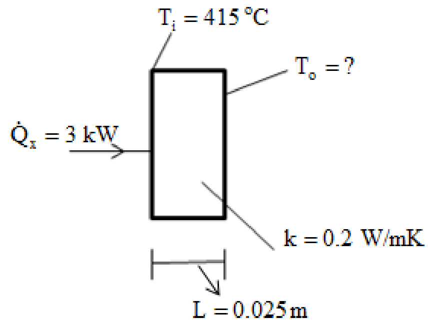
UNIT 1
TUTORIAL SET 1 (Pages 19-21)

Unit 1 Problem 1.



$$A_x = 10\,m^2$$

$$\dot{Q}_x = -kA_x \frac{dT}{dx}$$

$$\dot{Q}_x = \frac{-kA_x(T_o - T_i)}{L}$$

$$\dot{Q}_x = 3\,kW - 3000\text{ W}$$

$$A_x = 10\,m^2$$

$$\dot{Q}_x = \frac{kA_x(T_i - T_o)}{L}$$

Substituting values, we have

$$3000 = \frac{0.2 \times 10 \times (415 - T_o)}{0.025}$$

$$T_o = 415 - \left[\frac{0.025 \times 3000}{0.2 \times 10}\right]$$

$$T_o = 377.5\,^0C$$

Unit 1, Problem 2.

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 condition exists 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.

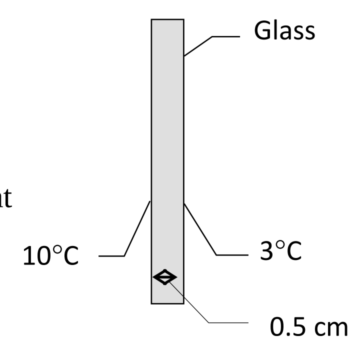
Analysis Under steady-state conditions, the rate of heat transfer through the glass by conduction is given b Fourier's law as:

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

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

$$Q = \dot{Q}_{cond}\Delta t = (4.368\text{ kJ/s})(5 \times 3600\text{ s}) = \mathbf{78{,}624\text{ kJ}}$$

If the thickness of the glass doubled to 1 cm, then the amount of heat transfer will go down by half to **39,312 kJ**.



Unit 1 Problem 3.

The total rate of heat transfer from a person by both convection and radiation to the surrounding air and surfaces at specified temperatures is to be determined.

Assumptions: **1** steady operating condition exists. **2** The person is completely surrounded by the interior surfaces of the room. **3** The surrounding surfaces are at the same temperature as the air in the room. **4** Heat conduction to the floor through the feet is negligible. **5** The convection coefficient is constant and uniform over the entire surface of the person.

Properties The emissivity of a person is given to be ε = 0.9.

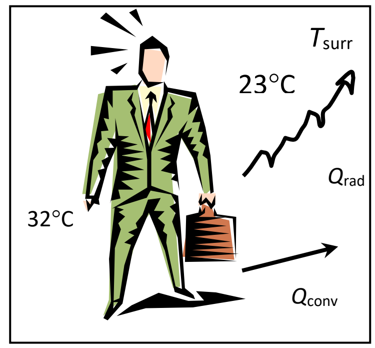
Analysis The person is completely enclosed by the surrounding surfaces, and he or she will lose heat to the surrounding air by convection and to the surrounding surfaces by radiation. The total rate of heat loss from the person is determined from

$$\dot{Q}_{rad} = \varepsilon\sigma A_s(T_s^4 - T_{surr}^4) = (0.90)(5.67\times10^{-8}\ \text{W/m}^2.\text{K}^4)(1.7\,\text{m}^2)[(32+273)^4 - (23+273)^4]\text{K}^4$$
$$= 84.8\ \text{W}$$

$$\dot{Q}_{conv} = hA_s\Delta T = (5\text{W/m}^2\cdot\text{K})(1.7\text{m}^2)(32-23)°\text{C} = 76.5\text{W}$$

and

$$\dot{Q}_{total} = \dot{Q}_{conv} + \dot{Q}_{rad} = 84.8 + 76.5 = \mathbf{161.3\ W}$$



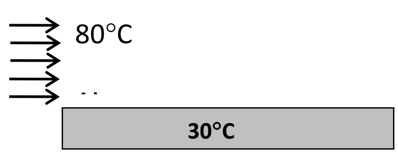
Unit 1, Problem 4.

