ENGR10004

ENGINEERING SYSTEMS DESIGN 1

WORKSHOP 3

Importing data to MATLAB, and plotting and fitting data.

Fluid mechanics – fittings, EBE, and system curves

When necessary throughout these workshop questions, 0 °C = 273 K

Question 1

Using the `dlmread` command, import the provided CO_2 density data from the tab delimited text file. Column 1 of the data is the temperature in Kelvin, column 2 is the pressure in MPa, and column 3 is the density in mol/m^3.

Plot the data on a 3D scatter plot using the `scatter3` command, with density on the z-axis; also label all three axes appropriately.

Question 2

Import the data from the provided comma separated/delimited text file; the first column is the x-axis data, and the second the y. It is believed that this data follows a linear correlation ($y = mx + c$).

Once you have imported the data, separate it in to two separate arrays and use the `polyfit` command to apply a linear regression ($n = 1$) to the data. What are the values of the gradient and the intercept?

Repeat the fit using only the first 100 points of data. What are the values of the gradient and intercept?

What are some possible reasons for any differences? You may want to graph the points for some insight.

Question 3

The path of a ball thrown from the top of a building was tracked using optical based tracking. The collected data is provided in a comma separated text file where the first column is the x-axis data (distance from roof in metres) and the second is the y-axis data (height above the ground in metres).

Separate the imported data in to two arrays and fit a quadratic (n = 2) using `polyfit`. It is anticipated the ball follows a conventional projectile motion path, and thus a 2nd order polynomial (quadratic) should be suitable.

Based on the coefficients of the polynomial, estimate the initial height, and the angle at which the ball was thrown.

Plot the data using black circles, and then generate an array from 0 to 7 with 100 points and overlay the quadratic obtained using a red solid line.

Question 4

An electrolysis experiment was carried out with an unknown solution. The mass of metal deposited on the electrode was weighed after certain time intervals while a fixed current was applied.

It is expected that the system obeys Faraday's law, where w is the mass of material (g), M the molar mass of the metal (g/mol), I the current (A), t the elapsed time (s), z the number of electrons transferred, and F the Faraday constant (96 485 C/mol).

$$\frac{w}{M} = \frac{I \cdot t}{z \cdot F}$$

As the solution was blue, some of the likely alternatives are $CrCl_2$, $CuSO_4$ and $CoCl_2$; in all of these instances, z = 2. The current was fixed at 1.5 A, and the mass data over time is below.

time (s)	0	30	60	90	120	150	180	210	240	270
mass (g)	0	0.01	0.03	0.04	0.05	0.07	0.08	0.10	0.11	0.12

time (s)	300	330	360	390	420	450	480	510	540	570
mass (g)	0.14	0.15	0.16	0.18	0.19	0.21	0.22	0.23	0.25	0.26

time (s)	600
mass (g)	0.27

Enter the data as two arrays in MATLAB and use the `polyfit` command to fit a linear regression (n = 1) to the data. Once you have obtained the slope of the line of best fit, back-calculate the molar mass. From this, determine which of the three suspected salt solutions it is.

Optional: plot the data using round symbols, and the line of best fit as a solid line on the same graph (different colours) to confirm that the fit is acceptable. This step is essential when undertaking actual (assignments, lab reports, research, employed etc.) work; and the plot should be included as evidence.

Question 5

The equilibrium of the following chemical reaction was studied over temperature, and the equilibrium constants determined:

$$N_2 + 3H_2 \rightleftharpoons 2\ NH_3$$

Given that:

$$\mathrm{K}_{eq} = \mathrm{e}^{-\frac{\Delta G}{RT}} \qquad \Delta G = \Delta H - T\Delta S$$

Determine the heat of reaction (ΔH) by fitting the equilibrium data provided with a linear regression.

Temperature [K]	**K_{eq} [-]**
573	$4.34 \cdot 10^{-3}$
673	$1.64 \cdot 10^{-4}$
723	$4.51 \cdot 10^{-5}$
773	$1.45 \cdot 10^{-5}$
823	$5.36 \cdot 10^{-6}$
873	$2.25 \cdot 10^{-6}$

Hint: you will need to rearrange the equations and linearise them.

Question 6

An unwise electrical engineer loaned their bench-top power supply and multimeter to Mehdi (from Electroboom). Safe to say, upon return, they were not in their original condition. They would like to confirm the value of a resistor they have, but they can only measure total power consumption, and current.

