CASE WESTERN RESERVE UNIVERSITY
Case School of Engineering

ECHE 225: Fall 2024

Homework #11: Heat transfer, steady-state conduction

Due: November 21

1. [Chapter 17] Consider a person standing in a room at 20°C with an exposed surface area of 1.5 m^2. The deep body temperature of the human body is 37°C and the thermal conductivity of human tissue is about 0.3 W/m·K. The body is losing heat a rate of 180 W by natural convection and radiation to the surroundings. Taking the body temprature 0.5 cm beneath the skin to be 37°C, determine the skin temperature of the person.

2. [Chapter 17] Consider a 1.2-m-high and 2-m-wide double-pane window consisting of two 3-mm-thick layers of glass (k=0.78 W/m·K) separated by a 12-mm-wide stagnant air space (k=0.026 W/m·K). 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 22°C while the temperature of the outdoors is -8°C. Take the convection heat transfer coefficients on the inner and outer surfaces to be $h_i = 15$ W/m^{2}K and $h_o = 30$ W/m^{2}K and disregard any heat transfer by radiation.

3. [Chapter 17] Clothing made of several thin layers of fabric with trapped air in between, often called ski clothing, is commonly used in cold climates because it is light, fashionable, and a very effective thermal insulator. So it is no surprise that such clothing has largely replaced thick and heavy old-fashioned coats. Consider a jacket of four layers of 0.1-mm-thick synthetic fabric (k=0.13 W/m·K) and 2 mm thick air (k=0.026 W/m·K) between each of the layers. Assuming the inner surface temperature of the jacket to be 30°C and the surface area to be 1.25 m^2, determine the rate of heat loss through the jacket when the temperature of the outdoors is 4°C. What would your response be if the jacket is made of a single layer of 0.4-mm-thick sythetic fabric? What should be the thickness of wool fabric (k=0.035 W/m·K) if the person is to achieve the same level of thermal comfort wearing a thick wool coat instead of a 4-layer ski jacket?

4. [Chapter 17] A typical section of a building wall extends in and out of the page and is repeated in the vertical direction. The wall support members are made of steel (k=50 W/m·K). The support members are 8 cm (t_{23}) x 0.5 cm (L_B). The remainder of the inner wall space is filled with insulation (k=0.03 W/m·K) and measures 8 cm (t_{23}) x 60 cm (L_A). The inner wall is made of gypsum board (k=0.5 W/m·K) that is 1 cm thick (t_{12}) and the outer wall is made of brick (k=1.0 W/m·K) that is 10 cm thick (t_{34}). What is the average heat flux through this wall when $T_1 = 20°$C and $T_4 = 35°$C?

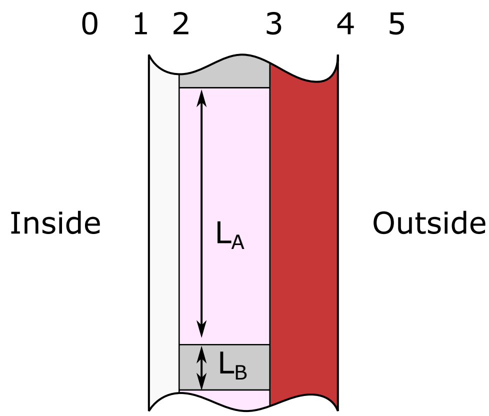

Figure 1: Schematic for Problem 4

5. [Chapter 17] A 9-mm-diameter spherical ball at 50°C is covered by a 1-mm-thick plastic insulation (k=0.13 W/m·K). The ball is exposed to a medium at 15°C with a combined convection and radiation heat transfer coefficient of 20 W/m^2·K. Determine if the plastic insulation on the ball will increase or decrease heat transfer from the ball.

Answers

1. 35°C
2. 126 W, 18.5 °C
3. 139 W, 10600 W, 8.18 mm
4. 50 W/m^2
5. Insulation will increase heat transfer (0.18 W without insulation, 0.22 W with insulation)