Problem 1.9.1

Rate of energy in (by cold air) – Rate of Energy out (by warmer air) + Rate of energy generation
= Rate of change in energy storage

Rate of energy in (by cold air)
\[(2.5m \times 1m)u_{air} \rho_{air} c_{p,air} (T_{in} - 0)\]

Rate of energy out (by cold air)
\[(2.5m \times 1m)u_{air} \rho_{air} c_{p,air} (T_{room} - 0)\]

Rate of energy generation (metabolic heat generation of the occupants)
= 60 W/person * 70 person

Rate of energy storage
= 0 (steady state)

Plugging in the energy balance equation above,
\[(2.5m \times 1m)u_{air} \rho_{air} c_{p,air} (T_{in} - 0) - (2.5m \times 1m)u_{air} \rho_{air} c_{p,air} (T_{room} - 0) + 60 \times 70 = 0\]

\[(2.5m \times 1m)0.1 \frac{m}{s} \times 1.1769 \frac{kg}{m^3} \times 1006 \frac{J}{kgK} \times (25 - 0)\]

\[-(2.5m \times 1m)0.1 \frac{m}{s} \times 1.1769 \frac{kg}{m^3} \times 1006 \frac{J}{kgK} \times (T_{room} - 0) + 60 \times 70W = 0\]

From which we get \(T_{room} = 39.19^\circ C\)

We do not require the dimensions of the room since at steady state the energy content of the room is not changing. We would need the dimensions if the problem is unsteady, i.e., the temperature and therefore the amount of energy in the room is changing.
**Problem 1.9.4**

**Given:** Mass of player, surface area, speed of running, air and wall temperature, convective heat transfer coefficient

**Find:** Heat balance, body surface temperature, effective heat transfer coefficient

**Schematic**

\[ m = 80 \text{ kg} \]
\[ H = 180 \text{ cm} \]
\[ A = 2 \text{ m}^2 \]
\[ v = 1.2 \text{ m/s} \]
\[ T_\infty = T_w = 20^\circ \text{ C} \]
\[ h = 20 \text{ W/m}^2 \cdot \text{K} \]
\[ h_{evap} = 0.124 \sqrt{v} \]
\[ = 0.124 \sqrt{1.2} = 0.136 \text{ W/m}^2\text{K} \cdot \text{Pa} \]

**Solution**

a) \[ \text{In – out + generation = storage} \]
\[ \Delta t \left( 4mv - h \cdot A \cdot (T_s - T_\infty) - \sigma A (T_s^4 - T_w^4) - h_{evap} \cdot A \cdot p_s \right) = m c_p \Delta T \]
\[ 4mv - hA(T_s - T_\infty) - \sigma A(T_s^4 - T_w^4) - h_{evap} \cdot A \cdot p_s = m c_p \frac{\Delta T}{\Delta t} \]
\[ \Delta t \to 0 \]
\[ 4mv - hA(T_s - T_\infty) - \sigma A(T_s^4 - T_w^4) - h_{evap} \cdot A \cdot p_s = m c_p \frac{dT}{dt} \]

b) Steady state \[ \frac{dT}{dt} = 0 \]
\[ 4mv - hA(T_s - T_\infty) - \sigma A(T_s^4 - T_w^4) - h_{evap} \cdot A \cdot 13.33e^{20.386-5132/T_s} = 0 \]
Problem 1.9.4

Alternate answer: since at steady state, \( q \) (total loss) = \( q \) (total gain)

\[
q \text{ (total loss)} = 4mv = 4(80)(1.2) = 384 \text{W}
\]

c) \( q \) (total loss) = \( hA(T_s - T_w) + \sigma A(T_s^4 - T_w^4) + h_{\text{evap}} \cdot A \cdot 13.33e^{20.386-5132/T_s} \)

\[
= (20)(2)(298.7 - 293) + (5.67 \cdot 10^{-8})(2)(298.7^4 - 293^4) + (0.136)(2)(13.33e^{20.386-5132/298.7})
\]

\[
= 384 \text{W}
\]

\( q \) (total loss) = \( \text{heff} \cdot A(T_s - T_w) \)

\[
\text{heff} = \frac{q \text{ (total loss)}}{A \cdot (T_s - T_w)} = \frac{384}{2(298.7 - 293)} = 33.7 \text{ W/m}^2 \cdot \text{K}
\]
Problem 2.7.2

KNOWN: Temperature of body and chair. Chair dimensions and thermal properties.

FIND: Determine the conductive heat flux from the body.

SCHEMATIC AND GIVEN DATA

STRATEGY:

ASSUMPTIONS:

(1) Steady-state 1-D heat transfer
(2) Thermal properties constant
(3) Temperature profile described by a linear approximation
(4) The chair surface immediately equilibrates to 33°C while other side is maintained at 20°C.

SOLUTION:

\[ q'' = -k \frac{\Delta T}{\Delta x} \]
\[ = -\left(0.208 \frac{W}{mK}\right) \left(\frac{20-33}{2.54\times10^{-2} \ m}\right) \]
\[ = 106.46 \ W/m^2 \]

COMMENTS: