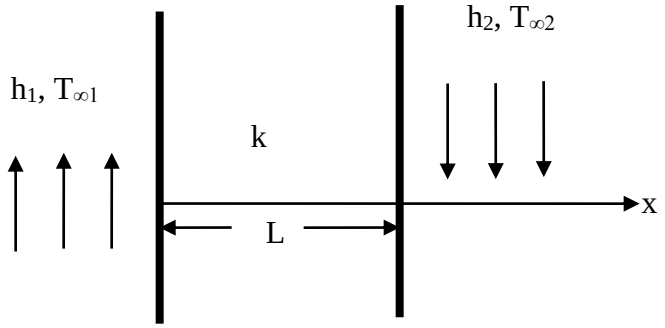
CANKAYA UNIVERSITY
FACULTY OF ENGINEERING
MECHANICAL ENGINEERING DEPARTMENT
ME 313 HEAT TRANSFER

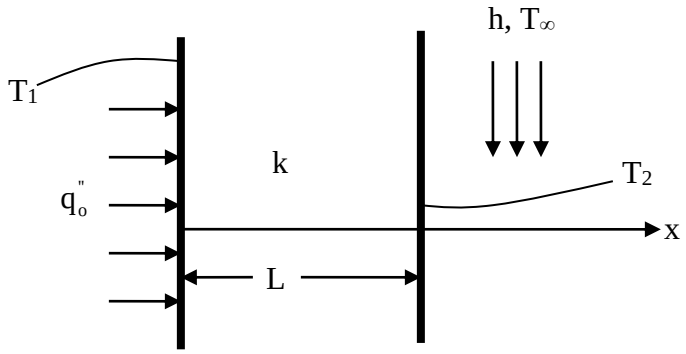
CHAPTER-3

EXAMPLES

1) Consider a slab of thickness L as illustrated in figure below. A fluid at temperature $T_{\infty 1}$ with heat transfer coefficient h_1 flows over the surface at x = 0, and another fluid at temperature $T_{\infty 2}$ with a heat transfer coefficient h_2 flows over surface at x = L of plate. Find the heat flow through area A. A = 1 m^2, $T_{\infty 1}$ = 130 ^oC, h_1 = 250 $W/m^2.^oC$, h_2 = 500 $W/m^2.^oC$, L = 4 cm, k = 20 W/m ^oC, $T_{\infty 2}$ = 30 ^oC.

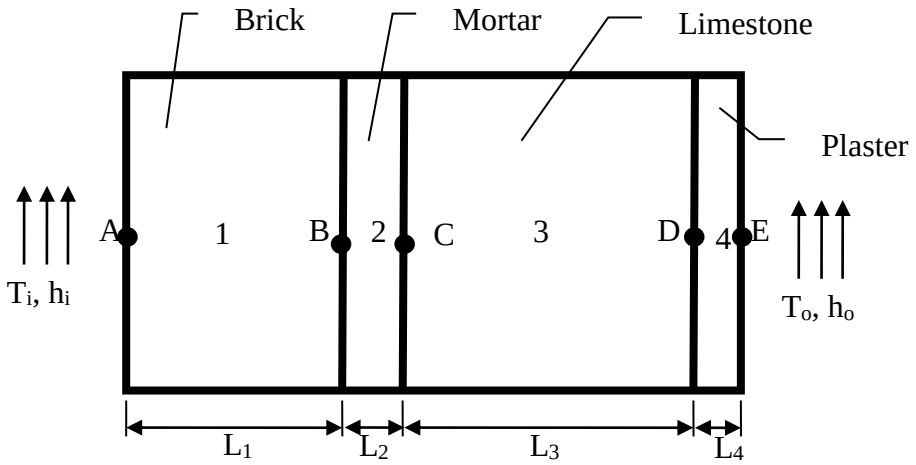


2) An iron plate of thickness L with thermal conductivity k is subjected to a constant uniform heat flux $q_o^{"}$ (W/m^2) at the boundary surface x = 0. From the other boundary surface x = L heat is dissipated by convection into a fluid at T_∞ with heat transfer coefficient h.



Develop expressions for the determination of surface temperatures T_1 and T_2 at the surfaces x = 0 and x = L respectively. Calculate T_1 and T_2 for L = 2 cm, k = 20 W/m.K, $q_o^{"} = 10^5\ W/m^2$, T_∞ = 50 ^oC, h = 5000 $W/m^2.^oC$.

3) A wall is constructed by several layers.

