(20-16) given: $L=0.2m$ $t=0.025m$ $K_w=15\ \frac{W}{mK}$

$T_{s,1}=100^\circ C$ $T_{\infty,2}=7^\circ C$

Solution: Find, T_{s2} $T_{s2,initial}=53.5^\circ C$

1. $T_f=\frac{53.5+7}{2}=30.25^\circ C$ $\beta=\frac{1}{30.25+273.15}=0.0033$

Table $Pr=5.42$ $\mu=794.1\times10^{-5}\ Pa\cdot s$ $K_w=618.55\times10^{-3}\ \frac{W}{mK}$

$\rho=996\ \frac{kg}{m^3}$

$$Gr_L=\frac{g\beta(T_{s,2}-T_{\infty,2})L^3}{\left(\frac{\mu}{\rho}\right)^2}=\frac{9.81\cdot(0.0033)(53.5-7)0.2^3}{\left(\frac{794.1\times10^{-5}}{996}\right)^2}$$

$Gr_L=18.68\times10^9$

$Ra_L=Gr_L\cdot Pr=10.12\times10^{10}$

$$Nu_L=\left(0.825+\frac{0.387Ra_L^{1/6}}{\left(1+\left(\frac{0.492}{Pr}\right)^{9/16}\right)^{8/27}}\right)^2$$

$$Nu_L=650.19=\frac{hL}{K}\Rightarrow h=\frac{Nu_L K}{L}=\frac{650.19\cdot617.55\times10^{-3}}{0.2}$$

$h=2007.62\ \frac{W}{m^2K}$

$q''_{cond}=q''_{conv}$

$$K\frac{(T_{s,1}-T_{s,2})}{t}=h(T_{s,2}-T_{\infty,2})$$

$$\frac{K}{t}T_{s,1}-\frac{K}{t}T_{s,2}=hT_{s,2}-hT_{\infty,2}$$

$$T_{s,2}=\frac{\left(\frac{K}{t}T_{s,1}+hT_{\infty,2}\right)}{h+\frac{K}{t}}=\frac{\frac{15}{0.025}\cdot(100+273.15)+2007.62\cdot(7+273.15)}{2007.62+\frac{15}{0.025}}$$

$T_{s,2}=28.4^\circ C$

$53.5\rightarrow 28.4^\circ C$

20-16 continued

2: $T_{s2} = 37°C = 310K$

$T_f = \frac{37+7}{2} = 22°C = 295K$

Table: $\mu = 959 \times 10^{-6}$ Ns $\quad Pr = 8.89 \quad \beta = \frac{1}{295} \frac{1}{K} \quad K_w = 606 \times 10^{-3} \frac{W}{mK}$

$\rho = 998 \frac{kg}{m^3}$

$$G_L = \frac{g\beta(T_{s2} - T_{\infty,2})L^3}{\left(\frac{\mu}{\rho}\right)^3} = \frac{9.81\left(\frac{1}{295}\right)(310-280)(0.2)^3}{\left(\frac{959\times10^{-6}}{998}\right)^3}$$

$G_L = 8.64 \times 10^9$

$Ra_L = Gr_L Pr = 8.64 \times 10^9 \cdot 8.89 = 7.6 \times 10^{10}$

$$Nu_L = \left(0.825 + \frac{0.387(7.6\times10^{10})^{1/6}}{\left(1+\left(\frac{0.492}{8.89}\right)^{9/16}\right)^{8/27}}\right)^2 = 610.55$$

$$h = \frac{Nu_L k}{L} = \frac{610.55 \times 606\times10^{-3}}{0.2} = 1849.96 \frac{W}{m^2K}$$

$q''_{cond} = q''_{conv}$

$$h(T_{s,2} - T_{s,\infty}) = \frac{k(T_{s,1} - T_{s,2})}{t}$$

$$T_{s,2} = \frac{\frac{k}{t}T_{s,1} + hT_{\infty,2}}{h + \frac{k}{t}}$$

$T_{s,2} = 29.79°C$

$37°C > 29.79°C$

2046 continued

3: $T_{s,2} = 32°C = 305K$

$T_f = \frac{32+7}{2} = 19.5°C = 292.5K$

$T_{\infty 2} = 7°C = 280K$

Table $\mu = 1019.5 \times 10^{-6}\ Pa \cdot s$ $Pr = 8.71$ $\beta = \frac{1}{292.5}$

