Heat Transfer Assignment 1 — Essentials of Conduction, Convection, and Radiation

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

A flat wall is exposed to an environmental temperature of 38° C. The wall is covered with a layer of insulation 2.5 cm thick whose thermal conductivity is 1.4 W/m$\cdot^\circ$C, and the temperature of the wall on the inside of the insulation is 315°C. The wall loses heat to the environment by convection. Compute the value of the convection heat-transfer coefficient which must be maintained on the outer surface of the insulation to ensure that the outer-surface temperature does not exceed 41° C.

Question #2

A black 20-by-20 cm plate has air forced over it at a velocity of 2 m/s and a temperature of 0° C. The plate is placed in a large room whose walls are at 30° C. The back side of the plate is perfectly insulated. Calculate the temperature of the plate resulting from the convection-radiation balance. Take the convective heat transfer h as 12 W/m$^2\cdot^\circ$C. Are you surprised at the result?

Question #3

Two large black plates are separated by a vacuum. On the outside of one plate is a convection environment of $T = 80^\circ$ C and $h = 100$ W/m$^2\cdot^\circ$C, while the outside of the other plate is exposed to 20°C and $h = 15$ W/m$^2\cdot^\circ$C. Make an energy balance on the system (i.e. apply the heat equation in control volume form) and determine the plate temperatures.

Question #4

Derive Fourier's law of heat conduction in a gas:

$$q''_x = -k\frac{\partial T}{\partial x}$$

with

$$k = \frac{5k_B}{4\sigma}\sqrt{\frac{3RT}{2}}$$

with k the thermal conductivity, σ the collision cross-section, k_B the Boltzmann constant and R the gas constant.

Question #5

Starting from the first law of thermo

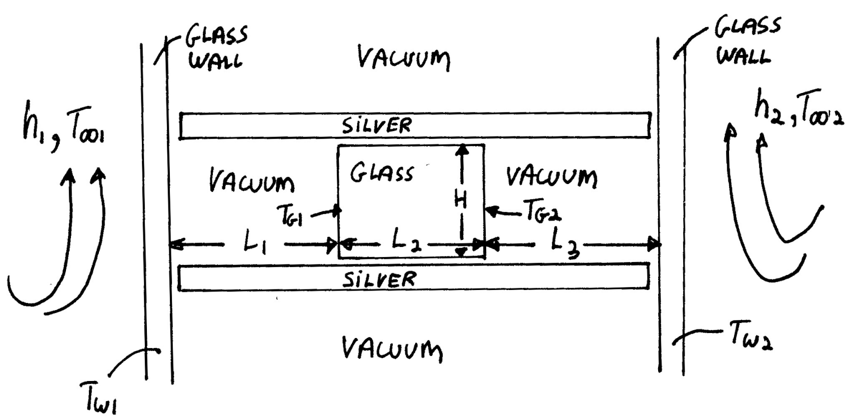
$d(me) + PdV = \delta Q - \delta W$

and Fourier's law $q''_x = -k\partial T/\partial x$ derive the heat equation:

$$\frac{\partial(\rho c T)}{\partial t} = \frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right) + S$$

Question #6

Consider a block of glass surrounded by two silver plates and two glass walls as follows:



It is known that the distance between the silver and the glass is much less than either L_1, L_2, L_3, or H. Knowing that $L_1 = 1$ m, $L_3 = 1$ m, $H = 1$ m, that the temperature on the right side of the glass block is $T_{G2} = 127°$C, that the temperature of the left wall is $T_{W1} = 227°$C, that the temperature of the environment is $T_{\infty 2} = 27°$C and $T_{\infty 1} = 727°$C, that the convective heat transfer coefficient on the right wall is $h_2 = 5.669$ W/m^2°C, do the following:

(a) Find the temperature of the right wall, T_{W2}.

(b) Find the heat flux in W/m^2 due to convective heat transfer on the right wall.

(c) Find the temperature on the left side of the glass block, T_{G1}.

(d) Find the length of the glass block, L_2.

You can use the following properties for glass and silver:

Property	Units	Glass	Silver
c	kJ/kgK	0.84	0.23
k	$\mathrm{W/m^\circ C}$	0.8	400
ρ	$\mathrm{kg/m^3}$	2700	10000
ϵ		1	0

Hints: You can assume that the walls are thin with no temperature gradient within. The temperature on the right face of the glass block is uniform.

Answers

1. $h \geq 5115\ \mathrm{W/m^{2\circ}C}$
2. $9.6^\circ\mathrm{C}$
3. 350 K and 312 K
6. 485.5 K, 0.174 m.

Due on Wednesday March 20th at 9:00. Do Questions #2, #5, and #6 only.

There was something in the schematic of A1Q6 that could lead to confusion: the left environment temperature was schematized as equal to the right environment temperature. Although the left environment temperature was not needed to solve the problem, this could lead to some confusion. Thus, the left and right environment temperatures are now given different symbols in the schematic.