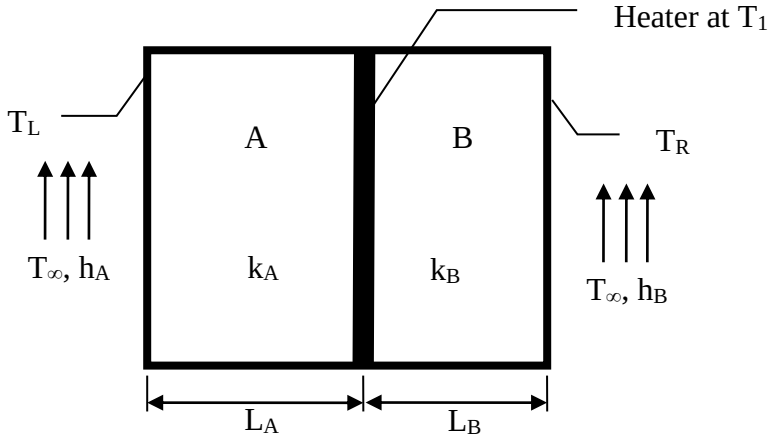


$\mathbf{L}_1$= 0.25 m, L_2 = 0.025 m, L_3 = 0.1 m, L_4 = 0.0125 m, k_1 =0.66 W/m.K, k_2 = 0.7 W/m.K, k_3 = 0.66 W/m.K, k_4 = 0.7 W/m.K, h_i = 5.8 W/m^2.K, T_i = 26 ^oC, h_o = 11.6 W/m^2.K, T_o = -7 ^oC.

Find;

a) overall heat transfer coefficient
b) overall thermal resistance
c) heat flow rate through composite wall
d) temperature at the inter face of mortar and limestone

4) A square plate heater (15 cm x 15 cm) is inserted between two slabs.

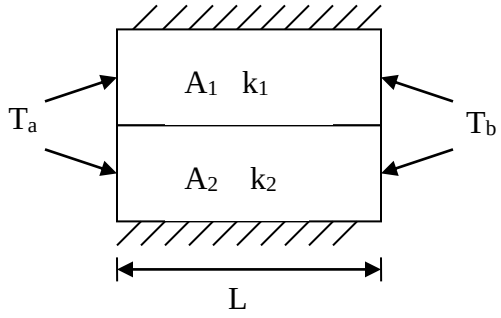


$\mathbf{L}_A$= 2 cm, L_B = 1 cm, k_A = 50 W/m.K, k_B = 0.2 W/m.K, h_A = 200 W/m^2.K, h_B = 50 W/m^2.K, T_∞ = 25 ^oC, Q = 1 kW = 1000 W, A = 15 cm x 15 cm = 225x10^{-4} m^2.

Find;

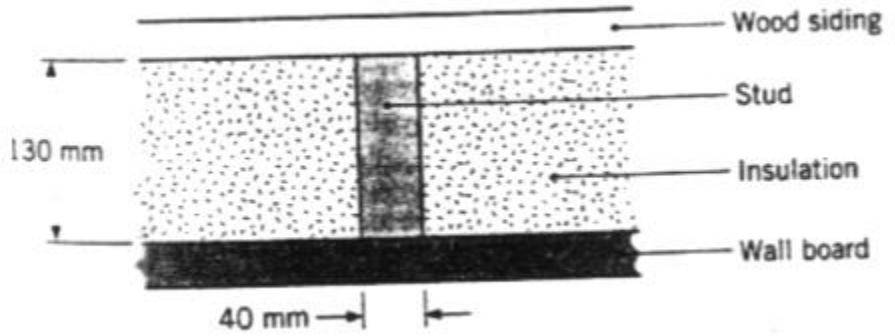
a) maximum temperature of the system
b) outer surface temperatures on both slabs

5) Consider the composite of two materials combined in parallel paths with the ends maintained at uniform temperatures as illustrated in the figure below.



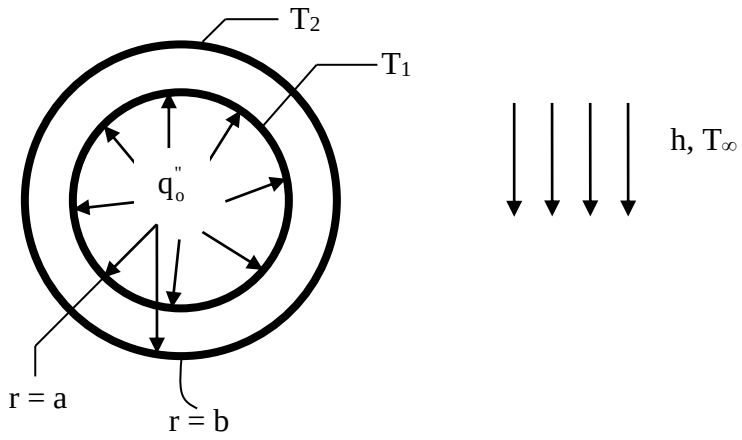
Various quantities are specified. $A_1 = 0.2\ m^2$, $k_1 = 20$ W/m.K, $A_2 = 0.4\ m^2$, $k_2 = 15$ W/m ^oC, L = 0.5 m, $T_a = 150^oC$, $T_b = 30^oC$. Calculate the rate of heat transfer, q across composite material.

