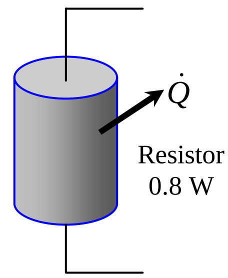
Chapter 1, Solution 12.

A cylindrical resistor on a circuit board dissipates 0.8 W of power. The amount of heat dissipated in 24 h, the heat flux, and the fraction of heat dissipated from the top and bottom surfaces are to be determined.

Assumptions Heat is transferred uniformly from all surfaces.

Analysis (*a*) The amount of heat this resistor dissipates during a 24-hour period is



$$Q = \dot{Q}\Delta t = (0.8 \text{ W})(24 \text{ h}) = \mathbf{19.2\ Wh = 69.1\ kJ} \quad \text{(since 1 Wh = 3600 Ws = 3.6 kJ)}$$

(*b*) The heat flux on the surface of the resistor is

$$A_s = 2\frac{\pi D^2}{4} + \pi DL = 2\frac{\pi(0.4\,\text{cm})^2}{4} + \pi(0.4\,\text{cm})(2\,\text{cm}) = 0.251 + 2.513 = 2.764\,\text{cm}^2$$

$$\dot{q}_s = \frac{\dot{Q}}{A_s} = \frac{0.80\text{ W}}{2.764\,\text{cm}^2} = \mathbf{0.289\ W/cm^2}$$

(*c*) Assuming the heat transfer coefficient to be uniform, heat transfer is proportional to the surface area. Then the fraction of heat dissipated from the top and bottom surfaces of the resistor becomes

$$\frac{Q_{\text{top-base}}}{Q_{\text{total}}} = \frac{A_{\text{top-base}}}{A_{\text{total}}} = \frac{0.251}{2.764} = \mathbf{0.091} \quad \text{or} \quad (9.1\%)$$

Discussion Heat transfer from the top and bottom surfaces is small relative to that transferred from the side surface.

Chapter 1, Solution 26.

A resistance heater is to raise the air temperature in the room from 7 to 25°C within 15 min. The required power rating of the resistance heater is to be determined.

Assumptions **1** Air is an ideal gas since it is at a high temperature and low pressure relative to its critical point values of -141°C and 3.77 MPa. **2** The kinetic and potential energy changes are negligible, $\Delta ke \cong \Delta pe \cong 0$. **3** Constant specific heats at room temperature can be used for air. This assumption results in negligible error in heating and air-conditioning applications. **4** Heat losses from the room are negligible.

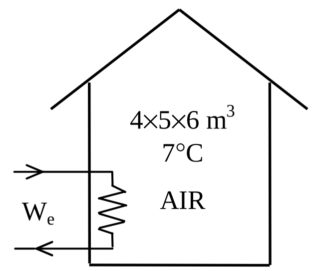
Properties The gas constant of air is R = 0.287 kPa·m^3/kg·K (Table A-1). Also, c_p = 1.007 kJ/kg·K for air at room temperature (Table A-15).

Analysis We observe that the pressure in the room remains constant during this process. Therefore, some air will leak out as the air expands. However, we can take the air to be a closed system by considering the air in the room to have undergone a constant pressure expansion process. The energy balance for this steady-flow system can be expressed as

$$\underbrace{E_{in} - E_{out}}_{\substack{\text{Net energy transfer}\\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{\text{system}}}_{\substack{\text{Change in internal, kinetic,}\\ \text{potential, etc. energies}}}$$

$$W_{e,in} - W_b = \Delta U$$

$$W_{e,in} = \Delta H = m(h_2 - h_1) \cong mc_p(T_2 - T_1)$$



or $$\dot{W}_{e,in}\Delta t = mc_{p,avg}(T_2 - T_1)$$

The mass of air is

$$V = 4\times5\times6 = 120\text{m}^3$$

$$m = \frac{P_1 V}{RT_1} = \frac{(100\text{kPa})(120\text{m}^3)}{(0.287\text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(280\text{K})} = 149.3\text{kg}$$

Using c_p value at room temperature, the power rating of the heater becomes

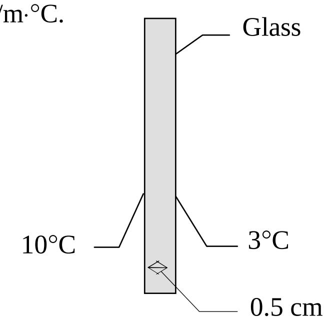
$$\dot{W}_{e,in} = (149.3\text{ kg})(1.007\text{ kJ/kg}\cdot°\text{C})(25-7)^\circ\text{C}/(15\times60\text{ s}) = \mathbf{3.01\ kW}$$

Chapter 1, Solution 56.

