

# Homework 9

Ch En 263 – Numerical Tools

Due: 3 Nov. 2025

## Instructions

- Complete the problems below and submit the following files to Learning Suite:
  - Handwritten portion: scan each page (or take a picture) and combine them into a single pdf named: `LastName_FirstName_HW9.pdf`
  - Excel portion: submit a workbook named `LastName_FirstName_HW9.xlsx` where each worksheet tab is named “Problem\_1”, “Problem\_2”, etc.
  - Python portion: submit a separate file for each problem named `LastName_FirstName_HW9_ProblemXX.py` where XX is the problem number.

## Problems

1. To find the power required to pump a fluid through a pipe we need a quantity called the friction factor. The friction factor is found from an empirical correlation called the Prandtl-Karman equation,

$$\frac{1}{\sqrt{f}} = 4 \log_{10} (Re \sqrt{f}) - 0.4$$

where  $f$  is the dimensionless friction factor and  $Re$  is a dimensionless number called the Reynolds number. Use Newton’s method in Excel to solve for  $f$  when  $Re = 10^4$ . A good guess is  $f \approx 0.005$ .

2. The Redlich/Kwong Equation of State is

$$P = \frac{RT}{V - b} - \frac{a}{T^{1/2}V(V + b)},$$

where  $T$  is temperature,  $V$  is molar volume,  $R$  is the universal gas constant,  $a$  and  $b$  are compound-specific constants. The roots of this cubic equation give the molar volume of a liquid and vapor phase in equilibrium. Write a Python code using Newton’s method to find the molar volume of both the liquid and vapor phase of ethane that is present at  $T = 77^\circ\text{C}$  and  $P = 1$  bar. For ethane,  $a = 2.877 \times 10^8 \text{ cm}^6 \text{ bar K}^{0.5} \text{ mol}^{-2}$  and  $b = 60.211 \text{ cm}^3 \text{ mol}^{-1}$ . Print the value of both molar volumes to the console.

*Hints: You should convert  $T$  to an absolute temperature scale, i.e.  $K$ . Use the ideal gas law to get a guess for the vapor volume, and use  $1.1b$  as a guess for the liquid volume. By the way, there is another root in between that of the vapor and liquid that is not physical.*

3. In this problem, we are going to find the *four* solutions for  $x$  and  $y$  to the following equations

$$2x^2 + y^2 = 1 \tag{1}$$

$$(0.5x - 0.5)^2 + 2(y - 0.25)^2 = 1. \tag{2}$$

- (a) Write out by hand the equations in standard, vector form  $\mathbf{f}(\mathbf{x}) = \mathbf{0}$  where  $f_0$  is Equation 1,  $f_1$  is Equation 2,  $x_0 = x$  and  $x_1 = y$ .

- (b) In Python, make a plot of the two equations with the variable  $y$  on the y-axis and the variable  $x$  on the x-axis. *Hint: Re-arrange Eq. 1 and Eq. 2 to solve for  $y$ . Remember that when solving  $y^2 = f(x)$  for  $y$ , the solution is  $y = \pm\sqrt{f(x)}$ .*
- (c) Write a Python code to solve for the four roots using root-finding methods. Use the plot from part (b) for your initial guesses. Please print the converged values to the console, so the grader can easily locate them.