**Cankaya University**
**Faculty of Engineering**
**Mechanical Engineering Department**
**ME 313 Heat Transfer**
**CH_1 Examples**
**Fall 2015**

**1)** Calculate the rate of heat flow through a 0.5 m wide, 0.3 m high and 3 mm thick steel plate, having a thermal conductivity of k = 45 W/mK when the temperature of surface at x = 0 is maintained at a constant temperature of 198$^o$C and its temperature at x = 3 mm is 199.7$^o$C.

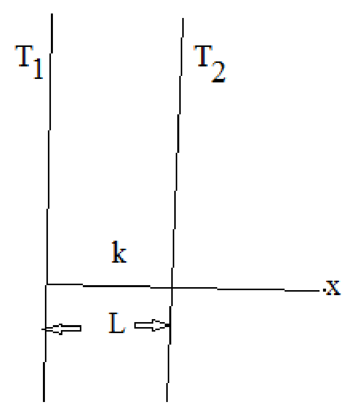
**2)** Determine the heat flow across a constant thermal conductivity of k=8.5 W/m.K when surface temperatures are steady at $100\,^0\mathrm{C}$ and $30\,^0\mathrm{C}$. The wall surface area is $3\mathrm{m}^2$ .Also find the temperature gradient in the flow direction.

**3)** The thermal conductivity of a sheet of rigid ,extruded insulation is reported to be $k = 0.019 \, {}^{W}\!/_{m.K}$ . The measured temperature difference across a 20-mm thick sheet of material is $\Delta T = T_1 - T_2 = 10\,^0\mathrm{C}$ .

a) What is the heat flux through a $2\,\mathrm{m} \times 2\,\mathrm{m}$ sheet of the insulation.

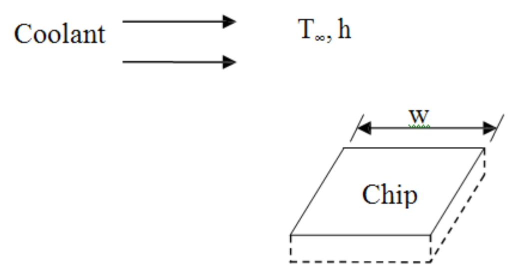
b) What is the rate of heat transfer through the sheet of insulation?

**4)** The thermal conductivity of a plane wall




Varies as $k = k_0\left(1 + bT + cT^2\right)$ where a, b, c are constants. Determine the heat flux through the wall.

5) A square isothermal chip is of width w = 5 mm on a side and is mounted in a substrate such that its side and back surfaces are well insulated, while the front surface is exposed to the flow of a coolant at $T_\infty$ = 15$^o$C. From reliability considerations, the chip temperature must not exceed T = 85$^o$C.




If the coolant is air and the corresponding convection coefficient is h = 200 $W/m^2.K$, what is the maximum allowable chip power? If the coolant is a dielectric liquid for which h = 3000 $W/m^2.K$, what is the maximum allowable power?

6) The surface temperature of a central heating radiator is $60^oC$. What is the net blackbody radiative heat transfer between the radiator and surroundings which are at $20^oC$?

7) 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?

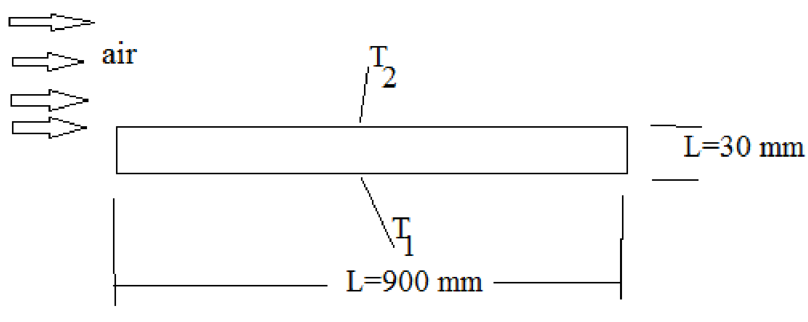
8) A hot plate is exposed to environment at $20^oC$. The measured data in boundary layer is given below.

| y (m) | T (K) |
|---|---|
| 0 | 400 |
| 0.00050 | 393.28 |
| 0.00102 | 386.30 |
| 0.00156 | 379.06 |
| 0.00212 | 371.59 |
| 0.00270 | 363.94 |
| 0.00331 | 356.17 |
| 0.00394 | 348.39 |
| 0.00460 | 340.75 |
| 0.00529 | 333.40 |
| 0.00600 | 326.54 |
| 0.00674 | 320.33 |
| 0.00751 | 314.95 |
| 0.00831 | 310.49 |
| 0.00914 | 306.98 |
| 0.01001 | 304.38 |
| 0.01091 | 302.57 |
| 0.01184 | 301.41 |
| 0.01282 | 300.71 |

The thermal conductivity of the environment fluid is k = 0.03 W/m.K. Calculate the local heat transfer coefficient at this particular point. Data is collected 0.5 m from the leading edge of the plate.

9) A refrigerator stands in a room where air temperature is 20$^{o}$C. The surface temperature on the outside of refrigerator is 16$^{o}$C. The sides are 30 mm thick and have thermal conductivity of 0.1 W/mK. The heat transfer coefficient on the outside is 10 W/m$^{2}$K. Assuming one dimensional conduction through sides, find surface temperature inside.

