .* B

A + B;

A ./ B;

[8 marks]

(c) Consider the following pictures, where the first picture is the input (256x256) and the second is the transformed output.

- Explain the image types for each picture.
- Write a command that will convert the first picture to the second, assuming a threshold value of 150. Explain how this command works.

[8 marks]

2. (a) Show the general form of a function in MATLAB.

Provide a definition of a *global variable*, and show how you could use this to implement two functions for a counter (add and subtract), where the counter state is a global variable. The two functions should not return any values, rather they should change the variable via a side-effect.

[8 marks]

(b) Write a function (m file) takes an array and replaces and values outside of the lower and upper ranges by 0. For example, the function could be used to remove any invalid examination grades, where a grade could be less than zero or greater than 100. Make use of the vectorisation capabilities of MATLAB, and therefore a loop should not be required for the solution. Here are sample calls, along with the output that should be generated.

```
rng(100);

test = randi([-10 110],4,5);

test_val = validate_data(test,0,100);
```

```
>> test

    55   -10     6    12    88
    23     4    59     3    10
    41    71    97    16    88
    92    89    15   108    23
```

```
>> test_val

    55     0     6    12    88
    23     4    59     3    10
    41    71    97    16    88
    92    89    15     0    23
```

[10 marks]

(c) Discuss the best use of anonymous functions in MATLAB.

Write an anonymous function that implements the following quadratic equation, where the input x is a row vector, and the constants are also passed into the anonymous function. Explain how the function works.

$$f(x) = ax^3 + bx^2 + cx + d$$

[7 marks]

3. (a) Write an anonymous function that will implement the following three differential equations, and assume that they equations can be solved via a call to the function ode45().

Show what you think would be the behaviour for each of the variables P_1, P_2 *and* P_3, given that their initial values are all 100.

$$\frac{dP_1}{dt} = 0.01\, P_1$$

$$\frac{dP_2}{dt} = 0.02\, P_2$$

$$\frac{dP_3}{dt} = -0.05\, P_3$$

Create a more efficient solution whereby one anonymous function could solve one general form of the differential equations. Show how it could be called in a flexible way (hint: look for a way to iterate through a vector of three growth constants).

[10 marks]

(b) As part of a heating experiment, you have been asked to design an algorithm, based on Newton's law of cooling, that will model the temperature of coffee in a cup, and predict the time when it will be closed to the desired temperature (by simply printing a message to the screen).

The following is the calling code for the algorithm, which uses the ode45 function. For the temperature (within the model function), print out the time it is within 1.0 degree from the target (either higher or lower). The parameters to be passed are: (1) the cooling constant, (2) the temperature of the environment and (3) the ideal temperature of the coffee.

```
[t,y] = ode45(@heat_model,[0:60],80,odeset,.10,16,45);
```

Here is sample output as a guide.

It shows that after about 8 minutes, the coffee is at its ideal temperature.

```
FOUND>> Time 7.800000e+00 Temperature = 45.370923 Ideal = 45.000000 diff = 0.370923
```

[10 marks]

(c) Explain the workings of following code, and fix the error that it contains.

```
f = @(t,x)[10*t 20];

[t,y] = ode45(f,0:10,[0 0]);
```

[5 marks]

4. (a) Given the following MATLAB table W1, write a command that will add a new column that indicates whether any rain fell during a given hour. Explain the workings of your solution.

station	month	day	hour	rain
{'DUBLIN AIRPORT'}	1	1	0	0.9
{'DUBLIN AIRPORT'}	1	1	1	0.2
{'DUBLIN AIRPORT'}	1	1	2	0.1
{'DUBLIN AIRPORT'}	1	1	3	0
{'MACE HEAD' }	1	1	0	0.5
{'MACE HEAD' }	1	1	1	0
{'MACE HEAD' }	1	1	2	0.1
{'MACE HEAD' }	1	1	3	0

Here is the resulting table.

