

Pertemuan ke-3

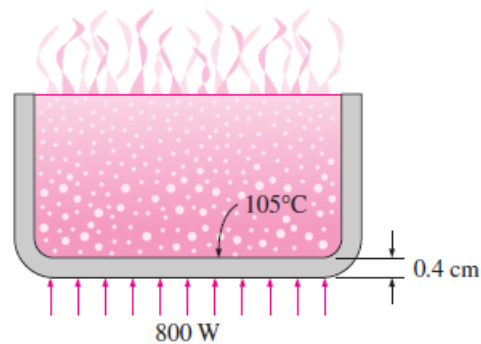
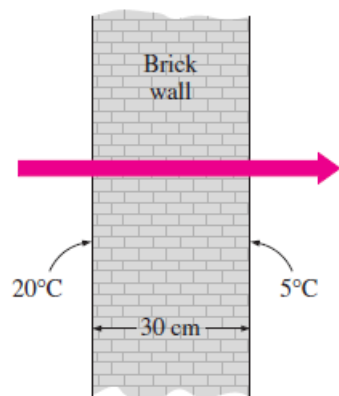
Operasi Perpindahan Kalor

Tutorial Problems

P1 The inner and outer surfaces of a 5-m \times 6-m brick wall of thickness 30 cm and thermal conductivity $0.69 \text{ W/m} \cdot ^\circ\text{C}$ are maintained at temperatures of 20°C and 5°C , respectively. Determine the rate of heat transfer through the wall, in W.

P2 The inner and outer surfaces of a 0.5-cm-thick 2-m \times 2-m window glass in winter are 10°C and 3°C , respectively. If the thermal conductivity of the glass is $0.78 \text{ W/m} \cdot ^\circ\text{C}$, determine the amount of heat loss, in kJ, through the glass over a period of 5 hours. What would your answer be if the glass were 1 cm thick?

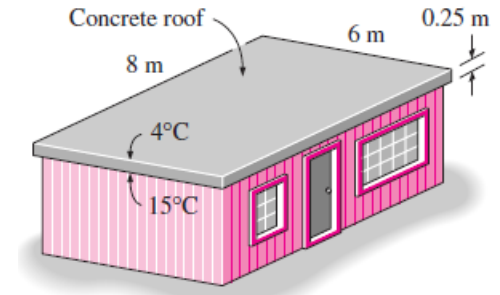
P3 An aluminum pan whose thermal conductivity is $237 \text{ W/m} \cdot ^\circ\text{C}$ has a flat bottom with diameter 20 cm and thickness 0.4 cm. Heat is transferred steadily to boiling water in the pan through its bottom at a rate of 800 W. If the inner surface of the bottom of the pan is at 105°C , determine the temperature of the outer surface of the bottom of the pan.



Tutorial Problems Contd..

P4

The roof of an electrically heated home is 6 m long, 8 m wide, and 0.25 m thick, and is made of a flat layer of concrete whose thermal conductivity is $k = 0.8 \text{ W/m} \cdot ^\circ\text{C}$. The temperatures of the inner and the outer surfaces of the roof one night are measured to be 15°C and 4°C , respectively, for a period of 10 hours. Determine (a) the rate of heat loss through the roof that night and (b) the cost of that heat loss to the home owner if the cost of electricity is $\$0.08/\text{kWh}$.