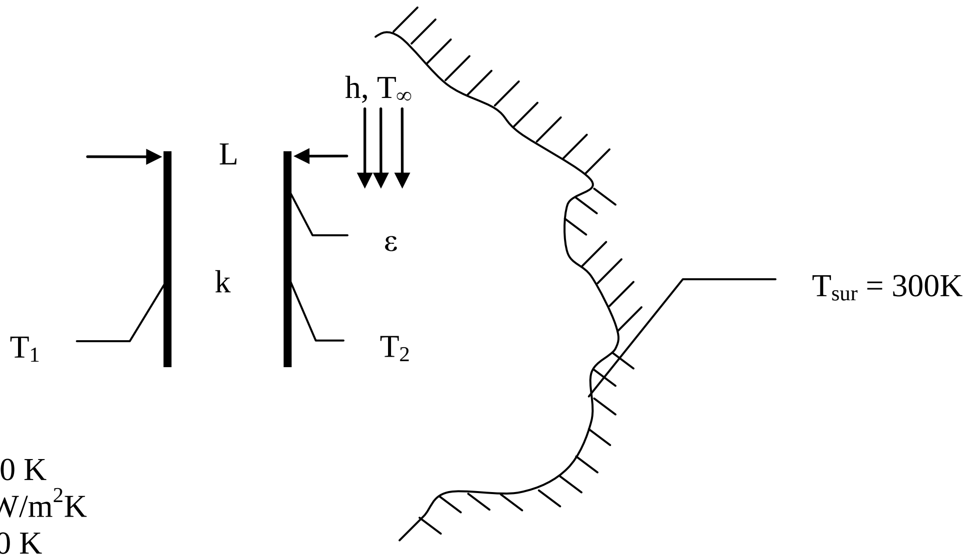
10) A horizontal plate (k=30 W/m.K) 600 mm by 900 mm by 30 mm is maintained at 300 $^{0}$C .The air at 30 $^{0}$C flows over the plate. If the coefficient of air over the plate is 22 W/m$^{2}$.K and 250 W of heat is lost from the plate




by radiation, calculate the bottom surface temperature of plate.

11) During its manufacture, plate glass at 600$^{o}$C is cooled by passing air over its surface such that the convection heat transfer coefficient is h = 5 W/m$^{2}$.K. To prevent cracking, it is known that the temperature gradient must not exceed 15$^{o}$C/mm at any point in the glass during the cooling process. If the thermal conductivity of the glass is 1.4 W/m.K. and its surface emissivity is 0.8, what is the lowest temperature of the air that can initially be used for the cooling? Assume that the temperature of the air equals that of the surroundings?

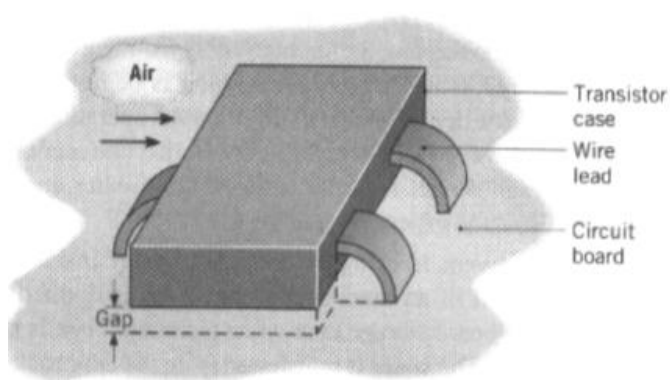
12)Consider a thick plate as shown below. What is the temperature of the left side of the slab?




$T_\infty = 300$ K
$h = 20$ W/m$^2$K
$T_2 = 400$ K
$\varepsilon = 0.8$
$L = 0.05$ m
$k = 0.7$ W/mK

13) Consider a surface mount type transistor on a circuit board whose temperature is maintained at 35$^o$C. Air at 25$^o$C flows over the upper surface of dimension 4 mm by 8 mm with a convection coefficient of 50 W/m$^2$K. Three wire loads, each of cross section 1 mm by 0.25 mm and length 4 mm, conduct heat from the case to the board. The gap between the case and the board is 0.2 mm. Assuming the case is isothermal and neglecting radiation, estimate the case temperature when 150 m.W is dissipated by the board and;

a) stagnant air
b) conductive past fills the gap. The thermal conductivities of the wire leads, air, and conductive paste are 25, 0.0263 and 0.12 W/mK respectively.




14)A spherical, stainless steel (AISI 302) canister is used to store reacting chemicals that provide for a uniform heat flux $q_i''$ to its inner surface. The canister is suddenly submerged in a liquid bath of temperature $T_\infty < T_i$, where $T_i$ is the initial temperature of the canister wall.

a) Assuming negligible temperature gradients in the canister wall and a constant heat flux $q_i''$, develop and equation that governs the variation the wall temperature with time during the transient process. What is the initial rate of change of wall temperature, if $q_i'' = 10^5\ W/m^2$ ?
b) What is the steady-state temperature of the wall?
c) The convection coefficient depends on the velocity associated with fluid flow over the canister and whether or not the wall temperature is large enough to induce boiling in the liquid. Compute and plot the steady-state temperature as a function of h for the range $100 \le h \le 10000\ W/m^2K$. Is there a value of h below which operation would be unacceptable?