Heat Transfer I, Hw # 1

Late homework will not be accepted

1- The concrete slab of a basement is 11 m long, 8 m wide, and 0.20 m thick. During the winter, temperatures are nominally 17 C and 10 C at the top and bottom surfaces, respectively. If the concrete has a thermal conductivity of 1.4 W/m K, what is the rate of heat loss through the slab? If the basement is heated by a gas furnace operating at an efficiency of 0.90 and natural gas is priced at $0.01/MJ, what is the daily cost of the heat loss?

2- A glass window of width"W" 1 m and height "H" 2 m is 5 mm thick and has a thermal conductivity of kg = 1.4 W/m _ K. If the inner and outer surface temperatures of the glass are 15C and 20C, respectively, on a cold winter day, what is the rate of heat loss through the glass? To reduce heat loss through windows, it is customary to use a double pane construction in which adjoining panes are separated by an air space. If the spacing is 10 mm and the glass surfaces in contact with the air have temperatures of 10 C and 15 C, what is the rate of heat loss from a 1 m * 2 m window? The thermal conductivity of air is ka = 0.024 W/m K.

3- What is the thickness required of a masonry wall having thermal conductivity 0.75 W/m K if the heat rate is to be 80% of the heat rate through a composite structural wall having a thermal conductivity of 0.25 W/m K and a thickness of 100 mm? Both walls are subjected to the same surface temperature difference.

4- The 5-mm-thick bottom of a 200 mm-diameter pan may be made from aluminum (k =240 W/m K) or copper (k = 390 W/m K). When used to boil water, the surface of the bottom exposed to the water is nominally at 110 C. If heat is transferred from the stove to the pan at a rate of 600 W, what is the temperature of the surface in contact with the stove for each of the two materials?

5- Air at 40 C flows over a long, 25-mm-diameter cylinder with an embedded electrical heater. In a series of tests, measurements were made of the power per unit length, P, required to maintain the cylinder surface temperature at 300_C for different freestream velocities V of the air. The results are as follows:

Air velocity, V (m/s) :	1	2	4	8	12
Power, P_ (W/m)	:450	658	983	1507	1963

(a) Determine the convection coefficient for each velocity, and display your results graphically.

(b) Assuming the dependence of the convection coefficient on the velocity to be of the form $h = CV^n$, determine the parameters C and n from the results of part (a).

6- A cartridge electrical heater is shaped as a cylinder of length L = 200 mm and outer diameter D= 20 mm. Under normal operating conditions the heater dissipates 2 kW while submerged in a water flow that is at 20 C and provides a convection heat transfer coefficient of h = 5000 W/m^2 K. Neglecting heat transfer from the ends of the heater, determine its surface temperature T_s. If the water flow is inadvertently terminated while the heater continues to operate, the heater surface is exposed to air that is also at 20 C but for which h = 50 W/m^2 K. What is the corresponding surface temperature? What are the consequences of such an event?

7- The free convection heat transfer coefficient on a thin hot vertical plate suspended in still air can be determined from observations of the change in plate temperature with time as it cools. Assuming the plate is isothermal and radiation exchange with its surroundings is negligible, evaluate the convection coefficient at the instant of time when the plate temperature is 225 C and the change in plate temperature with time (dT/dt) is -0.022 K/s. The ambient air temperature is 25 C and the plate measures 0.3 * 0.3 m with a mass of 3.75 kg and a specific heat of 2770 J/kg K.

8- A spherical interplanetary probe of 0.5-m diameter contains electronics that dissipate 150 W. If the probe surface has an emissivity of 0.8 and the probe does not receive radiation from other surfaces, as, for example, from the sun, what is its surface temperature?

9-Consider the conditions of Problem 7. However, now the plate is in a vacuum with a surrounding temperature of 25 C. What is the emissivity of the plate? What is the rate at which radiation is emitted by the surface?

10- An overhead 25 m-long, uninsulated industrial steam pipe of 100 mm diameter is routed through a building whose walls and air are at 25 C. Pressurized steam maintains a pipe surface temperature of 150 C, and the coefficient associated with natural convection is h = 10 W/m^2 K. The surface emissivity is 0.8.
(a) What is the rate of heat loss from the steam line?
(b) If the steam is generated in a gas-fired boiler operating at an efficiency of $_f$ _ 0.90 and natural gas is priced at C_g _ $0.01 per MJ, what is the annual cost of heat loss from the line?

11-Chips of width L = 15 mm on a side are mounted to a substrate that is installed in an enclosure whose walls and air are maintained at a temperature of T_{sur} =T=25C. The chips have an emissivity of 0.60 and amaximum allowable temperature of T_s = 85 C.
(a) If heat is rejected from the chips by radiation and natural convection, what is the maximum operating power of each chip? The convection coefficient depends on the chip-to-air temperature difference and may be approximated as $h = C(T_s - T)^{1/4}$, where C = 4.2 W/m^2 K$^{5/4}$.
(b) If a fan is used to maintain air flow through the enclosure and heat transfer is by forced convection, with h = 250 W/m^2 K, what is the maximum operating power?

12- Three electric resistance heaters of length L= 250 mm and diameter D= 25 mm are submerged in a 10 gallon tank of water, which is initially at 295 K. The water may be assumed to have a density and specific heat of 990 kg/m^3 and c = 4180 J/kg K.
(a) If the heaters are activated, each dissipating q_1 =500 W, estimate the time required to bring the water to a temperature of 335 K.
(b) If the natural convection coefficient is given by an expression of the form h= 370($T_s - T$)$^{1/3,}$ where T_s and T are temperatures of the heater surface and water, respectively, what is the temperature of each heater shortly after activation and just before deactivation?
Units of h and ($T_s - T$) are W/m^2 K and K, respectively.
(c) If the heaters are inadvertently activated when the tank is empty, the natural convection coefficient associated with heat transfer to the ambient air at T= 300 K may be approximated as $h = 0.70(T_s - T)^{1/3}$. If the temperature of the tank walls is also 300 K and the emissivity of the heater surface is 0.85, what is the surface temperature of eachheater under steady-state conditions?