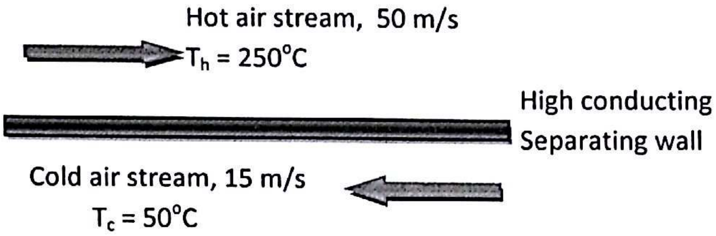
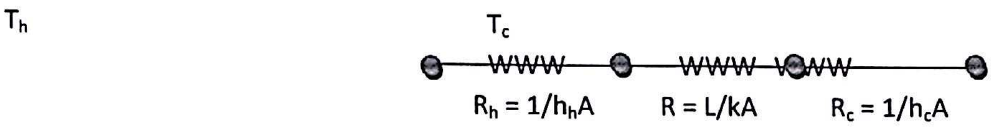
Answers to Test 2 SME4463

Question 2.1

b. consider the following sketch.



a. Physical problem



b. Its thermal circuit

Fig 2.1

The rate of heat loss through the wall,

$$Q = [T_h - T_c]/[1/h_hA + L/kA + 1/h_cA]$$

But the thermal conductivity of the wall is large, k >>1, thus R $\approx$ 0. Hence,

$$Q = [T_h - T_c]A/[1/h_h + 1/h_c)]$$

To Findi the corresponding coefficient of heat transfer across the separating wall.
Average temperature of the air stream, $T_{av} = [T_h + T_c]/2 = [250 + 50]/2 = 150$°C

Film temperature for hot air stream, $T_{fh} = [250 + 150]/2 = 200$°C
Hot air stream properties at T_{fh} = 200°C, => $v = 3.3 \times 10^{-5}$ s/m^2, k = 0.0386bW/m C, Pr = 0.682
Magnitude of Reynolds number hot air stream ,$Re_L = UL/v = 50 \times 2/(3.3\times10^{-5}] = 3.03 \times 10^6$
Thus flow is turbulent. The relevant correlation eqn. is,

$$Nu_L = 0.036\ [Re_L^{0.8} - 9200]Pr^{0.43}$$

Substituting the given and calculated values, yields ***h_h = 84.8 W/m^2 C.***

Film temperature for the cold air stream, T_{fc} = [150 + 50]/2 = 100°C.
Cold air stream properties at 100°C => $\nu = 2.31 \times 10^{-5}$ s/m^2, k = 0.0317 W/m C, Pr = 0.693
Thus,

$$Re_L = UL/\nu = 15x2/[2.31 \times 10^{-5}] = 1.3 \times 10^6.$$

This is again turbulent flow, hence

$$Nu_L = 0.036[Re_L^{0.8} - 9200]Pr^{0.43}$$

With the given values, this yields ***h_c = 32.4 W/m^2 C***
The heat loss from the plate, A = 2 x 1 m^2,

$$Q = \{(250 - 50) \times 2\}/[1/84.8 + 1/32.4] = \mathbf{9585\ W = 9.60\ kW}$$

Question 2.2

b. Consider the sketch below

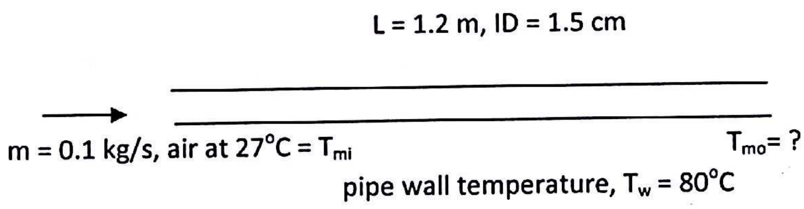


Fig 2.2

The rate of heat loss from the pipe is,

$$Q = hA\ LMTD$$

where h and LMTD are the coefficient of heat transfer and log. mean temperature different, respectively. These two parameters are to be determine in order to evaluate Q.

Determining h.
Fluid, i.e. air, properties must be determined at $T_m = [T_i + T_o]/2$. However outlet temperature of the air ***is not known!***Initial guess has to be made. Assume, T_o = 350 K.
Thus, T_m = [350 +(80+273)]/2 = 325 K.
Air properties at T_m = 325K, => $\nu = 1.82 \times 10^{-5}$ s/m^2, k = 0.0281 W/m K, c_p = 1.007 kJ/kg K,
ρ = 1.09 kg/m^3, $\mu = 2.03 \times 10^{-5}$ kg/s.m, Pr = 0.702

The mean velocity, $U = m/\rho A = 4m/\rho\pi d^2 = 4(0.1)/[1.09\pi(0.015)^2]$ = 530.3 m/s [too high!]
Thus, magnitude of Reynolds number, $Re_d = Ud/\nu = 4.3 \times 10^5$. This flow is turbulent.

There are several correlation equations can be chosen to determine the coefficient of heat transfer, h, namely:

i. $Nu_D = 0.023\ Re_D^{4/5} Pr^{0.4}$, Dittus – Boelter eqn.

ii. $Nu_D = 0.027\ Re_D^{4/5}\ Pr^{1/3}(\mu/\mu_s)^{0.14}$, Sieder – Tate eqn., with $T_s \gg T_m$

iii. $Nu_D = [(f/8)(Re_D - 1000)Pr]/[1 + 12.7(f/8)^{1/2}(Pr^{2/3} - 1)]$, Gnielinski's eqn.

iv. $Nu_D = [RePr(f/8)(\mu/\mu_s)^{0.14}]/[1.07 + 12.7(f/8)^{1/2}(Pr^{2/3} - 1)$, Petkov 's eqn.

On using Gnielinski's eqn. with friction factor determine from smooth pipe eqn., i.e.,

$$f = [1.82 \ln Re - 1.64]^{-2} = 0.0135$$

Gnielinski'seqn.,

$$Nu_D = [(f/8)(Re_D - 1000)Pr]/[1 + 12.7(f/8)^{1/2}(Pr^{2/3} - 1)] = 528.3,$$

Or,

$$\mathbf{h = 528.3k/d = 991.1 W/m^2\ C}$$

Note:

If Sieder – Tate's eqn is used, $h = [0.027x(4.3x10^5)^{4/5}(0.71)^{1/3}](0.0281/0.015)$ = ***1500.0 W/m² C****, with no correction since the water and wall temperatures are not too much a difference. The value obtained is not too far off!. You may tried other correlations, if you used.*

Now the actual outlet temperature can be re-evaluated using the following eqn. obtained energy balance,

$$[T_S - T_2]/[T_S - T_1] = \exp[-Ph/mc_p)$$

Or,

$$[353 - T_2]/[353 - 300] = \exp[-\pi(0.015)(12)/(0.1x1007.4)]$$

This gives, $T_2 = 352.8°C$ [***i.e., closed to initial guessing***]

Now, $LMTD = [T_2 - T_1]/\ln[(T_2 - T_1)/(T_1 - T_2)$

Hence,

$$Q = hALMTD = 991.1(\pi(0.015)(12)(353\text{-}300)/\ln[(353 - 300)/(300 - 352)]$$

This gives,

Q = 5303 W = 5.30 kW