Homework 3

Ch En 263 – Numerical Tools

Due: 29 Jan. 2024

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_HW3.pdf`
  - Excel portion: submit a workbook named `LastName_FirstName_HW3.xlsx` where each worksheet tab is named "Problem_1", "Problem_2", etc.
  - Python portion: submit a separate file for each problem named `LastName_FirstName_HW3_ProblemXX.py` where XX is the problem number.

Problems

1. Write a function in a Python program called `uc` ("uc" for unit "conversion") that takes a string as an argument and returns a factor for a unit conversion. The value the string should determine the unit conversion factor. For example, If I have a variable `x` in units of meters, and I want to convert it to feet and store that value in variable `y`, I would call it using:

   ```
   y = x*uc('m_to_ft').
   ```

   Set up the function to allow conversion from: `m_to_ft`, `hr_to_s`, `kg_to_slug`, `K_to_degR` and the inverse for each. Use your function to convert: (a) 8.3 m to ft, (b) 9700 s to hr, (c) 3.4 slug to kg, and (d) 270 K to °R. Print each value to the console.

2. Write a function in a Python program that can evaluate the following formula,

   $$y(t) = 5\left[1 - \exp\left(-\frac{(t-\theta)}{\tau}\right)\right] S(t)$$

   $$S(t) = \begin{cases} 0 & \text{when } t < \theta \\ 1 & \text{when } t \geq \theta \end{cases}$$

   where t is an argument to the function, but θ and τ are global variables defined before the function. Evaluate $y(11.0)$, $y(11.4)$, $y(11.8)$, $y(12.2)$, $y(12.6)$, $y(13.0)$ when $\theta = 12$ and $\tau = 1.8$ and print the values to the console. Use the `numpy` module to import the necessary math functions.

3. Write a function called `factorial` that uses a loop to evaluate the expression $n!$ where n is an integer. Call `factorial(5)` to evaluate 5!, `factorial(10)` to evaluate 10! and `factorial(20)` to evaluate 20! and print the results to the console.

4. As we go up in the atmosphere, the pressure and temperature decrease. We can derive a relationship between pressure and height using a force balance and the ideal gas law. A force balance gives,

   $$\frac{dP}{dz} = -\rho g$$

where P is pressure, z is height, ρ is the density of the air and g is gravitational acceleration. The ideal gas law gives an expression for the density,

$$\rho = \frac{MP}{RT}$$

where M is the mean molecular weight of air, T is temperature (K), and R is the gas constant.

Combining these equations, separating variables and integrating gives

$$P = P_0 \exp\left(-\frac{Mgz}{RT}\right) \tag{1}$$

where $P_0 = 1$ atm is the pressure at sea level. (This equation assumes a constant temperature, i.e. isothermal conditions.)

Write a function that will take a variable z (in meters) and return the pressure, P from Eq. 1 in atmospheres. Use a loop to output the value of P for z ranging from 0 to 30,000 feet (the height of Mt. Everest) in increments of 1000 ft. Your output on each line should look something like:

z = 0 ft, P = 1.0 atm

Assume that $M = 29$ kg/kmol, $g = 9.81$ m/s^2 and $T = 300$ K.