ME 355 – System Modeling and Numerical Methods
Fall 2023

Project 1

Due Date: Friday, September 29 by 11:59 pm
Preliminary functions due Friday, September 22 by 11:59 pm
This project must be turned in on Blackboard.

1 Introduction

As your research project, you are recreating a mock vascular system. To do so, you are substituting a pump for the heart, and tubing for the veins. For cost reasons, you decide to just use a single diameter tube size. You choose PTFE Teflon tubing (roughness of about 0.003 mm) at a diameter of 10 mm (the average diameter of a vein). For your vascular structure, you want the blood (viscosity of 0.0035 N s / m^2 and density of 1050 kg/m^3) to visit four different areas of interest. To do so, you configure the pipes as shown in Figure 1. Now, you want to calculate the flow rate in each of the individual pipes of your system assuming a flow rate of 5.5 liters per minute from the *heart*.

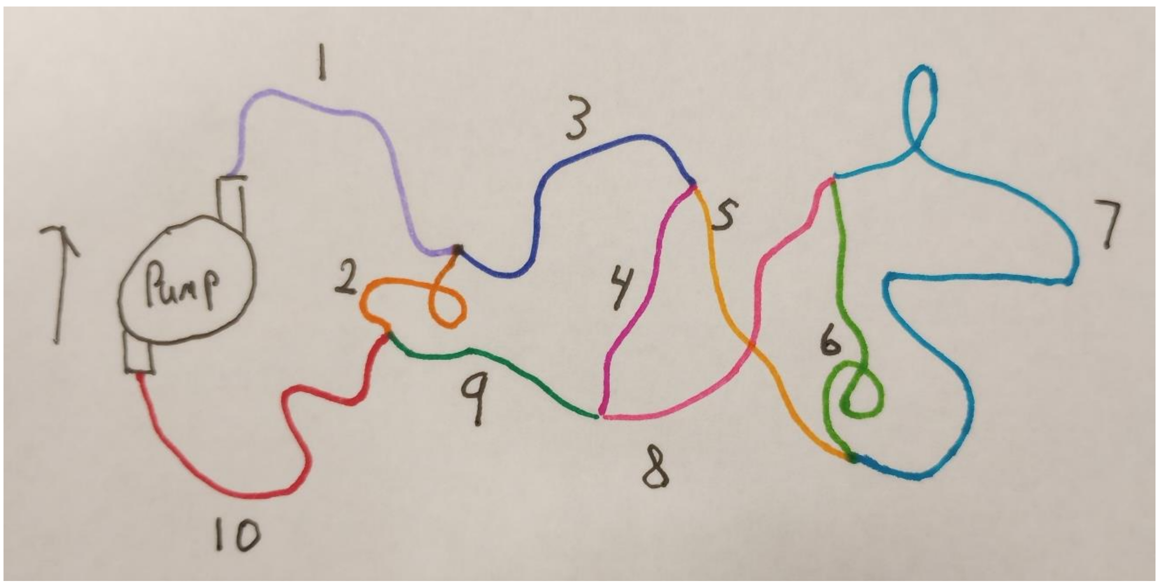

Figure 1. Rough schematic of the vascular system design. The numbers label the specific piping segment.

To do accomplish your task, you will:

1. Create a system model of the piping system.
2. Create an electrical model of from your system model.
3. Develop a system of equations, listing your knowns and unknowns!
4. Develop MATLAB code to solve this system of equations using root finding.

Pipe	Length in meters
1	3
2	4
3	1
4	5
5	2
6	4
7	10
8	2
9	3
10	5

2 Functions

To complete this task, you will need to develop **3** MATLAB functions. Preliminary versions of these functions are due on the date specified above. To get full credit for the preliminary functions you must have made a legitimate attempt. You may make changes to the functions after the preliminary function due date and prior to the final due date.