6) 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)?

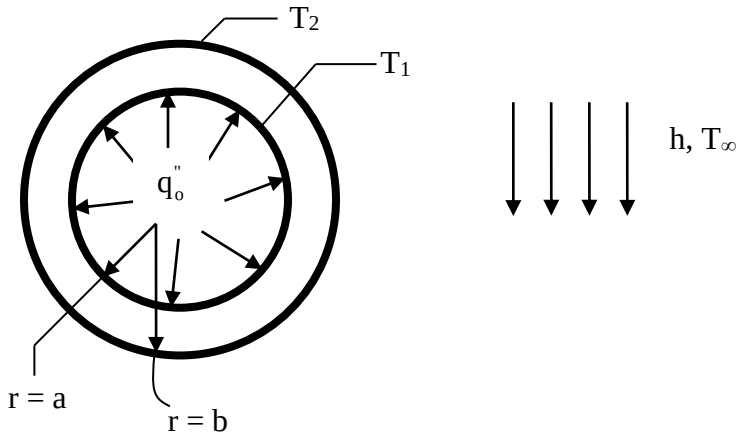


7) Two large aluminum plates (k = 240 W/m.K), each 1 cm thick with 10 μm surface roughness are placed in contact under a pressure of 1 bar in air (k = 0.026 W/m.K). The temperature at inside and outside surfaces are 400 ^oC, and 150 ^oC. Calculate;
a) heat flux
b) temperature drop due to contact resistance

8) A hollow cylinder with inner cylinder radius r = a and outer radius r = b is heated at the inner surface at a rate of $q_o^{''}\ (W/m^2)$, and dissipates heat by convection from the outer surface into a fluid at temperature T_∞ with a heat transfer coefficient h. There is no energy generation and thermal conductivity is constant. Develop expressions for the determination of temperatures at T_1 and T_2 of inner and outer surfaces of the cylinder. Calculate T_1 and T_2 for a = 3 cm, b = 5 cm, h = 400 $W/m^2.^oC$, T_∞ = 100 ^oC, k = 15 W/m.K, $q_o^{''} = 10^5\ W/m^2$.



9) A hollow sphere of inside radius r = a and outside radius r = b is electrically heated at the inner surface at a constant rate of q_o'' (W/m^2). At the outer surface it dissipates heat by convection into fluid at temperature T_∞ with a heat transfer coefficient h. Thermal conductivity of solid is constant.

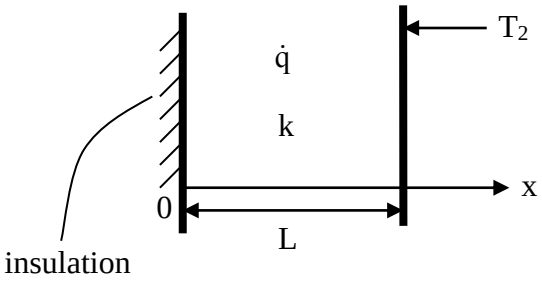


Develop expressions for the determination of the inner and outer surface temperatures T_1 and T_2 of sphere. Calculate the inner and outer surface temperatures for a = 3 cm, b = 5 cm, h = 400 W/m^2.^{o}C, T_∞ = 100 ^{o}C, k = 15 W/m.^{o}C and $q_o'' = 10^5$ W/m^2.

10) A pressure vessel for a nuclear reactor is approximated as a large flat plate of thickness L. The inside surface of the plate at x = 0 is insulated, the outside surface at x = L is maintained at a uniform temperature T_2, and the gamma-ray heating of the plate can be represented as a heat generation term in the form

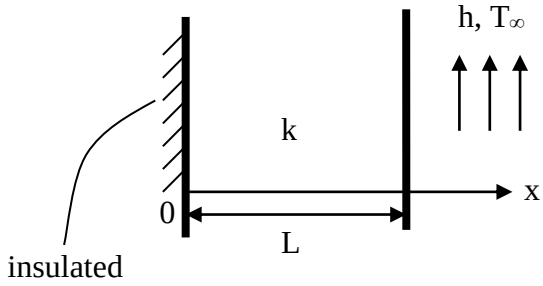
$$\dot{q}(x) = g_0 e^{-\gamma x} \text{ W/m}^3$$

where g_0 and γ are constants



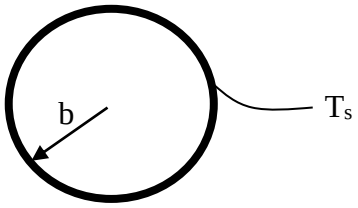
a) develop an expression for temperature distribution in the plate
b) develop an expression for the temperature at x = 0 of the plate
c) develop an expression for heat flux at the outer surface

11) Consider a slab of thickness L and constant thermal conductivity k in which energy is generated at a constant rate of $\dot{q}\left(W/m^3\right)$.