The inner and outer surfaces of a window glass are maintained at specified temperatures. The amount of heat transfer through the glass in 5 h is to be determined.

Assumptions **1** Steady operating conditions exist since the surface temperatures of the glass remain constant at the specified values. **2** Thermal properties of the glass are constant.

Properties The thermal conductivity of the glass is given to be k = 0.78 W/m·°C.



Analysis Under steady conditions, the rate of heat transfer through the glass by conduction is

$$\dot{Q}_{\text{cond}} = kA\frac{\Delta T}{L} = (0.78\ \text{W/m}\cdot{}^\circ\text{C})(2\times 2\ \text{m}^2)\frac{(10-3)^\circ\text{C}}{0.005\text{m}} = 4368\ \text{W}$$

Then the amount of heat transfer over a period of 5 h becomes

$$Q = \dot{Q}_{\text{cond}}\Delta t = (4.368\ \text{kJ/s})(5\times 3600\ \text{s}) = \mathbf{78{,}620\ \ kJ}$$

If the thickness of the glass doubled to 1 cm, then the amount of heat transfer will go down by half to **39,310 kJ**.

Chapter 1, Solution 64.

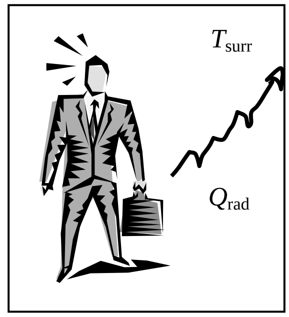
The rate of radiation heat transfer between a person and the surrounding surfaces at specified temperatures is to be determined in summer and in winter.

Assumptions **1** Steady operating conditions exist. **2** Heat transfer by convection is not considered. **3** The person is completely surrounded by the interior surfaces of the room. **4** The surrounding surfaces are at a uniform temperature.

Properties The emissivity of a person is given to be ε = 0.95

Analysis Noting that the person is completely enclosed by the surrounding surfaces, the net rates of radiation heat transfer from the body to the surrounding walls, ceiling, and the floor in both cases are:

(*a*) Summer: T_{surr} = 23+273=296



$$\begin{aligned}\dot{Q}_{\text{rad}} &= \varepsilon\sigma A_s (T_s^4 - T_{\text{surr}}^4) \\ &= (0.95)(5.67\times10^{-8}\ \text{W/m}^2.\text{K}^4)(1.6\,\text{m}^2)[(32+273)^4 - (296\,\text{K})^4]\text{K}^4 \\ &= \mathbf{84.2\ W}\end{aligned}$$

(*b*) Winter: T_{surr} = 12+273= 285 K

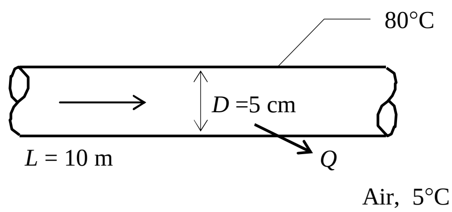
$$\begin{aligned}\dot{Q}_{\text{rad}} &= \varepsilon\sigma A_s (T_s^4 - T_{\text{surr}}^4) \\ &= (0.95)(5.67\times10^{-8}\ \text{W/m}^2.\text{K}^4)(1.6\,\text{m}^2)[(32+273)^4 - (285\,\text{K})^4]\text{K}^4 \\ &= \mathbf{177.2\ W}\end{aligned}$$

Discussion Note that the radiation heat transfer from the person more than doubles in winter.

Chapter 1, Solution 71.

A 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. The rate of heat loss from the pipe by convection is to be determined.

Assumptions **1** Steady operating conditions exist. **2** Heat transfer by radiation is not considered. **3** The convection heat transfer coefficient is constant and uniform over the surface.



Analysis The heat transfer surface area is

$$A_s = \pi DL = \pi(0.05\text{ m})(10\text{ m}) = 1.571\text{ m}^2$$

Under steady conditions, the rate of heat transfer by convection is

$$\dot{Q}_{\text{conv}} = hA_s\Delta T = (25\text{W/m}^2\cdot\text{°C})(1.571\text{ m}^2)(80-5)\text{°C} = \mathbf{2945\ W}$$