$K = 602 \times 10^{-3}\ \frac{W}{mK}$ $\rho = 998.5\ \frac{kg}{m^3}$

$$Gr_L = \frac{g\beta(T_{s,2} - T_{\infty 2})L^3}{\left(\frac{\mu}{\rho}\right)^2} = \frac{9.81\left(\frac{1}{292.5}\right)(305-280)(0.2)^3}{\left(\frac{1019.5\times10^{-6}}{998.5}\right)^2}$$

$Gr_L = 6.43 \times 10^9$

$Ra_L = Gr_L \cdot Pr = 6.43 \times 10^9 \cdot 8.71 = 5.65 \times 10^{10}$

$$Nu_L = \left(0.825 + \frac{0.387 \cdot (5.65\times10^{10})^{1/6}}{\left(1+\left(\frac{0.492}{8.71}\right)^{9/16}\right)^{8/27}}\right)^2$$

$Nu_L = 554.63 = \frac{hL}{K}$ $h = \frac{Nu_L K}{L} = \frac{554.63 \cdot 604 \cdot 10^{-3}}{0.2}$

$h = 1674.98$

$$T_{s,2} = \frac{\frac{K}{L}T_{s,1} + hT_{\infty 2}}{h + \frac{K}{L}} = 31.6°C$$

$32°C \approx 31.6°C$

$\therefore$

$T_{s,2} = 32°C$

20-30 given: $h = 0.15\,m$ $w = 0.2\,m$ $A = 0.03\,m^2$ $\rho = 0.7$

$T_\infty = 20^\circ C$ $\dot{Q} = 8\,W$

Find: T_s a) vertical b) horizontal up c) horizontal down

Solution: a) $T_s = 45^\circ C = 318.15\,K$

$T_f = 32.5^\circ C = 305.65\,K$

Table: $\mu = \frac{1.872\times10^{-5} + 1.845\times10^{-5}}{2} = 1.8835\times10^{-5}\ \frac{kg}{ms}$

$K = \frac{0.02588 + 0.02625}{2} = 0.026065\ \frac{W}{mK}$

$\rho = \frac{1.164 + 1.145}{2} = 1.1545\ \frac{kg}{m^3}$

$Pr = 0.7275$

$\beta = \frac{1}{305.65K}$

$Ra_L = \frac{g\beta(T_s - T_\infty)L^3}{(\frac{\mu}{\rho})^2} Pr = \frac{9.81\cdot(\frac{1}{305.65})(45-20)\cdot0.2^3}{(\frac{1.8835\times10^{-5}}{1.1545})^2} 0.7275 = 1.75\times10^7$

$Nu = \left(0.825 + \frac{0.387\cdot(1.75\times10^7)^{1/6}}{(1+(\frac{0.492}{0.7275})^{9/16})^{8/27}}\right)^2 = 37.4$

$\frac{hL}{k} = Nu \Rightarrow h = \frac{Nu\,k}{L} = \frac{37.4\cdot0.026065}{0.2} = 4.876\ \frac{W}{m^2K}$

$\dot{Q} = \dot{Q}_{rad} + \dot{Q}_{conv}$

$\dot{Q} = \sigma\varepsilon A(T_s^4 - T_\infty^4) + hA(T_s - T_\infty)$

$8 = 5.67\times10^{-8}\cdot0.8\cdot0.03((T_s+273.15)^4 - (20+273.15)^4) + 4.876\cdot0.03\cdot(T_s - 20)$

numerically $T_s = 46.6^\circ C$

20-30 continued:

b) $T_s = 45°C = 318.15K$

$T_f = 32.5°C = 305.65K$

Table: $\nu = \frac{1.608\times10^{-5} + 1.655\times10^{-5}}{2} = 1.6315\times10^{-5}\ \frac{m^2}{s}$

$k = 0.026065\ \frac{W}{mK}$ $\quad Pr = 0.7275$ $\quad \beta = \frac{1}{305.65}$

$$Ra = \frac{g\beta(T_s - T_\infty)\left(\frac{A}{P}\right)^3}{\nu^2} = \frac{9.81\cdot\frac{1}{305.65}\cdot(45-20)\left(\frac{0.03}{0.7}\right)^3}{(1.6315\times10^{-5})^2} = 1.728\times10^5$$

$$Nu = 0.1\,Ra_L^{1/3} = 0.1\cdot 1.728\times10^{5\frac{1}{3}} = 11.01$$

$$h = \frac{Nu\,k}{\frac{A}{P}} = \frac{11.01\cdot 0.026065}{\frac{0.03}{0.7}} = 6.696\ \frac{W}{m^2K}$$

$$\dot{Q} = \sigma\varepsilon A(T_s^4 - T_\infty^4) + hA(T_s - T_\infty)$$

$$8 = 5.67\times10^{-8}\cdot.8\cdot0.03\left((T_s+272.15)^4 - (20+272.15)^4\right) + 6.7\cdot0.03(T_s - 20)$$

