***Read all of the following information before starting the exam:***

* The exam is open book, open notes, open Python documentation, open internet, etc.
* You **MAY NOT** use any form of technology to communicate with, send to, or receive information from another person (e.g., classmates, other instructors, anonymous or known persons on the internet). HOWEVER, you are **encouraged** to submit written questions to the professor or TA by email and/or have a private help session with the instructor through ZOOM.
* **MODULES/PACKAGES:** You may now use any Python packages you wish. However, you must follow specific instructions even if a package/library may be the easier way. You may use/reuse code (with proper attribution; e.g., “this function is modified from Dr. Smay’s.py file” or “this import is from my HW1 file”)
* **COMMENTS/DOCUMENTATION:** **ALL** of your functions (especially class constructors) should use docstrings to explain what the function does and what the arguments are and what is returned. Other comments inside the function as necessary.
* **SUBMISSION:** You must place all your work (.py files, .txt files, etc.) in a single folder called EX2SP24 and create a private github repository. To submit your exam, you must invite the TA and the instructor to your private repository and submit the URL for your repository on CANVAS.
* **GRADING:** When we grade your assignment, we will run your program with those given numerical values, looking for correct answers. Then we will change the numerical values (including changing the SIZES of the arrays) and look for correct answers for those modified values as well. We will only use numerical values, array sizes and functions that make sense. We will not be testing your program to see how it handles bad data. As you have seen in your homework, comments/documentation will count for about 20% of the grade on a problem.

1. (25 points) (using solve\_ivp, quad and matplotlib) Write a python program that solves the following initial value problem over the interval from using a step size of using solve\_ivp from scipy.integrate.

,

The exact solution for this i.v.p. is: : where

Your program must show the solution for the I.V.P. as a plot of y(x) for the exact solution as a solid line and the numerical solution as upward facing triangles at 0.2 increments.

Plot requirements:

1. x-axis from 0.0 to 6.0 titled as x with tick marks pointed inward on both top and bottom sides.
2. y-axis from 0.0 to 1.0 titled as y with tick marks pointed inward on both left and right sides.
3. A legend with exact solution titled as ‘Exact’ and I.V.P. numerical solution titled as ‘Numerical’.
4. Numbers on x and y axes formatted with one digit (e.g., 0.6)
5. Title the plot with the title: “IVP: , ”

Hint: the exact solution involves a difficult integral S(x), which you may solve numerically using quad from scipy.integrate.

Your graph should look like:

A graph of a function

Description automatically generated

1. (25 points) (using solve\_ivp, quad and pyplot) Write a python program that graphs the currents i1, i2 and voltage across *C* (*vc*) for 10 seconds for the following RLC network:

Diagram, schematic

Description automatically generated

Notes:

* + 1. You must write your system of differential equations in state form and solve using solve\_ivp.
    2. R=10Ω, L=20H, C=0.05F, *v*(*t*)=20⋅sin(20⋅t+0)
    3. Your plot should look like this in every detail:

Chart

Description automatically generated

3. (50 points) You have analyzed a pipe network with sprinklers in homework 6. Modify your program, appropriately, to analyze the pipe network below and output a nicely formatted report for the: **i) flow rate and direction in each pipe, ii) the head loss in each pipe (in inches of water), and iii) the pressure at each node in psi with the knowledge that the node h pressure is 80 psi.**

Notes:

1. The 12” and 16” pipes are cast iron (roughness = 0.00085 ft) while the 18” and 24” pipes are concrete (roughness = 0.003 ft).
2. Minor losses may be ignored.
3. cfs stands for cubic feet per second.
4. Room temperature water is the fluid (μ=20.50×10-6 lb⋅s/ft2, γ=62.3 lb/ft3).
5. You must use object orient programming to accomplish the requirements of this problem.

Chart, diagram

Description automatically generated

My output looks like:

The flow in segment a-b is 3.57 (cfs) and Re=286475.8

The flow in segment a-h is -3.57 (cfs) and Re=214856.8

The flow in segment b-c is 2.57 (cfs) and Re=205762.6

The flow in segment b-e is 1.01 (cfs) and Re=90802.3

The flow in segment c-d is 0.53 (cfs) and Re=42434.3

The flow in segment c-f is 2.04 (cfs) and Re=183744.4

The flow in segment d-g is -1.47 (cfs) and Re=132658.6

The flow in segment e-f is 1.46 (cfs) and Re=175422.0

The flow in segment e-i is -3.45 (cfs) and Re=276764.5

The flow in segment f-g is -1.50 (cfs) and Re=180909.5

The flow in segment g-j is -2.97 (cfs) and Re=238525.1

The flow in segment h-i is 6.43 (cfs) and Re=386467.2

The flow in segment i-j is 2.97 (cfs) and Re=178893.9

Check node flows:

net flow into node a is 0.00 (cfs)

net flow into node b is 0.00 (cfs)

net flow into node h is 0.00 (cfs)

net flow into node c is -0.00 (cfs)

net flow into node e is 0.00 (cfs)

net flow into node d is -0.00 (cfs)

net flow into node f is 0.00 (cfs)

net flow into node g is 0.00 (cfs)

net flow into node i is -0.00 (cfs)

net flow into node j is 0.00 (cfs)

Check loop head loss:

head loss for loop A is 0.00 (psi)

head loss for loop B is -0.00 (psi)

head loss for loop C is 0.00 (psi)

head loss for loop D is -0.00 (psi)

head loss in pipe a-b (L=1000.00 in, d=18.00 in) is 12.22 in of water

head loss in pipe a-h (L=1600.00 in, d=24.00 in) is 4.39 in of water

head loss in pipe b-c (L=500.00 in, d=18.00 in) is 3.18 in of water

head loss in pipe b-e (L=800.00 in, d=16.00 in) is 1.23 in of water

head loss in pipe c-d (L=500.00 in, d=18.00 in) is 0.15 in of water

head loss in pipe c-f (L=800.00 in, d=16.00 in) is 4.67 in of water

head loss in pipe d-g (L=800.00 in, d=16.00 in) is 2.51 in of water

head loss in pipe e-f (L=500.00 in, d=12.00 in) is 6.63 in of water

head loss in pipe e-i (L=800.00 in, d=18.00 in) is 9.13 in of water

head loss in pipe f-g (L=500.00 in, d=12.00 in) is 7.03 in of water

head loss in pipe g-j (L=800.00 in, d=18.00 in) is 6.81 in of water

head loss in pipe h-i (L=1000.00 in, d=24.00 in) is 8.70 in of water

head loss in pipe i-j (L=1000.00 in, d=24.00 in) is 1.92 in of water

Pressure at node a = 79.84 psi

Pressure at node b = 79.40 psi

Pressure at node h = 80.00 psi

Pressure at node c = 79.29 psi

Pressure at node e = 79.36 psi

Pressure at node d = 79.28 psi

Pressure at node f = 79.12 psi

Pressure at node g = 79.37 psi

Pressure at node i = 79.69 psi

Pressure at node j = 79.62 psi