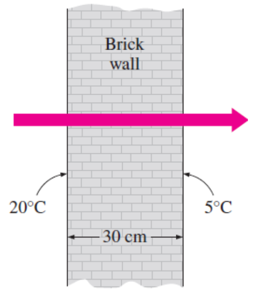
In-Class Exercise n°01

| *Basics of Heat Transfer* |

Exercise 1.1

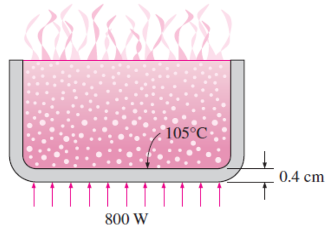
The inner and outer surfaces of a **4-m x 7-m** brick wall of thickness **30 cm** and thermal conductivity **0.69 W/m·K** are maintained at temperatures of **20°C** and **5°C**, respectively. Determine the rate of heat transfer through the wall, in **W**.



(Figure 1–1)

Exercise 1.2

An aluminium pan whose thermal conductivity is **237 W/m·°C** has a flat bottom with diameter **15 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.



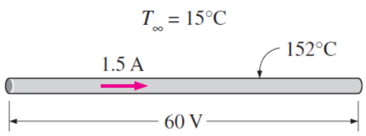
(Figure 1–2)

Exercise 1.3

A **5-cm-external-diameter**, **10-m-long** hot-water pipe at **80°C** is losing heat to the surrounding air at **5°C** by natural convection with a heat transfer coefficient of **25 W/m^2·°C**. Determine the rate of heat loss from the pipe by natural convection.

Exercise 1.4

A **2-m-long**, **0.3-cm-diameter** electrical wire extends across a room at **15°C**, as shown in **Fig. 1–3**. Heat is generated in the wire as a result of resistance heating, and the surface temperature of the wire is measured to be **152°C** in steady operation. Also, the voltage drop and electric current through the wire are measured to be **60 V** and **1.5 A**, respectively. Disregarding any heat transfer by radiation, determine the convection heat transfer coefficient for heat transfer between the outer surface of the wire and the air in the room.



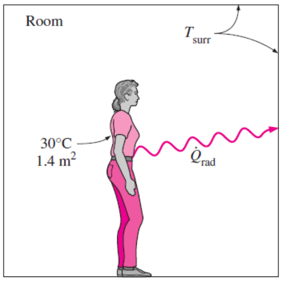
(Figure 1–3)

Exercise 1.5

Using the conversion factors between **W** and **Btu/h**, **m** and **ft**, and **K** and **R**, express the Stefan–Boltzmann constant **σ = 5.67 x 10^{-8} W/m^2·K^4** in the English unit **Btu/h · ft^2·R^4**.

Exercise 1.6

Consider a person standing in a room maintained at **22°C** at all times. The inner surfaces of the walls, floors, and the ceiling of the house are observed to be at an average temperature of **10°C** in winter and **25°C** in summer. Determine the rate of radiation heat transfer between this person and the surrounding surfaces if the exposed surface area and the average outer surface temperature of the person are **1.4 m²** and **30°C**, respectively (**Fig. 1–4**).

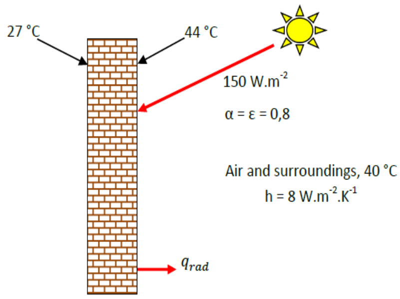


(Figure 1–4)

Exercise 1.7

The inner and outer surfaces of a **25-cm-thick** wall in summer are at **27°C** and **44°C**, respectively. The outer surface of the wall exchanges heat by radiation with surrounding surfaces at **40°C**, and convection with ambient air also at **40°C** with a convection heat transfer coefficient of **8 W/m²·°C**. Solar radiation is incident on the surface at a rate of **150 W/m²**.