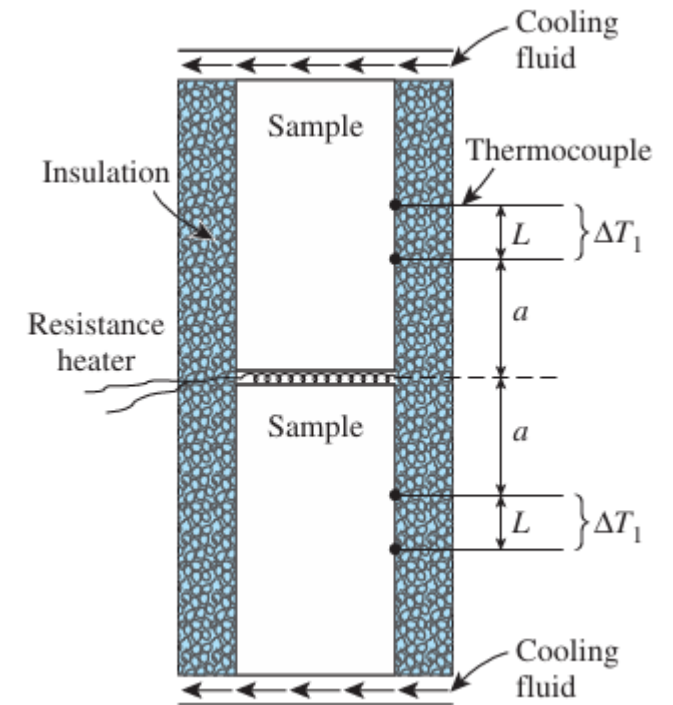


Tutorial Problem

P5. The north wall of an electrically heated home is 20 ft long, 10 ft high, and 1 ft thick, and is made of brick whose thermal conductivity is $k = 0.42 \text{ Btu/h}\cdot\text{ft}\cdot^\circ\text{F}$. On a certain winter night, the temperatures of the inner and the outer surfaces of the wall are measured to be about 62°F and 25°F , respectively, for a period of 8 h. Determine (a) the rate of heat loss through the wall that night and (b) the cost of that heat loss to the home owner if the cost of electricity is $\$0.07/\text{kWh}$.

Tutorial Problem

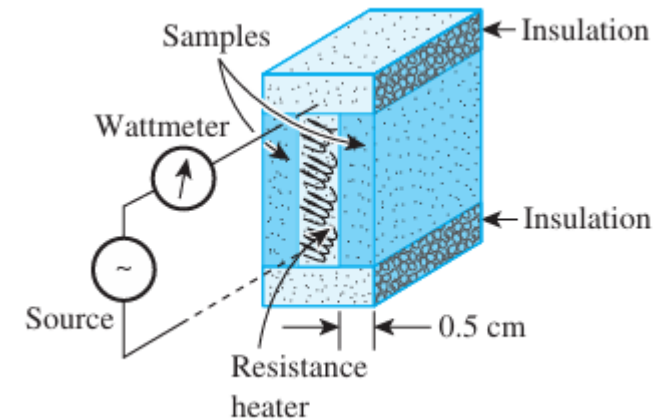
P6. In a certain experiment, cylindrical samples of diameter 4 cm and length 7 cm are used. The two thermocouples in each sample are placed 3 cm apart. After initial transients, the electric heater is observed to draw 0.6 A at 110 V, and both differential thermometers read a temperature difference of 8°C . Determine the thermal conductivity of the sample.



Tutorial Problem

P7. One way of measuring the thermal conductivity of a material is to sandwich an electric thermofoil heater between two identical rectangular samples of the material and to heavily insulate the four outer edges, as shown in the figure. Thermocouples attached to the inner and outer surfaces of the samples record the temperatures.

During an experiment, two 0.5-cm thick samples $10\text{ cm} \times 10\text{ cm}$ in size are used. When steady operation is reached, the heater is observed to draw 25 W of electric power, and the temperature of each sample is observed to drop from 82°C at the inner surface to 74°C at the outer surface. Determine the thermal conductivity of the material.



Tutorial Problem

P8. A thick-walled cylindrical tubing made of hard rubber, having an inside radius of 5 mm and an outside radius of 20 mm, is used as a temporary cooling coil in a bath. Ice water flows rapidly inside the tubing, and the temperature of the inner wall is 274.9 K. The temperature of the outer surface is 297.1 K. A total of 14.65 W of heat must be removed from the bath by the cooling coil. Determine the length of tubing required.

Tutorial Problem

P9. A cold-storage room is constructed with an inner layer of 12.7 mm of pine, a middle layer of 101.6 mm of cork board, and an outer layer of 76.2 mm of concrete. The temperature at the inner surface of the wall is 255.4 K, while the temperature at the outer surface of the concrete is 297.1 K.

Use the following thermal conductivities (from Appendix A.3 Geankoplis):

- Pine: 0.151 W/m·K
- Cork board: 0.0433 W/m·K
- Concrete: 0.762 W/m·K

Calculate:

- The heat loss (in W) through 1 m² of wall area
- The temperature at the interface between the pine (wood) and the cork board

Tutorial Problem

P 10. A thick-walled tube made of stainless steel (A) with a thermal conductivity $k = 21.63 \text{ W/m.K}$ has an inner diameter of 0.0254 m and an outer diameter of 0.0508 m. The tube is covered with a 0.0254 m thick layer of asbestos insulation (B) with a thermal conductivity $k = 0.2423 \text{ W/m.K}$.

