CH EN 3453 – HEAT TRANSFER – FALL 2014

HOMEWORK #2

Due Friday, September 5, at 4:00 PM

Turn in to the CH EN 3453 basket at the main desk of the Chemical Engineering offices (MEB 3290)

Help session Wednesday, September 3 at 4:30 p.m. in MEB 2325

For this assignment, you must…
- *show your work*
- *write legibly and not in micro-font*
- *circle or put a box around your final answer*

1. (15 pts) Define the following physical properties. Include whether it is a thermodynamic or transport property as well as correct units (AE and SI) and the corresponding symbol.

a. Thermal conductivity
b. Kinematic viscosity
c. Density
d. Specific heat
e. Thermal diffusivity

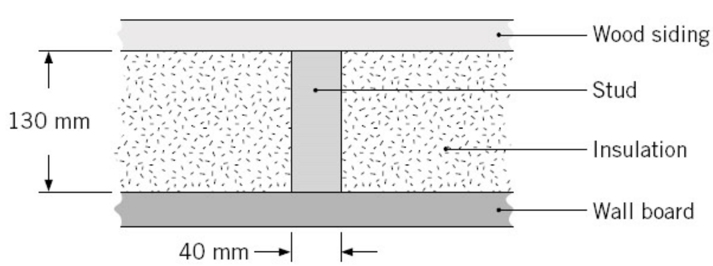
2.* (9 pts) The steady-state temperature distribution in a one-dimensional wall of thermal conductivity 50 W/m·K and thickness 50 mm is observed to be $T(°\text{C}) = a + bx^2$ where $a = 200°\text{C}$, $b = –2000°\text{C/m}^2$ and x is in meters.

(a) What is the heat generation rate $\dot{q}$ in the wall?

(b) Determine the heat fluxes at the two wall faces. In what manner are these heat fluxes related to the heat generation rate?

3.* (9 pts) A thermopane window consists of two pieces of glass 7 mm thick that enclose an air space 7 mm thick. The window separates room air at 20°C from outside ambient air at –10°C. The convection coefficient associated with the inner (room-side) surface is 10 W/m^2·K. If the convection coefficient associated with the outer (ambient) air is h_o = 80 W/m^2·K, what is the heat loss through a window that is 0.8 m long by 0.5 m wide? Neglect radiation, and assume the air enclosed between the panes to be stagnant (i.e., ignore convection to and from the air between the two panes – but don't neglect conduction through that air).

4.* (9 pts) Consider a composite wall that includes an 8-mm-thick hardwood siding, 40-mm by 130-mm hardwood studs on 0.65-m centers with glass fiber insulation (paper faced, 28 kg/m^3) and a 12-mm layer of gypsum (vermiculite) wall board. What is the thermal resistance associated with a wall that is 2.5 m high by 6.5 m wide (having 10 studs, each 2.5 m high)?



More problems on the other side…

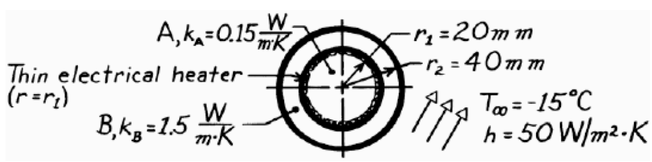
* Solutions for these problems are available on the course website: www.chen3453.com

5.* (9 pts) A 304 stainless steel tube used to transport a chilled pharmaceutical has an inner diameter of 36 mm and a wall thickness of 2 mm. The pharmaceutical and ambient air are at temperatures of 6°C and 23°C, respectively, while the corresponding inner and outer convection coefficients are 400 W/m^2·K and 6 W/m^2·K, respectively.

(a) What is the heat gain per unit tube length?
(b) What is the heat gain per unit length if a 10-mm-thick layer of calcium silicate insulation (k_{ins} = 0.050 W/m·K) is applied to the outside of the tube?

6.* (9 pts) A thin electrical heater is inserted between a long circular rod and a concentric tube with inner and outer radii of 20 and 40 mm. The rod (A) has a thermal conductivity of k_A = 0.15 W/m·K, while the tube (B) has a thermal conductivity k_B = 1.5 W/m·K and its outer surface is subjected to convection with a fluid of temperature T_∞ = –15°C and heat transfer coefficient 50 W/m^2·K. The thermal contact resistance between the cylinder surfaces and the heater is negligible.

(a) Determine the electrical power per unit length of the cylinders (W/m) that is required to maintain the outer surface of cylinder B at 5°C.
(b) What is the temperature at the center of cylinder A?



7. (20 pts) A furnace wall is made up of a 0.25-m thick layer of fireclay brick (k = 2.5 W/m·K), a 0.20-m thick layer of insulating cement (k = 0.16 W/m·K) and a 0.10-m outer layer of masonry face brick. Furnace gases on the inside of the furnace are at 1000°C with a convective heat transfer coefficient of 115 W/m^2·K while the outer wall is exposed to air at 20°C (h = 25 W/m^2·K).

(a) Ignoring radiation, compute heat loss per square meter of wall.

(b) Determine the temperature of the outer surface of the furnace.

(c) If the maximum temperature of the masonry face brick cannot exceed 50°C, by how much must the insulating cement thickness be adjusted to satisfy this requirement?

8. (20 pts) The case covering the back of my cell phone is soft vulcanized rubber 1/8 inch thick. On the front I have a screen protector of 1/16-inch thick soda lime glass. The phone itself is 2.3 inches wide, 4.5 inches tall and 0.4 inches thick. Each Friday night I watch Star Wars on my phone, which results in heat production of 10 Watts. I notice that the front of the phone (between the phone and glass) is 3°C cooler than the back of the phone (between the phone and rubber). If the air temperature on my windy back porch is 28°C and the convective heat transfer coefficient is 150 W/m^2·K, what are the temperatures at (a) the phone-rubber interface and (b) the phone-glass interface? Ignore any heat loss through the edges of the phone (i.e., consider only heat loss through the front and back).

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