If both the emissivity and the solar absorptivity of the outer surface are **0.8**, determine the effective thermal conductivity of the wall.



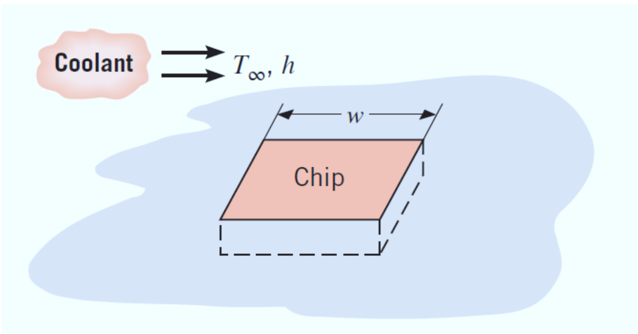
(Figure 1–5)

Exercise 1.8

The heat flux through a wood slab **50 mm** thick, whose inner and outer surface temperatures are **40** and **20°C**, respectively, has been determined to be **40 W/m²**. What is the thermal conductivity of the wood?

Exercise 1.9

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; the front surface is exposed to the flow of a coolant at **T_∞ = 15°C**. From reliability considerations, the chip temperature must not exceed **T = 85°C**.



(Figure 1–6)

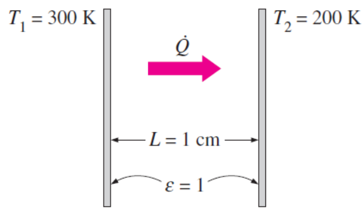
- If the coolant is air and the corresponding convection coefficient is **h = 200 W/m²·K**, what is the maximum allowable chip power?
- If the coolant is a dielectric liquid for which **h = 3000 W/m²·K**, what is the maximum allowable power

Exercise 1.10

The inner and outer surfaces of a **0.5-cm thick 2-m x 2-m** window glass in winter are **10°C** and **3°C**, respectively. If the thermal conductivity of the glass is **0.78 W/m·K**, determine the amount of heat loss through the glass over a period of **5 h**. What would your answer be if the glass were **1 cm** thick?

Exercise 1.11

Consider steady heat transfer between two large parallel plates at constant temperatures of **T_1 = 300 K** and **T_2 = 200 K** that are **L = 1 cm** apart, as shown in **Fig. 1–7**. Assuming the surfaces to be black (**emissivity ε = 1**), determine the rate of heat transfer between the plates per unit surface area assuming the gap between the plates is



(Figure 1–7)

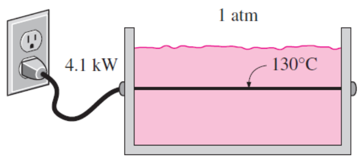
a) filled with atmospheric air (**k = 0.0219 W/m·K**),
b) evacuated,
c) filled with urethane insulation (**k = 0.026 W/m·K**), and
d) filled with superinsulation that has an apparent thermal conductivity of **0.00002 W/m·K**.

Exercise 1.12

A **5-cm-diameter** spherical ball whose surface is maintained at a temperature of **70°C** is suspended in the middle of a room at **20°C**. If the convection heat transfer coefficient is **15 $W/m^2·°C$** and the emissivity of the surface is **0.8**, determine the total rate of heat transfer from the ball.

Exercise 1.13

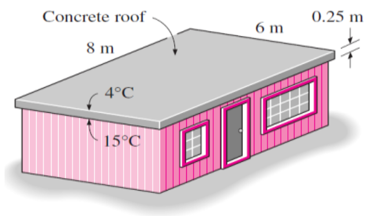
A **50-cm-long**, **2-mm-diameter** electric resistance wire submerged in water is used to determine the boiling heat transfer coefficient in water at **1 atm** experimentally. The wire temperature is measured to be **130°C** when a wattmeter the electric power consumed to be **4.1 kW**. Using Newton's law of cooling, determine the boiling heat transfer coefficient.



(Figure 1–8)

Exercise 1.14

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 W/m·°C** (**Fig. 1–9**). 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



(Figure 1–9)

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/kWh**.