Assignment 3

(Assume suitable values wherever necessary. Submission deadline: 11-09-2023)

Q1. [10 marks]

Water, initially at 10°C, is contained within a thin-walled cylindrical vessel having a diameter of 40 cm. Plot the water temperature vs. time up to 1 h if the water and container are immersed in an oil bath at a constant temperature of 90°C. Assume that the water is well stirred and that the convective heat transfer coefficient between the oil and cylindrical surface is 125 $W/m^2 \cdot K$. The cylinder is immersed to a depth of 70 cm. Consider ρ = 1000 kg/m3; c = 4200 J/kg−K;

1) Find the time required for water to reach 99% of steady state temperature
2) Find the total heat transferred to reach a steady state temperature
3) Does the above answer match heat stored by the water in the form of sensible heat?

Q2 [5 marks]

A person is found dead at 5 p.m. in a room whose temperature is 20°C. The temperature of the body is measured to be 25°C when found, and the heat transfer coefficient is estimated to be 8 W/m^2K. Model the body as a 30 cm dia, 1.7 m long cylinder and estimate the time of death of that person. (Take k = 6.15 $W/m \cdot K$, c_p = 4178 J/kgK, ρ=1000 kg/m^3)

Q3. [5 marks]

In April, a concrete highway may reach a temperature of 50°C. Suppose that a stream of water is directed on the highway so that the surface temperature is suddenly lowered to 35°C. How long will it take to cool the concrete to 40°C at a depth of 5 cm from the surface? (in hours). Consider thermal diffusivity of concrete as $\alpha = 7\times10^{-7} m^2/sec$. Use Error function table

z	$erf(z)$	z	$erf(z)$	z	$erf(z)$
0	0	0.55	0.5633	1.3	0.9340
0.025	0.0282	0.60	0.6039	1.4	0.9523
0.05	0.0564	0.65	0.6420	1.5	0.9661
0.10	0.1125	0.70	0.6778	1.6	0.9763
0.15	0.1680	0.75	0.7112	1.7	0.9838
0.20	0.2227	0.80	0.7421	1.8	0.9891
0.25	0.2763	0.85	0.7707	1.9	0.9928
0.30	0.3286	0.90	0.7970	2.0	0.9953
0.35	0.3794	0.95	0.8209	2.2	0.9981
0.40	0.4284	1.0	0.8427	2.4	0.9993
0.45	0.4755	1.1	0.8802	2.6	0.9998
0.50	0.5205	1.2	0.9103	2.8	0.9999

Q4 [15 marks]

Spheres A and B are initially at 800 K, and they are simultaneously quenched in large constant temperature baths, each having a temperature of 320 K. The following parameters are associated with each of the spheres and their cooling processes. (Use relevant tables and equations from Incropera)

	Sphere A	**Sphere B**
Diameter(mm)	300	30
Density(kg/m^3)	1600	400
Specific heat (KJ/kg·K)	0.4	1.60
Thermal conductivity (W/m·K)	170	1.70
Convection coefficient. (W/m^{2}K)	5	50

a) Show in a qualitative manner, on T – t coordinates, the temperatures at the center and at the surface for each sphere as a function of time. Briefly explain the reasoning by which you determine the relative positions of the curves.
b) Calculate the time required for the surface of each sphere to reach 415 K.
c) Determine the energy that has been gained by each of the baths during the process of spheres cooling to 415 K.

Q5 [15 marks]

Consider a one dimensional rod of steel of length L. Initially the rod is in equilibrium with uniform T of T_i . At time t= 0, the left end (x=0) of the rod is subjected to constant temp boundary condition T_{left} and the right end is insulated. [q(x=L)=0]Further, due to non uniform heat-generation inside the rod the governing equation for t>0, is given by:

$$\frac{k}{\rho c}\frac{\partial^2 T}{\partial x^2} + \frac{q_{gen}}{\rho c} = \frac{\partial T}{\partial t}$$

where, $$q_{gen} = q_0 \sin\left(\frac{\pi x}{L}\right)e^{-\frac{t}{\tau}}$$

Take, $k_{steel} = 10$, $\alpha = 0.05$, L=1, T_i=0 ,T_{left}=100, τ=20.

Write a Python/MATLAB code to determine T(t). Submit your solution for:

a. Code with N_x=31, N_t=10001 corresponding for t=20 s.
b. Submit Temp(x,t) for 0<t<20 and 0<x<L, similar to the plot shown in class.
c. What would happen if N_x=11, N_t=101.

Comment on your results.