The temperature at the inner wall of the pipe is 811 K, and the temperature at the outer surface of the insulation is 310.8 K.

For a pipe length of 0.305 m, determine:

- The heat loss (W) from the pipe
- The temperature at the interface between the metal and the insulation

Tutorial Problem

P 11. A thick-walled stainless steel tube (A) with a thermal conductivity $k = 21.63 \text{ W/m}\cdot\text{K}$ has an inner diameter of 0.0254 m and an outer diameter of 0.0508 m. The tube is covered with an asbestos insulation layer (B) of thickness 0.0254 m, with a thermal conductivity $k = 0.2423 \text{ W/m}\cdot\text{K}$.

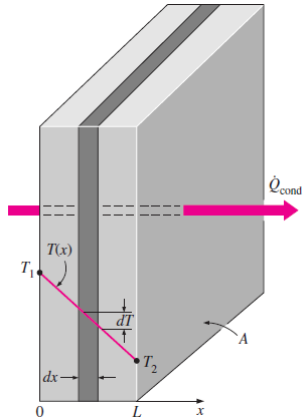
- The temperature at the inner wall of the pipe is 811 K, while the temperature at the outer surface of the insulation is 310.8 K.
- For a pipe length of 0.305 m, determine:
- The rate of heat loss (in W)
- The temperature at the interface between the metal pipe and the insulation

Measurement of Average Properties

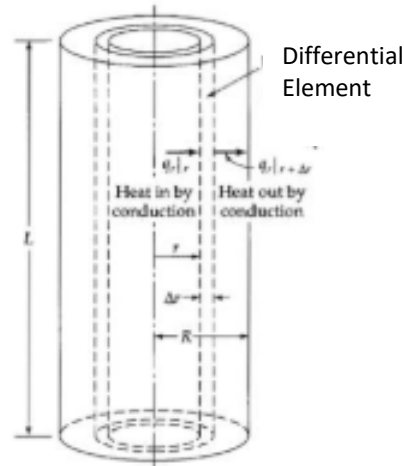
- ❖ When thermal conductivity varies significantly with temperature within the specified temperature range

$$k_{\text{ave}} = \frac{\int_{T_1}^{T_2} k(T) dT}{T_2 - T_1}$$

- ❖ For measuring average temperature,



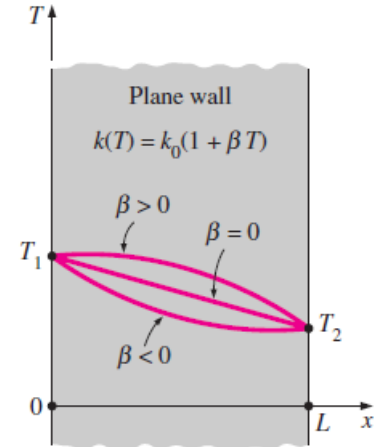
Heat Conduction in Single Wall



Heat Conduction through Solid Cylinder

$$\dot{Q}_{\text{plane wall}} = k_{\text{ave}} A \frac{T_1 - T_2}{L} = \frac{A}{L} \int_{T_2}^{T_1} k(T) dT$$

$$\dot{Q}_{\text{cylinder}} = 2\pi k_{\text{ave}} L \frac{T_1 - T_2}{\ln(r_2/r_1)} = \frac{2\pi L}{\ln(r_2/r_1)} \int_{T_2}^{T_1} k(T) dT$$



Variation of Temperature in Plane Wall

Steady State Conduction in 1D through Variable Area: Sphere

❖ Assumptions

- Steady state heat flow
- Thermal conductivity is NOT a function of temperature

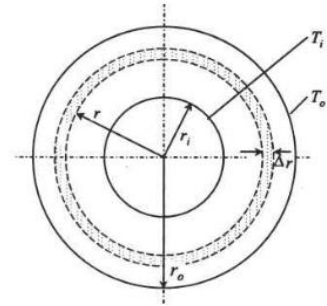
For heat conduction in hollow sphere (without heat generation),

$$\dot{Q} = k(4\pi r_i r_o) \frac{T_i - T_o}{r_o - r_i}$$

For heat generation in solid sphere,

$$T = T_o + \frac{\psi_v}{6k} (r_o^2 - r^2)$$

$$T_{\max} = T_o + \frac{\psi_v r_o^2}{6k}$$



Heat Conduction through Hollow Sphere

THANK YOU