Heat Transfer and Industrial Furnaces (Code: MEP293)

1. **Consider a flat plate solar collector placed at the roof of a house. The temperatures at the inner and outer surfaces of glass cover are measured to be 28°C and 25°C, respectively. The glass cover has a surface area of $2.2\ m^2$ and a thickness of 0.6 cm and a thermal conductivity of $0.7\ W/m\,.\,°C$. Heat is lost from the outer surface of the cover by convection and radiation with a convection heat transfer coefficient of $10\ W/m^2\,.\,°C$ and an ambient temperature of 15°C. Determine the fraction of heat lost from the glass cover by radiation.**

2. **Air at 120°C flows over the top of a large horizontal 5-cm-thick stainless steel plate whose upper surface is maintained at 250°C. The convective-heat-transfer coefficient is $30\ W/m^2°C$. The upper surface of the plate loses $700\ W/m^2$ by radiation to the air. Determine the steady temperature of the lower surface of the plate.**

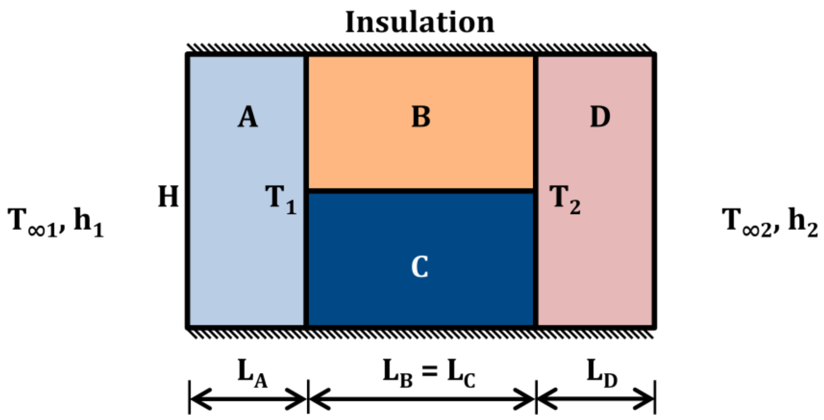
3. **A large window glass $L = 0.5$ cm thick with thermal conductivity $k = 0.78\ W/m.°C$ is exposed to warm air at $T_{\infty,i} = 25°C$ over its inner surface, and the heat transfer coefficient for the inside air is $h_i = 15\ W/m^2.°C$. The outside air is at $T_{\infty,o} = -15°C$, and the heat transfer coefficient associated with the outside surface is $h_o = 50\ W/m^2.°C$. What are the temperatures of the inner and outer surfaces of the glass?**

4. **Consider a 0.8 m high and 1.5 m wide double-pane window consisting of two 4 mm thick layers of glass ($k = 0.78\ W/m\,.\,°C$) separated by a 10 mm wide stagnant air space ($k = 0.026\ W/m\,.\,°C$). Determine the steady rate of heat transfer through this double-pane window and the temperature of its inner surface for a day during which the room is maintained at 20°C while the temperature of the outdoors is $-10°C$. Take the convection heat transfer coefficients on the inner and outer surfaces of the window to be $h_1 = 10\ W/m^2\,.\,°C$ and $h_2 = 40\ W/m^2\,.\,°C$, which includes the effects of radiation.**

5. **The wall of a refrigerator is constructed of fiberglass insulation ($k = 0.035\ W/m\,.\,°C$) sandwiched between two layers of 1 mm thick sheet metal ($k = 15.1\ W/m°C$). The refrigerated space is maintained at 3°C, and the average heat transfer coefficients at the inner and outer surfaces of the wall are $4\ W/m^2\,.\,°C$ and $9\ W/m^2\,.\,°C$, respectively. The kitchen temperature averages 25°C. It is observed that condensation occurs on the outer surfaces of the refrigerator when the temperature of the outer surface drops to 20°C. Determine the minimum thickness of fiberglass insulation that needs to be used in the wall in order to avoid condensation on the outer surfaces.**

6. **A square plate heater (15 cm x 15 cm) is inserted between two slabs. Slab A is 2 cm thick ($k = 50\ W/m\,.\,°C$) and slab B is 1 cm thick ($k = 0.2\ W/m\,.\,°C$). The outside heat transfer coefficients on side A and B are $200\ W/m^2\,.\,°C$ and $50\ W/m^2\,.\,°C$, respectively. The temperature of surrounding air is 25°C. If rating of heater is 1 kW, find: (a) maximum temperature in the system, (b) outer surface temperature of two slabs and (c) draw an equivalent electrical circuit.**

7. A composite wall of height H and unit length normal to the page is insulated at its ends and is comprised of four different materials, arranged as shown in the diagram.



a) Sketch the thermal circuit of the system.

b) Consider a wall for which $H_A = H_D = 3$ m, $H_B = H_C = 1.5$ m, $L_A = L_D = 0.05$ m, $L_B = L_C = 0.10$ m. $k_A = k_D = 50$ W/m.°C, $k_B = 10$ W/m.°C, and $k_C = 1$ W/m.°C, under conditions for which $T_{\infty1} = 200$, $h_1 = 50$ W/m^2.°C, $T_{\infty2} = 25$°C and $h_2 = 10$ W/m^2.°C. What is the rate of heat transfer through the wall? What are the interface temperatures, T_1 and T_2?

8. A cylindrical insulation for a steam pipe has an inside radius $r_1 = 6$ cm, outside radius $r_2 = 8$ cm, and a thermal conductivity $k = 0.5$ W/m.°C. The inside surface of the insulation is at a temperature $T_1 = 430$°C, and the outside surface at $T_2 = 30$°C. Determine the heat loss per 1-m length of this insulation.

9. A circular duct carries hot combustion gases from a furnace. The duct has a temperature of 500°C and an outside diameter of 0.5 m. Determine the thickness of insulation ($k = 0.05$ W/m.K) that is necessary to reduce the outside surface of the insulation to a level that would not injure anyone who touches the surface. The gases have a specific heat of 1000 J/kg.K, a flow rate of 1.0 kg/s and experience a temperature drop of 10°C over a duct length of 40 cm. Assume that the thermal resistance of the duct is small compared to that of the insulation and that the highest temperature that one could be subjected to without injury is 69°C.

10. Steam at 320°C flows in a stainless steel pipe ($k = 15$ W/m.°C) whose inner and outer diameters are 5 cm and 5.5 cm, respectively. The pipe is covered with 3 cm thick glass wool insulation ($k = 0.038$ W/m.°C). Heat is lost to the surroundings at 5°C by natural convection and radiation, with a combined natural convection and radiation heat transfer coefficient of 15 W/m^2.°C. Taking the heat transfer coefficient inside the pipe to be 80 W/m^2.°C, determine the rate of heat loss from the steam per unit length of the pipe. Also determine the temperature drops across the pipe shell and the insulation.

11. Consider an aluminum hollow sphere of inside radius $r_1 = 2$ cm, and outside radius $r_2 = 6$ cm, and thermal conductivity $k = 200$ W/(m.°C). The inside surface is kept at a uniform temperature $T_1 = 100$°C, and the outside surface dissipates heat by convection with a heat transfer coefficient $h_\infty = 80$ W/(m^2.°C) into the ambient air at temperature $T_\infty = 20$°C. Determine the outside surface temperature of the sphere and the rate of heat transfer from the sphere.