Hot air is blown over a flat surface at a specified temperature. The rate of heat transfer from the air to the plate is to be determined.

Assumptions: **1** steady operating condition exists. **2** Heat transfer by radiation is not considered. **3** The convection heat transfer coefficient is constant and uniform over the surface.

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

$$\dot{Q}_{conv} = hA_s\Delta T = (55\text{W/m}^2\cdot^\circ\text{C})(2\times4\text{m}^2)(80-30)^\circ\text{C} = \mathbf{22{,}000W}$$

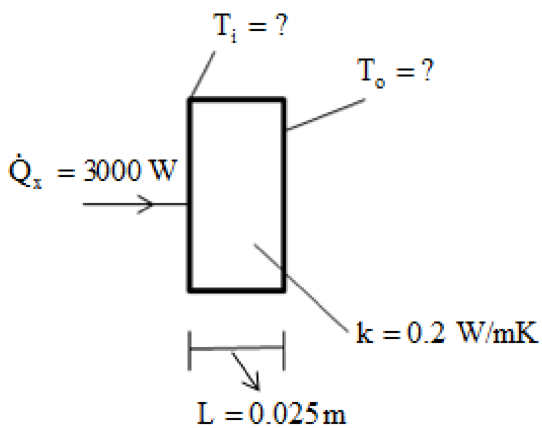


Unit 1, Problem 5

(a) $\dot{Q}_{rad,summer} = \varepsilon A_s\sigma(T_p{}^4 - T_{surr}{}^4) = 0.95\ \text{x}1.6\ \ \text{x}5.67\ \ \text{x}10^{-8}\ \text{x}(305^4 - 296^4) = 84.2\ \text{W}$

(b) $\dot{Q}_{rad,winter} = \varepsilon A_s\sigma(T_p{}^4 - T_{surr}{}^4) = 0.95\ \text{x}1.6\ \ \text{x}5.67\ \ \text{x}10^{-8}\ \text{x}(305^4 - 285^4) = 177.2\ \text{W}$

Unit **1, Problem 6**.



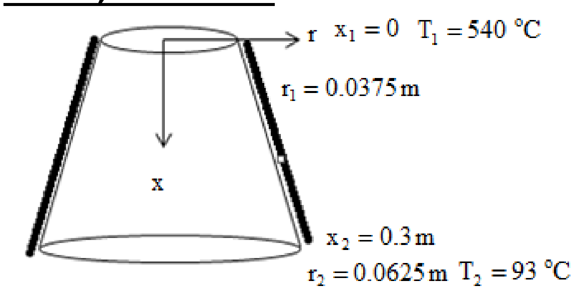
$$\dot{Q}_x = -kA_x \frac{dT}{dx}$$

$$\dot{Q}_x = \frac{-kA_x(T_o - T_i)}{L}$$

$$\dot{Q}_x = \frac{kA_x(T_i - T_o)}{L}$$

$$(T_i - T_o) = \frac{\dot{Q}_x \times L}{k \times A} = \frac{0.025 \times 3000}{0.2 \times 0.6} = 625\ ^{o}C$$

Unit 1, Problem 7.



$$r_x = ax + b$$

$$r_x = 0.0833x + 0.0375$$

$$A_x = \pi r_x^{\ 2}$$

$$\dot{Q}_x = -kA_x \frac{dT}{dx}$$

$$\int_{x=0}^{x=0.3m} \dot{Q}_x \frac{dx}{A_x} = \int_{540}^{93} -k\,dT$$

For steady state heat transfer $\dot{Q}_x$ = constant

Hence, $\dot{Q}_x \displaystyle\int_{x=0}^{x=0.3m} \frac{dx}{\pi(0.0833x + 0.0375)^2} = k[540 - 93]$

Upon integrating we obtain,

$$\frac{-\dot{Q}_x}{\pi \times (0.0833)}\left(\frac{1}{(0.0833x + 0.0375)}\right)\Bigg|_0^{0.3} = 304 \times 477$$

Evaluating yields,

$$-\dot{Q}_x \times 3.821 \times (16 - 26.67) = 304 \times 477$$

$$\dot{Q}_x = \frac{(304 \times 477)}{40 \cdot 7707} = 2387\ W$$

Unit 1, Problem 8.