Matlab $\boxed{T_s = 42.6°C}$

$Ra = 1.728\times10^5$

c) $Nu = 0.27\,Ra_L^{1/4} = 0.27\cdot(1.728\times10^5)^{1/4} = 5.505$

$$h = \frac{Nu\,k}{\frac{A}{P}} = \frac{5.505\cdot 0.026065}{\frac{0.03}{0.7}} = 3.34\ \frac{W}{m^2K}$$

$$\dot{Q} = \sigma\varepsilon A(T_s^4 - T_\infty^4) + hA(T_s - T_\infty)$$

$$8 = 5.67\times10^{-8}\cdot.8\cdot0.03\left((T_s+273)^4 - (20+273)^4\right) + (3.34)(.03)(T_s - 20)$$

Matlab $\boxed{T_s = 50.7°C}$

(20-60) given: $D = 0.08m$ $P = 60W$ $eff = 0.1$ $T_\infty = 25°C = 298.15K$

$\varepsilon = 0.9$

Find: T_s

Solution:

$$\dot{Q} = 60 \cdot 0.9 = 54W$$

1: $T_s = 170°C = 443.15K$

$$T_f = \frac{(170°C + 25°C)}{2} = 97.5°C \qquad \beta = \frac{1}{443.15}$$

Table: $\nu = 2.306 \times 10^{-5} \frac{m^2}{s}$ $\quad k = 0.03095 \frac{W}{mK}$

$Pr = 0.7111$

$$Ra_D = \frac{g\beta(T_s - T_\infty)D^3}{\nu^2} Pr = \frac{9.81 \frac{1}{443.15}(170-25)(0.08)^3}{(2.306\times10^{-5})^2} 0.7111 = 2.198 \times 10^6$$

$$Nu = 2 + \frac{0.589 Ra_D^{1/4}}{\left(1+\left(\frac{0.469}{Pr}\right)^{9/16}\right)^{4/9}} = 19.5$$

$$h = \frac{Nu\,k}{L} = \frac{19.5 \cdot 0.03095}{0.08} = 7.54 \frac{W}{m^2K}$$

$$\dot{Q} = \sigma \varepsilon A (T_s^4 - T_\infty^4) + hA(T_s - T_\infty)$$

$$54 = (5.67\times10^{-8})(0.9)(4\pi(0.04)^2)(T_s^4 - (298.15)^4) + (7.54)(4\pi(0.04)^2)(T_s - 298.15)$$

matlab $T_s = 169\ °C$

Table of Contents

ASEN 3113 - Assignment 10 - Main

```
Author: Samuel Razumovskiy
Collaborators: None
Date: 12/2/2019 (last revised: 12/2/2019)

clear,clc
```

20-30 a)

```
Q = 8; % W
ep = 0.8;
A = 0.03; % m^2
h = 4.876; % W/m^2
Tinf = 293.15; % K
Ts = 318.15; % K

Tsa = findTemp(Q,ep,A,Ts,Tinf,h) - 273.15;
```

20-30 b)

```
h = 6.696; % W/m^2

Tsb = findTemp(Q,ep,A,Ts,Tinf,h) - 273.15;
```

20-30 c)

```
h = 3.34; % W/m^2

Tsc = findTemp(Q,ep,A,Ts,Tinf,h) - 273.15;
```

20-60

```
Q = 54; % W
ep = 0.9;
A = 4*pi*.04^2; % m^2
h = 7.54; % W/m^2
Tinf = 298.15; % K
Ts = 443.15; % K
```

```
Ts = findTemp(Q,ep,A,Ts,Tinf,h) - 273.15;
```

Function

```
function Ts = findTemp(Q,ep,A,Ts,Tinf,h)
    sigma = 5.67e-8;
    Qguess = 0;
    while abs(Q-Qguess) > 0.001
        if Q-Qguess > 0 && Qguess ~= 0
            Ts = Ts+0.001;
        elseif Q-Qguess < 0 && Qguess ~= 0
            Ts = Ts-0.001;
        end
        Qguess = sigma*ep*A*(Ts^4-Tinf^4)+h*A*(Ts-Tinf);
    end
end
```

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