Note: All functions will be run through an auto grader, with the code reviewed manually for comments. All inputs and outputs must be **EXACTLY** as listed below.

a. FrictionFactor.m
frictionfactor = FrictionFactor(pipe_roughness, pipe_diameter, Re)
This calculates the friction factor using the *Colebrook equation*. You must use *fzero* in the **closed form** to solve this equation. Use appropriate bounds.

b. **Pressure.m**
delta_P = Pressure(Q, L, D, Re, fluid_density, pipe_roughness)
This calculates the pressure drop in a circular pipe with a given flow rate (Q), pipe length (L), pipe diameter (D), Reynolds number (Re), fluid density (ρ), and pipe roughness (ϵ).

c. MathModel.m
zeros = MathModel(Q, L, D, fluid_density, dynamic_viscosity, pipe_roughness)
This function outputs the six system of equations setup for root finding to solve for the Q_2 through Q_7 flow rates. Q, L, and D are vectors of length 10 corresponding to the flow rate of the liquid in m^3/s, length of the pipes in m, and diameter the pipes in m for pipes 1 through 10. Example, $Q = [Q_1, Q_2, \dots, Q_{10}]$.

3 Documentation

All code for this portion of the project should be written in a MATLAB file called **project1.m** and submitted with your project!

a) Using *fsolve*, solve for the flow rates in each tube using the parameters in the Introduction section of this project.
b) Change the diameter of the tubes entering/leaving the *heart*. Does this impact the flow rate in the rest of the vascular system? Why or why not?

For this project, you want to provide the following information in an outline to your research advisor.

1. Title Page
2. Figures
   All figures must have a **descriptive** caption. The caption should be the main point!
   a. Figure of your System Model. This can be hand drawn, but it must be neat.
   b. Figure of your Electrical Model. This can be hand drawn, but it must be neat.
3. System of equations, knowns, and unknowns.
   You **MUST** use the equation editor in Word or Google Docs.
   Put each equation on a different line.
   Knowns and unknown can be comma delimited and labeled on their own line.

4. A table with all the flow rates, Q_1 through Q_{10}, in liters per minute for the standard diameters and the modified diameters.
   Put in your caption what you changed the diameters of the input and output pipe to.
   Your **project1.m** file will be checked to verify consistency between this table and your code!
5. A sentence or two about why the flow rate is or is not impacted by the diameter of the tubes entering/leaving the *heart*.

4 Deliverables

Be sure to submit all 5 files!

1. FrictionFactor.m
2. Pressure.m
3. MathModel.m
4. project1.m
5. Documentation PDF

5 Rubric (Total 100 Points)

Functions 1 – **10 Points**
Functions 2 – **10 Points**
Functions 3 – **20 Points**
Turned in preliminary functions on time **– 10 Points**

Documentation – **45 Points**
System Model, Electrical Model, System of Equations, Knowns, and Unknowns – **30 Points**
Table – **10 Points**
Short Discussion – **5 Points**

Documentation format and Code Comments – **5 Points**

6 Notes for Report

For any **equations**, please use the equation editor.
For **Figures** and **Tables**, please follow the guidelines outlined in the example report on Blackboard.
Include a title page.

7 Notes for Functions

These notes do not apply to the **project1.m** file.
All functions must be named EXACTLY as listed above. This includes capitalization.
Functional inputs and outputs must be EXACTLY as defined in the Functions section.

8 Test Data

If you run the following code below in the MATLAB command window, you should get the following output. Do note, this does NOT guarantee your code is correct.

Code

```
FrictionFactor(0.02, 0.5, 5678)
Pressure(2, 3.3, 0.5, 6548, 0.001, 0.003)
x = MathModel([1,2,3,4,5,6,7,8,9,10], [1,2,3,4,5,6,7,8,9,10], [1,2,3,4,5,6,7,8,9,10], 0.001, 0.00002,
0.00003)
x(4:6)
```

Output

```
ans =  0.0690


ans =  0.0142


x =
    4.0000
    6.0000
    8.0000
   -0.0000
    0.0000
   -0.0000


ans =
   1.0e-04 *

   -0.1128
    0.0368
   -0.0130
```

Note: Your output for x MAY be in a different order.