$$A = \pi r^2 ; r_i = 0.26\,\text{m} ; r_o = 0.285\ \text{m}$$

$$q = -k \times 4 \times \pi \times r^2 \times \frac{dT}{dr}$$

$$\int_{r_i}^{r_o} \dot{Q}_r \frac{dr}{r^2} = \int_{T_i}^{T_o} -4\pi\, k dT$$

$$\dot{Q}_r \int_{r_i}^{r_o} \frac{dr}{r^2} = -4\pi\, k \int_{T_i}^{T_o} dT$$

$$\dot{Q}_r = \frac{-4\pi\, k(T_o - T_i)}{\frac{1}{r_i} - \frac{1}{r_o}}$$

$$\dot{Q}_r = \frac{-4\pi\, k(21+196)}{0.337382}$$

$\dot{Q}_r = -1 \cdot 617\ \text{W}$ (Heat is lost from the insulated material.

$$\dot{Q}_r = \dot{m} h_{fg}$$

$$\dot{m}_{evaporated} = \frac{1.617\left(\frac{J}{s}\right)}{199{,}000\left(\frac{J}{kg}\right)} = 8.13 \times 10^{-6}\ \text{kg/s}$$

$$= 8.13 \times 10^{-6} \times 3600 \times 24\, {}^{kg}\!/_{h}$$

$$\dot{m}_{evaporated} = 0.702\, {}^{kg}\!/_{day}$$

Unit 1, Problem 9.

$$\frac{Q}{L} = \frac{(T_i - T_\infty)}{\frac{\ln\left({}^{r_o}\!/_{r_i}\right)}{2\pi k} + \frac{1}{9 \times \pi \times d_o}}$$

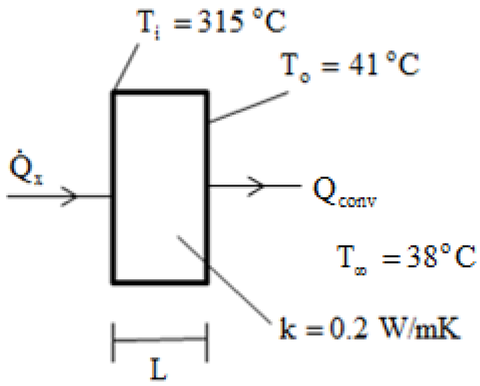
$$\frac{Q}{L} = \frac{(30+20)}{\frac{\ln\left({}^{30}\!/_{25}\right)}{2\pi \times 7} + \frac{1}{9 \times \pi \times 0 \cdot 6}} = 792 \cdot 6\ {}^{W}\!/_{m}$$

Unit 1, Problem 10

$$\dot{Q} = hA_s\,(T_s - T_{fluid}) = 3500\ x\pi\ x0.025\ x3\ x40 = 32991\ \text{W}$$

$$\dot{Q} = \dot{m} C_{pw} \Delta T_{fluid} \Rightarrow \Delta T_{fluid} = \frac{\dot{Q}}{\dot{m} C_{pw}} = \frac{32991}{0.5\,x\,4180\ J/kg^0C} = 15.8\ {}^0C$$

Unit 1, Problem 11.



$$\dot{Q} = -kA\frac{dT}{dx} = hA(T_o - T_\infty)$$

$$\dot{Q} = \frac{k(T_i - T_o)}{L} = h(T_o - T_\infty)$$

$$\dot{Q} = \frac{1\cdot 4\times(315-41)}{0.025} = h(41-38)$$

Hence, $h = 5114\cdot 7 \;{}^{W}\!/_{m^2\,°C}$

Unit 1, Problem 13:

$$\frac{Q_{total}}{L} = \frac{Q_{rad}}{L} + \frac{Q_{conv}}{L}$$

$$= \varepsilon\sigma\pi d(T_s^4 - T_{sur}^4) + h\times\pi\times d\times(T_s - T_\infty)$$

$$= 0.7\times5.67\times10^{-8}\times3.142\times0.05(473^4 - 283^4) + 180\times3.142\times0.05\times(473-303)$$

$$272\;{}^{W}\!/_{m} + 4.807\;{}^{W}\!/_{m}$$

$$5079\;{}^{W}\!/_{m}$$

Comment : Heat transfer by convection accounts for about 95 % of the total loss per unit length of the cylinder.