MME 9621: Computational Methods in Mechanical Engineering

Assignment 1

(**Due date: 07 February 2024**, **Wednesday**. *Submit through owl*)

Note: *Symbols have their usual meanings.*
Please submit your computer programs with necessary outputs.

1. Convert the following base 10 numbers to binary and express each as a floating point number fl(x) by using the IEEE Rounding to Nearest Rule, (Note: write all 52 bits)
(a) 9.6, (b) 100.2

2. Calculate the expression $\dfrac{1-\sec x}{\tan^2 x}$ using double precision arithmetic in MATLAB for $x=10^{-1}, 10^{-2}, \ldots, 10^{-10}$. Then, using an alternate form of the expression that doesn't suffer from subtracting nearly equal numbers, repeat the calculation, and make a table of results. Report the number of correct digits, and comment.

3. A pipe of length L =25m and diameter d =0.1m, carrying steam, loses heat to the ambient air and surrounding surfaces by convection and radiation as shown in Figure 1. The total heat loss Q emanating from the surface of the pipe is determined by the following equation:

$$Q = \pi d L[h(T_s - T_{air}) + \varepsilon\sigma(T_s^4 - T_{surr}^4)]$$

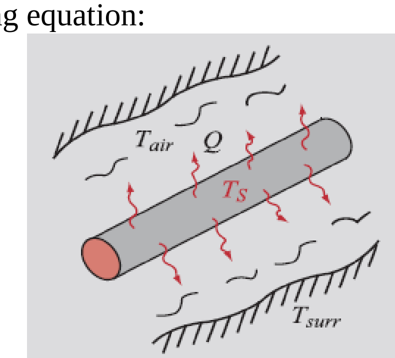


Figure 1.

where T_s is the surface temperature of the pipe, ε =0.8 is the radiative emissivity of the surface of the pipe, and σ =5.67 $\times 10^{-8}$ W/m^2/K^4 is the Stefan–Boltzmann constant.
If total heat flow Q =18405W, heat transfer coefficient h = 10 W/m^2/K, ambient air temperture T_{air} = 298K and surrounding temperature T_{surr} =298K, find the surface temperature of the pipe T_s.

Use (i) Bisection method and (ii) *fzero* (2 initial guesses)

Note: Rewrite the equation such that it forms a polynomial in T_s.

4. A beam is loaded with a distributed load, as shown in Figure 2. The deflection y of the center line of the beam as a function of the position x is given by the equation,

$$y = \frac{w_0}{120LEI}\left(3L^3x^2 - 7L^2x^3 + 5Lx^4 - x^5\right)$$

where L =3 m is the length, E =70 GPa is the elastic modulus, I =52.9$\times 10^{-6}$ m^4 is the moment of inertia, and w_0 =15 kN/m.

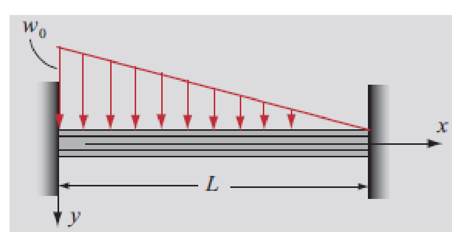


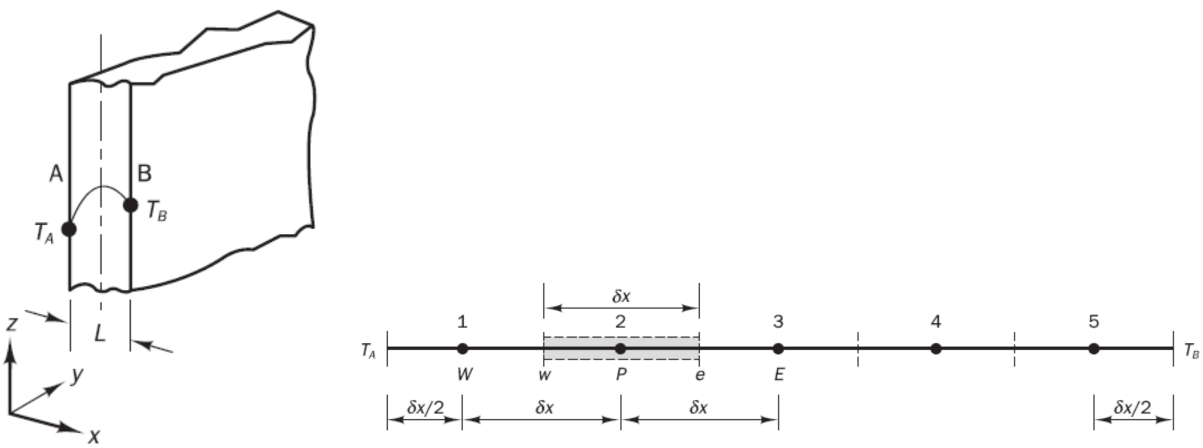
Figure 2.

Find the position x where the deflection of the beam is maximum, and determine the deflection at this point.

Note: The maximum deflection is at the point where $\frac{dy}{dx} = 0$.

a) Use (i) Newton's method and (ii) *fzero* (1 initial guess).
b) Plot the deflection curve.

5. Consider a large plate of thickness L = 2 cm with constant thermal conductivity k = 0.5 W/m.K and uniform heat generation $q = 10^6$ W/m^3 as shown in Figure 3a. The faces A and B are at temperatures of T_A = 100°C and T_B = 200°C respectively. Assuming that the dimensions in the y- and z-directions are so large that temperature gradients are significant in the x direction only, and the governing equation describing the process can be written as $\frac{d}{dx}\left(k\frac{dT}{dx}\right) + q = 0$.



(a) (b)

Figure 3.

To solve the above governing equation, a discretization approach with five nodes is used (see Figure 3b), and the following system of five linear equations is obtained,

$$\left(\frac{kA}{\delta x} + \frac{2kA}{\delta x}\right)T_1 = \frac{kA}{\delta x}T_2 + \frac{2kA}{\delta x}T_A + qA\delta x$$
$$\frac{2kA}{\delta x}T_2 = \frac{kA}{\delta x}T_1 + \frac{kA}{\delta x}T_3 + qA\delta x$$
$$\frac{2kA}{\delta x}T_3 = \frac{kA}{\delta x}T_2 + \frac{kA}{\delta x}T_4 + qA\delta x$$
$$\frac{2kA}{\delta x}T_4 = \frac{kA}{\delta x}T_3 + \frac{kA}{\delta x}T_5 + qA\delta x$$
$$\left(\frac{kA}{\delta x} + \frac{2kA}{\delta x}\right)T_5 = \frac{kA}{\delta x}T_4 + \frac{2kA}{\delta x}T_B + qA\delta x$$

(i) Solve the above system using (i) Tridiagonal solver, (ii) MATLAB '\', and 'inv' function.
Assume, δx = 0.004 m, and area A =1 m^2.
(ii) Plot the temperature distribution in the plate as a function of x.
