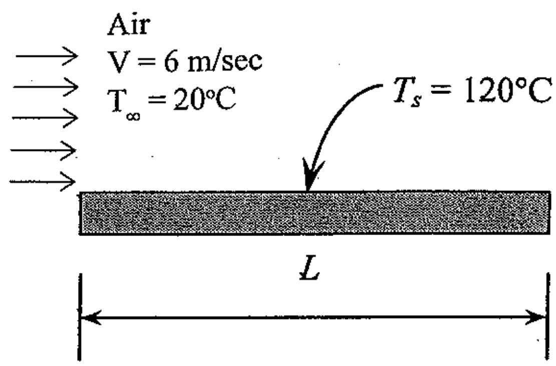
1. The top surface of a hot plate 8 m long and 2.5 m wide with a surface temperature of 120°C is to be cooled by forced air at 6 m/sec and 20°C. Assuming an atmospheric pressure of 1 atm, a critical Reynold's number of 5 x 10^5, and steady convective heat transfer, determine a) the convective heat transfer coefficient h, and b) the heat transfer from the plate in kW.



$$T_{avg} = \frac{120 + 20}{2} = 70^\circ C$$

From A-22, p. 798

$\rho = 1.028\ kg/m^3$ $\quad k = .02881\ \frac{W}{m\,^\circ C}$

$\nu = 1.995 \times 10^{-5}\ m^2/sec$

$P_r = 0.7177$

$$Re_L = \frac{VL}{\nu} = \frac{6\ m/sec\ (8\ m)}{1.995 \times 10^{-5}\ m^2/sec} = 2.406 \times 10^6$$

Turbulent at X = 8 m

$$N_u = (.037\, Re_L^{.8} - 871)\, P_r^{1/3} = 3{,}439.29 = \frac{hL}{k}$$

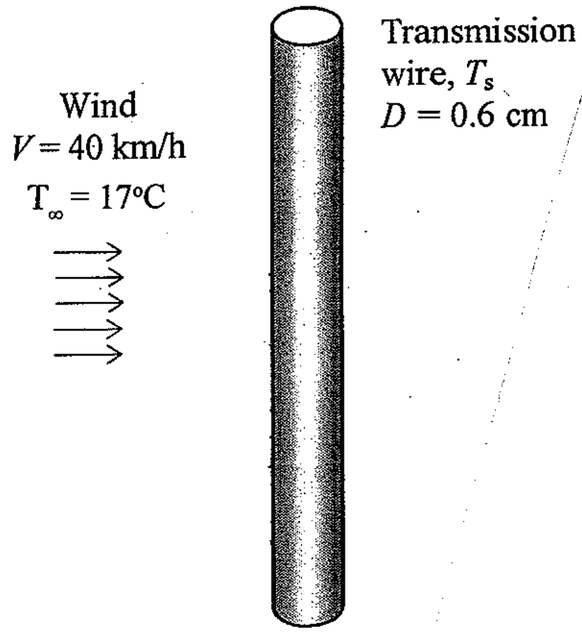
$$h = \frac{.02881}{8}(3439.29) = 12.386\ W/m^2 \cdot K$$

$$A_s = 2.5 \times 8 = 20\ m^2$$

$$\dot{Q} = hA_s(T_s - T_\infty) = 12.386\ \frac{W}{m^2 \cdot K}\ (20) m^2 (120 - 20)$$

$$= 24{,}771.5\ W \quad \text{or} \quad \underline{24.77\ KW}$$

2. Wind at 17°C is blowing directly across a 0.6 cm diameter wire of a transmission line at 40 km/hr. The rate of heat generated in the electrical line per meter length is 5 W/m. Neglect radiation effects and determine a) the convective heat transfer coefficient h, and b) the steady state surface temperature of the wire T_s. Use the temperature of 20°C to determine the properties of air.



