Heat Transfer Assignment 4 — Transient Conduction

Instructions

ξ is a parameter related to your student ID, with ξ_1 corresponding to the last digit, ξ_2 to the last two digits, ξ_3 to the last three digits, etc. For instance, if your ID is 199225962, then $\xi_1 = 2$, $\xi_2 = 62$, $\xi_3 = 962$, $\xi_4 = 5962$, etc. Keep a copy of the assignment — the assignment will not be handed back to you. You must be capable of remembering the solutions you hand in.

Question #1

On a hot summer day a concrete driveway may reach a temperature of 50° C. Suppose that a stream of water is directed on the driveway so that the surface temperature is suddenly lowered to 10° C. How long will it take to cool the concrete to 25° C at a depth of 5 cm from the surface?

Question #2

A plate of stainless steel (18% Chrome, 8% Nickel) has a thickness of 3.0 cm and is initially uniform in temperature at 500° C. The plate is suddenly exposed to a convection environment on both sides at 40° C with $h = 150$ W/m$^2\cdot^\circ$C. Calculate the times for the center and face temperatures to reach 100° C.

Question #3

A stainless steel cylinder (18% Chrome, 8% Nickel) is heated to a uniform temperature of 200° C and then allowed to cool in an environment where the air temperature is maintained constant at 30° C. The convection heat-transfer coefficient may be taken as 200 W/m$^2\cdot^\circ$C. The cylinder has a diameter of 10 cm and a length of 15 cm. Calculate the temperature of the geometric center of the cylinder after a time of 10 min. Also calculate the heat loss.

Question #4

Show that the general solution of the heat equation for 2D transient problems corresponds to:

$$\frac{T - T_\infty}{T_\mathrm{i} - T_\infty} = \left(\frac{T_1 - T_\infty}{T_\mathrm{i} - T_\infty}\right)\left(\frac{T_2 - T_\infty}{T_\mathrm{i} - T_\infty}\right)$$

with:

$$\frac{1}{\alpha}\frac{\partial T_1}{\partial t} = \frac{\partial^2 T_1}{\partial x^2}$$

$$\frac{1}{\alpha}\frac{\partial T_2}{\partial t} = \frac{\partial^2 T_2}{\partial y^2}$$

Question #5

Consider a 0.0245m-radius sphere made in yellow-pine wood initially at a temperature of 200°C. The sphere is cooled with cold air at a temperature of $T_\infty = 20^\circ$C and a convective heat transfer coefficient $h = 3$ W/m^{2}K. Knowing that after a time Δt, the sphere loses 13.114 kJ to the environment, do the following:

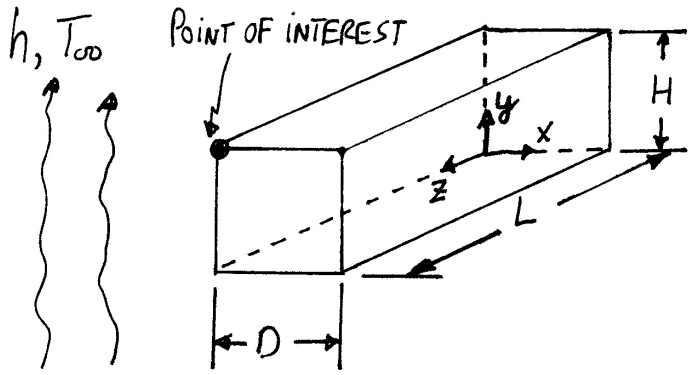
(a) Find the time elapsed, Δt, in seconds.

(b) At a time of $t = \Delta t$, find the center temperature of the sphere in Celcius.

(c) At a time of $t = \Delta t$, find the temperature on the surface of the sphere in Celcius.

Question #6

Consider a block of concrete initially at a temperature of 100°C cooled by some air flow as follows:



Knowing that the dimensions and properties of the concrete can be taken as:

$L = 0.4$ m, $H = 0.2$ m, $D = 0.2$ m

$c = 900$ J/kg$^\circ$C, $\rho = 2000$ kg/m^3, $k = 1.4$ W/m$^\circ$C

and that h can be taken as 14 W/m$^2{}^\circ$C and that T_∞ corresponds to 20°C, find the following temperatures at a time 3 hours after the concrete starts to be cooled by the air flow:

(a) The temperature at the point $(x = 0, y = H, z = L)$

(b) The average temperature within the concrete

Question #7

Consider a cylinder made of concrete with a length of 20 cm and a diameter of 10 cm. The cylinder is initially at a temperature of 500°C and is cooled by a fluid with a temperature T_∞ of 20°C and a convective heat transfer coefficient h of 10 W/m^2°C. Noting that the thermal conductivity, density and heat capacity of concrete can be taken as 1.37 W/m°C, 1900 kg/m^3, and 880 J/kg°C, do the following tasks:

(a) Find the time needed for the minimum temperature within the cylinder to reach 100°C

(b) At the time found in part (a), find the average temperature within the cylinder

Answers

1. 7086 s.
2. 788 s, 767 s.
3. 72°C, 533 kJ.
5. 5853 s, 92°C, 76°C.
6. 24.1°C, 39.2°C.
7. 5400 s, 130°C.

Due on Wednesday April 10th at 9:00. Do Questions #1, #6, and #7 only.