station	month	day	hour	rain	rained
{'DUBLIN AIRPORT'}	1	1	0	0.9	true
{'DUBLIN AIRPORT'}	1	1	1	0.2	true
{'DUBLIN AIRPORT'}	1	1	2	0.1	true
{'DUBLIN AIRPORT'}	1	1	3	0	false
{'MACE HEAD' }	1	1	0	0.5	true
{'MACE HEAD' }	1	1	1	0	false
{'MACE HEAD' }	1	1	2	0.1	true
{'MACE HEAD' }	1	1	3	0	false

[5 marks]

(b) Consider the following table W2 that contains 10 records, and capturing the hourly average windspeed (in knots) for October 16th 2017.

station	month	day	hour	wdsp
{'DUBLIN AIRPORT'}	10	16	7	16
{'DUBLIN AIRPORT'}	10	16	8	17
{'DUBLIN AIRPORT'}	10	16	9	16
{'DUBLIN AIRPORT'}	10	16	10	19
{'DUBLIN AIRPORT'}	10	16	11	24
{'MACE HEAD' }	10	16	7	36
{'MACE HEAD' }	10	16	8	32
{'MACE HEAD' }	10	16	9	30
{'MACE HEAD' }	10	16	10	26
{'MACE HEAD' }	10	16	11	27

Explain (using a diagram) how the **splitapply** process works in order to calculate the maximum and wind speed for each station.

Write the necessary code to generate the following table.

station	max_wdsp	min_wdsp
{'DUBLIN AIRPORT'}	24	16
{'MACE HEAD' }	36	26

[12 marks]

(c) Explain how logical vectors can be used to filter the results from a table in MATLAB.

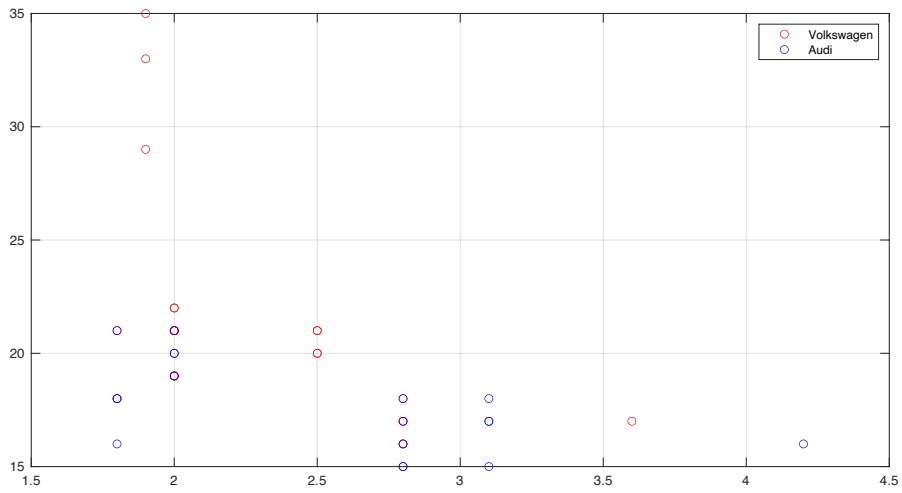
Consider the following table with 234 records (the first and final three are shown).

manufacturer	model	class	displ	cty
"audi"	"a4"	"compact"	1.8	18
"audi"	"a4"	"compact"	1.8	21
"audi"	"a4"	"compact"	2	20
:	:	:	:	:
"volkswagen"	"passat"	"midsize"	1.8	21
"volkswagen"	"passat"	"midsize"	1.8	18
"volkswagen"	"passat"	"midsize"	2	19

Based on this, construct the following filtering queries.

- Show all cars with a **cty** value greater than the mean of **cty.**
- Show all cars made by **audi** that have a displacement (displ) larger than 2.
- Show all cars made by **volkswagen** that have a displacement value less than the mean of **displ**.

Show the MATLAB code that will plot the following graph, showing the relationship between disply and cty for two manufacturers, "audi" and "Volkswagen". (Hint: you need to extract two different data sets, one for each manufacturer).



[8 marks]