AT 20°C From A-22, p. 798

$\rho = 1.204\ kg/m^3$

$k = .02514\ W/m\,°C$

$\nu = 1.516 \times 10^{-5}\ m^2/sec$

$P_r = 0.7309$

$$Re_D = \frac{VD}{\nu} = \frac{40(1000)(.006)}{1.516\times 10^{-5}}$$

$$= 4397.54$$

From Table 12-3, p. 555 $\quad N_u = 0.193\, Re^{.618}\, P_r^{1/3}$

$$= 31.03$$

$$h = \frac{k}{D} N_u = \frac{.02514}{.006}(31.03)$$

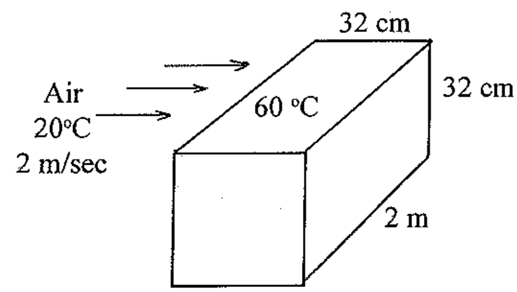
$$= 129.985\ W/m^2\,°C$$

$A = .006\,\pi\ m^2/m$

$$\dot{W} = 5\ \frac{W}{m} = 129.985(.006)\pi(T_s - 17)$$

$$T_s = 19.04\ °C$$

3 Electronic components are housed in a box 32 cm high, 32 cm wide and 2 m long. Air blows over the box perpendicular to the length at 20 °C and 2 m/sec. The surface temperature of the box is not to exceed 60°C. Determine the total power rating of the electronic devices that can be housed in the box.



$$T_{avg} = \frac{60 + 20}{2} = 40^\circ C$$

$$k = .02662 \, W/m\,^\circ C$$

$$\nu = 1.702 \times 10^{-5} \, m^2/sec$$

$$P_r = 0.7255$$

$$Re_D = \frac{V D_h}{\nu} = \frac{(2)(.32)}{1.702 \times 10^{-5}} = 37{,}603$$

$$N_u = \frac{hD}{k} = .102 \, Re_D^{.675} \, P_r^{1/3} = 112.31$$

(Table 12-3) p. 555

$$h = \frac{k}{D} N_u = 9.336 \, W/m^2\,^\circ C$$

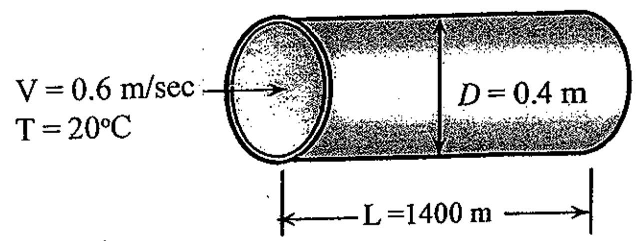
$$A = 4(.32)2 = 2.56 \, m^2$$

$$\dot{Q} = h A_s (T_s - T_\infty) = 9.336(2.56)(40) = \underline{955.98 \text{ W}}$$

If the ends are included $A = 2.56 + 2(.32)^2 = 2.765 \, m^2$

$$\dot{Q} = 9.336(2.765)(40) = \underline{1032.5 \text{ W}}$$

4. Engine oil initially at 20°C flows through a 40-cm-diameter pipe at an average velocity of 0.6 m/sec. A 1400-m-long section of the pipe is exposed to cold water at 0°C. Assume the pipe surface is also at 0°C, and disregarding the thermal resistance of the metal pipe walls, determine a) the mass flow rate through the pipe, b) the temperature of the oil, T_e as it leaves the 1400-m section, c) the log mean temperature difference, ΔT_{ln} and d) rate of heat transfer from the oil. Properties of the engine oil can be evaluated at 20°C.



From Table A-19, p 794

$\rho = 888.1\ kg/m^3$, $P_r = 10{,}863$

$\nu = 9.429 \times 10^{-4}\ m^2/sec$ $\quad k = 0.145\ \frac{W}{m\,°C}$

$C_p = 1881\ J/kg\,°C$

$Re_D = \frac{VD}{\nu} = \frac{0.6(.4)}{9.429 \times 10^{-4}} = 254.53$ laminer

a) $\dot{m} = \rho A_c V_{avg} = 881.1(\pi)\frac{.4^2}{4}(.6) = \underline{66.96\ kg/sec}$