Given that:

$$P = I^2 R$$

Use the following data to help determine the value of the resistor:

Test Current [A]	Measured Power [W]
0.001	0.0047
0.003	0.042
0.005	0.114
0.007	0.237
0.009	0.381
0.011	0.563
0.013	0.802
0.015	1.05
0.017	1.32
0.019	1.70

Further thought: why is it not wise to just substitute one set of values from the table in to the equation, and determine the resistance?

Optional: look up a standard resistor value (E24) table, to obtain the marked value of the resistor.

Question 7

The population of an animal pest species was monitored over a ten-year interval. It is expected that the population follows an exponential growth model:

$$P(t) = P_0 \cdot e^{k \cdot t}$$

Where P is the population 't' years after the species was introduced, P_0 is the initial population and k is the growth rate.

Based on the following data, estimate the initial population (P_0) and growth rate (k) of the species.

t	P
75	9316
80	13039
85	19347
90	26783
95	39367
100	59593

Question 8

Determine the pressure drop over a 90 ° PVC elbow with a 250 mm ID, for water flowing at 0.5 m^3/s.

Then, determine the length of 250 mm ID PVC pipe required to have the same pressure drop as the elbow.

$\varepsilon_{PVC} = 3.00 \cdot 10^{-6}$ m

$\rho_{H2O} = 998\ kg/m^3$ $\mu_{H2O} = 1.00 \cdot 10^{-3}\ Pa \cdot s$

Question 9

Determine the pressure drop over a 45 ° elbow with a 25 mm ID, for heptane flowing at 75 L/min.

What is the corresponding pressure drop if two such 45 ° elbows were connected in series?

What is the pressure drop if one 90 ° elbow were to be used?

$\rho_{Hept} = 679\ kg/m^3$ $\mu_{Hept} = 3.88 \cdot 10^{-4}\ Pa \cdot s$

Question 10

What is the pressure drop over the following path for methanol flowing at 0.024 m^3/s through 0.100 m ID steel piping?

- 2 m of straight pipe
- 90 ° elbow
- 2 m of straight pipe

What percentage of the total pressure loss is due to piping, and due to fittings?

$\varepsilon_{Steel} = 6.00 \cdot 10^{-5}$ m

$\rho_{MeOH} = 0.791$ g/mL $\qquad \mu_{MeOH} = 5.94 \cdot 10^{-4}$ Pa·s

Question 11

How do the results to question 10 change if engine oil is being transported instead of methanol?

What can be determined from this?

$\rho_{Oil} = 0.841$ g/mL $\qquad \mu_{Oil} = 290 \cdot 10^{-3}$ Pa·s

Question 12

Determine the pressure drop of black pen ink flowing through a 50 mm to 25 mm ID stainless steel reducer at the following flow rates:

- 10 L/min
- 30 L/min
- 50 L/min

$\varepsilon_{SS} = 3.00 \cdot 10^{-7}$ m

$\rho_{Ink} = 1070$ kg/m^3 $\mu_{Ink} = 4.88 \cdot 10^{-3}$ Pa·s

Question 13

Determine the pressure drop over a 300 to 600 mm ID stainless steel expander for air flowing at the following flow rates:

- 250 L/min
- 1000 L/min
- 4000 L/min

$\varepsilon_{SS} = 3.00 \cdot 10^{-7}$ m

$\rho_{Air} = 1.18$ kg/m^3 $\mu_{Air} = 1.85 \cdot 10^{-5}$ Pa·s

Question 14

Determine the pressure drop for the following flow path with jet fuel flowing at 10 L/s through stainless steel.

- Pipe entrance
- 90 ° elbow
- 10 m of 100 mm ID pipe
- 100 mm to 50 mm ID reducer
- Union
- Pipe exit

$\varepsilon_{SS} = 3.00 \cdot 10^{-7}$ m

$\rho_{A1} = 804$ kg/m^3 $\mu_{A1} = 3.70 \cdot 10^{-3}$ Pa·s

Question 15

Water is being taken from a reservoir at the top of a hill and transferred to a town below. The water is taken from the bottom of the reservoir, which is 22 m above the town, and the water has a depth of 3 m. The pipe is 500 mm ID and constructed from concrete, what is the pressure at the end of the pipe if its length is 44 m and the water is flowing at 1.18 m^3/s?

Hint: do not forget to include the pipe entrance and exit losses.

$\varepsilon_{Conc} = 5.00 \cdot 10^{-4}$ m

$\rho_{Water} = 998$ kg/m^3 $\mu_{Water} = 1.00 \cdot 10^{-3}$ Pa·s

Question 16

Water is stored in a water tower, of which the outlet is 50 m above the ground, and the height of water in the tank is 2.5 m. What is the pressure at the outlet of the pipeline if 4.5 m^3/s of water is being transferred through an 800 mm ID concrete pipe with the following path?