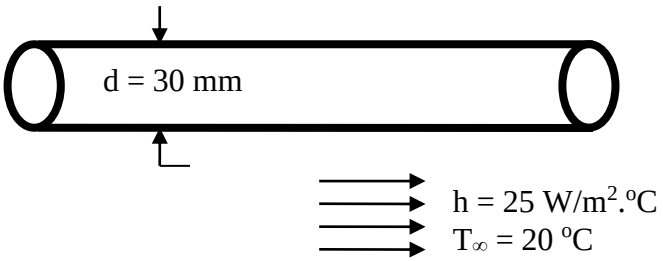


The boundary at x = 0 is insulated and that x = L dissipates heat by convection with a heat transfer coefficient h into a fluid at a temperature T_∞. Develop expressions for temperature T (x) and heat flux $q''(x)$ in the slab. Calculate temperatures at x = 0 and x = L under the following conditions. L = 1 cm, k = 20 W/m.K, $\dot{q} = 8\times10^7\ W/m^3$, h = 4000 W/m.^{o}C, T_∞ = 100 ^{o}C.

12) Consider a solid cylinder of radius r = b in which energy is generated at a constant rate of g_o (W/m^3), while the boundary surface at r = b is maintained at constant temperature T_s. Develop an expression for one dimensional, radial, steady state temperature distribution T(r) and heat flux $q''(r)$. Calculate the center temperature T(0) and the heat flux at the boundary surface r = b for b = 1 cm, $g_o = 2\times10^8\ W/m^3$, k = 20 W/m.^{o}C, T_s = 100 ^{o}C.

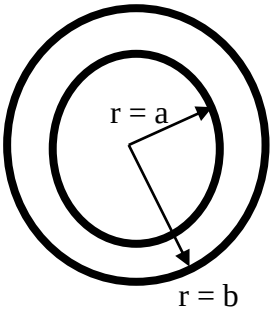


13) 250 A current flows through a copper cable (as shown in the figure) exposed to convective air.



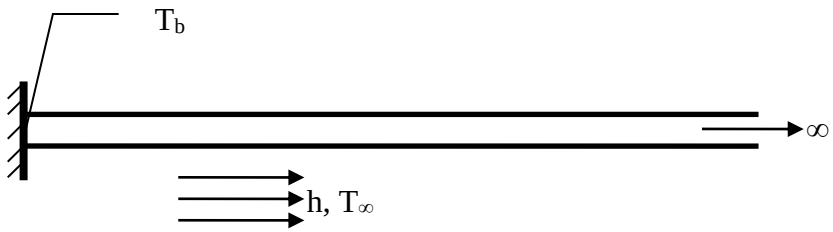
a) Find maximum temperature in the wire
b) Find surface of temperature in the wire

14) Develop an expression for the steady state temperature distribution T (r) in a long, hollow cylinder, a ≤ r ≤ b, in which heat generation at a rate of $\dot{q}(r) = g_o(1 + Ar)$ W/m^3 where g_o and A are constants, while the boundary surfaces at r = a and r = b are kept at zero temperatures.



r = a T = 0
r = b T = 0

15) A very long fin (k = 380 W/m.K) has a diameter of 25 mm. Fin extends from a surface at 120 ^{o}C. The temperature of the surrounding air is 25 ^{o}C and the heat transfer coefficient over the rod is 10 W/m^2.K. Calculate:
a) heat loss from the rod
b) how long the rod should be in order to be considered infinite?



16) A steel rod of diameter D = 2 cm, length L = 25 cm, and thermal conductivity k = 50 W/m.^{o}C is exposed to ambient air at T_∞ = 20 ^{o}C with a heat transfer coefficient h = 64 W/m^2.^{o}C. If one end of the rod is at temperature of 120 ^{o}C, calculate heat loss from the fin.

17) Consider a stainless steel spoon (k = 15.1 W/m.K) partially immersed in boiling water at 95 ^{o}C in a kitchen at 25 ^{o}C. The handle of the spoon has a cross section 0.2 cm x 1 cm and it extends 18 cm in the air from the free surface of water. If the local heat transfer on the exposed surface of spoon is 15 W/m^2.K, calculate the temperature difference across exposed surface of the spoon handle. State your assumptions, if any.