$L_t = .05\, Re_D P_r D = .05(254.53)(10{,}863)(.4) = 55{,}299$

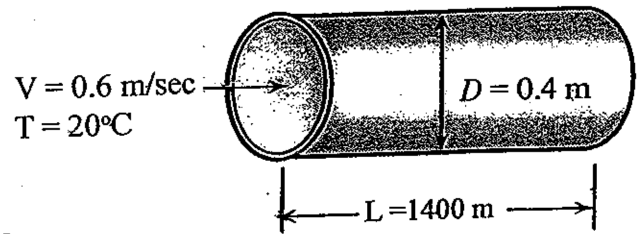
Boundary layer has not developed

From equation 13-62

$$N_u = \frac{hD}{k} = 3.66 + \frac{.065(D/L)Re_D P_r}{1 + .04[D/L\ Re_D P_r]^{2/3}} = 15.286$$

$$h = \frac{k}{D} N_u = \frac{0.145}{.4}(15.286) = 5.541\ W/m\,°C$$

4. Engine oil initially at 20°C flows through a 40-cm-diameter pipe at an average velocity of 0.6 m/sec. A 1400-m-long section of the pipe is exposed to cold water at 0°C. Assume the pipe surface is also at 0°C, and disregarding the thermal resistance of the metal pipe walls, determine a) the mass flow rate through the pipe, b) the temperature of the oil, T_e as it leaves the 1400-m section, c) the log mean temperature difference, ΔT_{ln} and d) rate of heat transfer from the oil. Properties of the engine oil can be evaluated at 20°C.



$$A_s = \pi D L = \pi(.4)(1400)$$

$$= 1759.29 \ m^2$$

$$\dot{m} = 66.96 \ Kg/sec \qquad C_p = 1881 \ J/Kg\,°C$$

$$h = 5.541 \ W/m\,°C$$

b) $$T_e = T_s - (T_s - T_i)\, e^{-\frac{hA}{\dot{m} C_p}}$$

$$= 0 - (0 - 20)\, e^{-\frac{(5.54)(1759)}{1881(66.96)}} = \underline{18.51\,°C}$$

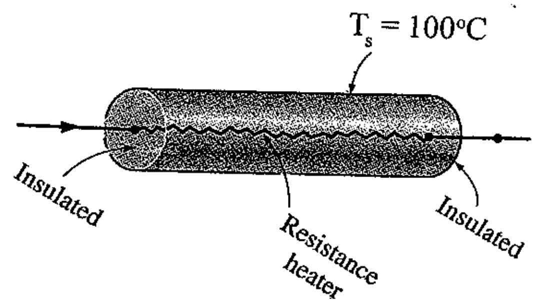
c) $$\Delta T_{ln} = \frac{T_e - T_i}{\ln\left[\frac{T_s - T_e}{T_s - T_i}\right]} = \underline{19.24\,°C}$$

d) $$\dot{Q}_{avg} = h A_s \Delta T_{ln} = 5.541(1759.29)(19.24)$$

$$= 187{,}546 \ W$$

$$= 187.55 \ KW$$

5. A 40-W resistance heater 60 cm long is placed along the center of a cylinder that has a diameter D = 2 cm. The ends are insulated and the surface emissivity ε = 0.1. The average surface temperature of the cylinder is maintained at 100°C while the room temperature is at a constant 20°C. Assume that radiation from the environment is also at 20°C. For steady state operation, determine a) the Rayleigh number, b) the Nusselt number from Table 14-1, c) the amount of heat transferred by free convection, and d) the amount transferred by radiation.



$$T_{avg} = \frac{100+20}{2} = 60°C$$

From Table A-22

$k = .0281 \frac{W}{m\,°C}$ $\quad P_r = .7202$

$\nu = 1.896 \times 10^{-5}\ m^2/sec$ $\quad \beta = \frac{1}{T} = .003\ K^{-1}$ $\quad \delta = .02\ m$

$$R_a = \frac{g\beta(T_s - T_{surr})\delta^3 P_r}{\nu^2} = 37,735$$

From Table 14.1, Eq 14.25

$$N_u = \left\{ .6 + \frac{.387\, Ra^{1/6}}{\left[1 + \left(\frac{.559}{P_r}\right)^{9/16}\right]^{8/27}} \right\}^2 = 6.064 = \frac{h\delta}{k}$$

a) $h = \frac{6.064(.0281)}{.02} = 8.514\ W/m^2\,°C$ $\quad A = \pi D L = .0377 m^2$

$\dot{Q}_{conv} = hA\Delta T = 25.68\ W$

b) $\dot{Q}_{rad} = \epsilon \pi D L \sigma (T_s^4 - T_{surr}^4)$

$= 0.1\pi(.02).6(5.67 \times 10^{-8})(373^4 - 293^4)$

$= 2.56\ W$