- Open gate valve
- 50 m of pipe
- 90 ° elbow
- 25 m of pipe

You may use the properties from question 15.

Question 17

Water flows through the following path in 150 mm ID PVC piping, and the pressure and flow rate at the outlet are measured to be 50 kPa and 1800 L/min respectively. Determine the pressure at the inlet of the piping network.

- 3 m of vertical pipe (down)
- 90 ° elbow
- Open gate valve
- 333 m of pipe
- 90 ° elbow
- 3 m of pipe

$\varepsilon_{PVC} = 7.00 \cdot 10^{-6}$ m

$\rho_{Water} = 998$ kg/m^3 $\mu_{Water} = 1.00 \cdot 10^{-3}$ Pa·s

Question 18

Determine the pressure at the outlet of the following system if PVC pipe is used to transport water, flowing at 1200 L/min.

- Water tank 17 m above the ground with 3 m water height
- 17 m of 600 mm ID pipe
- 90 ° elbow
- 120 m of 600 mm ID pipe
- 600 mm to 100 mm ID reducer
- 90 ° elbow
- 5 m of 100 mm ID pipe

The properties provided in question 17 may be used.

Question 19

For questions 14 through 18, calculate the pressure drop of the respective systems at 5 flow rate points. You may use an m-file to accomplish this if you wish.

The flow rate points you should include are:

- 10 % of original value
- 40 % of original value
- 70 % of original value
- 130 % of original value
- 160 % of original value

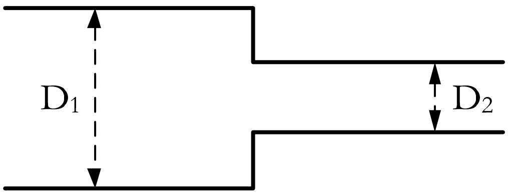
As you now have 7 pressure drop points for each question, the original value, the additional 5, and (0,0); produce a flow rate-pressure drop plot for each system.

K values for fittings

Fitting	K
45 ° elbow	0.35
90 ° elbow	0.75
180 ° bend	1.5
Tee – run through – branch blocked	0.4
Tee – all other flow patterns	1
Coupling	0.04
Union	0.04
Pipe exit	1
Pipe entrance	0.75
Gate valve – open	0.17
Gate valve – ¾ open	0.9
Gate valve – ½ open	4.5
Gate valve – ¼ open	24

K value functions for expanders and reducers

<u>Reducers</u>



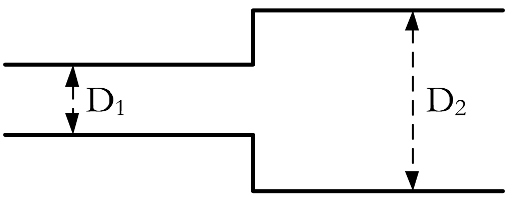
$\mathrm{Re}_1 < 2500$

$$K = \left(1.2 + \frac{160}{\mathrm{Re}_1}\right)\left[\left(\frac{D_1}{D_2}\right)^4 - 1\right]$$

$\mathrm{Re}_1 \geq 2500$

$$K = (0.6 + 0.48 f_1)\left(\frac{D_1}{D_2}\right)^2 \left[\left(\frac{D_1}{D_2}\right)^2 - 1\right]$$

<u>Expanders</u>



$\mathrm{Re}_1 < 4000$

$$K = 2\left[1 - \left(\frac{D_1}{D_2}\right)^4\right]$$

$\mathrm{Re}_1 \geq 4000$

$$K = (1 + 0.8 f_1)\left[1 - \left(\frac{D_1}{D_2}\right)^2\right]^2$$

Goudar-Sonnad correlations for f

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$$a = \frac{2}{\ln(10)} \qquad b = \frac{\varepsilon/D}{3.7} \qquad d = \frac{\ln(10)}{5.02} \cdot \mathrm{Re}$$

$$s = b \cdot d + \ln(d) \qquad q = s^{\frac{s}{s+1}}$$

$$g = b \cdot d + \ln\left(\frac{d}{q}\right) \qquad z = \ln\left(\frac{q}{g}\right)$$

$$\delta_{LA} = \left(\frac{g}{g+1}\right) \cdot z$$

$$\delta_{CFA} = \delta_{LA} \cdot \left[1 + \frac{z/2}{(g+1)^2 + (z/3) \cdot (2g-1)}\right]$$

$$\frac{1}{\sqrt{f}} = \phi = a \cdot \left[\ln\left(\frac{d}{q}\right) + \delta_{CFA}\right]$$

$$f = \left(1/\phi\right)^2$$