Chapter 16 Problem 68 [†]

Given

$A = 4.6\ m^2$
$\Delta x = 4.0\ mm = 0.0040\ m$
$T_i = 650\ °C$
$T_o = 647\ °C$

Solution

a) What is the rate of heat conduction through the walls of the stove?

Since stove is made out of cast iron, the conductivity is $80.4\ W/m \cdot K$. Using the conductive heat flow equation gives

$$H = -kA\frac{\Delta T}{\Delta x} = -(80.4\ W/m \cdot K)(4.6\ m^2)\frac{647\ °C - 650\ °C}{0.0040\ m} = 277,000\ W = 277\ kW$$

b) What is the rate of heat loss by radiation?

The temperature of the outside of the stove in kelvin is

$$T_o = 647\ °C + 273 = 920\ K$$

Assuming the stove has an emissivity of 1 and using Stefan-Boltzmann's equation gives

$$P = \epsilon\sigma AT^4 = (5.67 \times 10^{-8}\ W/m^2 \cdot T^4)(4.6\ m^2)(920\ K)^4 = 187,000\ W = 187\ kW$$

c) How much heat is lost by conduction and convection to the surrounding air?

The difference between heat flow through the wall of the stove and the amount radiated is the amount lost by the other two mechanisms of heat transfer. Therefore conduction and convection combined have a heat flow rate of

$$277,000\ W - 187,000\ W = 90,000\ W = 90\ kW$$

[†]Problem from Essential University Physics, Wolfson