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"Problem 2.5
We will do only parts a and c; part b is done similarly to part a"
P_infinity=1e5
T_infinity=300
U_infinity=1
T_s=350
x_1=0.01
x_2=0.1
x_3=0.3
"Part a
First, find the properties of air"
T_ref=0.5*(T_s+T_infinity)
rho_a=density(air, P=P_infinity, T=T_ref)
k_a=conductivity(air, T=T_ref)
C_P_a=CP(air, T=T_ref)
mu_a=viscosity(air, T=T_ref)
Pr_a=Prandtl(air, T=T_ref)
alpha_a=mu_a*C_P_a/k_a
"Find Reynolds numbers"
Re_a_1=rho_a*U_infinity*x_1/mu_a
Re_a_2=rho_a*U_infinity*x_2/mu_a
Re_a_3=rho_a*U_infinity*x_3/mu_a
"The boundary layer will be laminar in all three points. therefore"
delta_a_1=5.*x_1/sqrt(Re_a_1)
delta_th_a_1/delta_a_1=Pr_a^(-1/3)
delta_a_2=5.*x_2/sqrt(Re_a_2)
delta_th_a_2/delta_a_2=Pr_a^(-1/3)
delta_a_3=5.*x_3/sqrt(Re_a_3)
delta_th_a_3/delta_a_3=Pr_a^(-1/3)

"Part c"
T_s_c=450.
T_infinity_c=400
T_ref_c=0.5*(T_s_c+T_infinity_c)
U_infinity_c=2.
"First, find the properties of Sodium.  For simplicity use properties at 370 K"
rho_c=929
k_c=86.2
C_P_c=1.38e3
nu_c=7.5e-7
mu_c=rho_c*nu_c
Pr_c=0.011
alpha_c=mu_c*C_P_c/k_c
"Find Reynolds numbers"
Re_c_1=rho_c*U_infinity_c*x_1/mu_c
Re_c_2=rho_c*U_infinity_c*x_2/mu_c
Re_c_3=rho_c*U_infinity_c*x_3/mu_c
"The boundary layers at x=0.01 and x=0.1 are all laminar, but it is turbulent at x=0.3 m.  Therefore,"
delta_c_1=5.*x_1/sqrt(Re_c_1)
delta_th_c_1/delta_c_1=Pr_c^(-1/2)
delta_c_2=5.*x_2/sqrt(Re_c_2)
delta_th_c_2/delta_c_2=Pr_c^(-1/2)
"For the turbulent boudary layer the thermal and velocity boundary layers are approximately of the same thickness. We cna use an empirical correlation
for estimating the thickness of the turbulent boundary layer"
delta_c_3=0.37*x_3/(Re_c_3^(1/5))
delta_th_c_3/delta_c_3=1
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Problem 2.5
We will do only parts a and c; part b is done similarly to part a

$P_{\infty} = 100000$

$T_{\infty} = 300$

$U_{\infty} = 1$

$T_s = 350$

$x_1 = 0.01$

$x_2 = 0.1$

$x_3 = 0.3$

Part a
First, find the properties of air

$T_{ref} = 0.5 \cdot [T_s + T_{\infty}]$

$\rho_a = \rho[\text{'Air'}, P = P_{\infty}, T = T_{ref}]$

$k_a = \mathbf{k}[\text{'Air'}, T = T_{ref}]$

$C_{P,a} = \mathbf{Cp}[\text{'Air'}, T = T_{ref}]$

$\mu_a = \mathbf{Visc}[\text{'Air'}, T = T_{ref}]$

$Pr_a = \mathbf{Pr}[\text{'Air'}, T = T_{ref}]$

$\alpha_a = \mu_a \cdot \frac{C_{P,a}}{k_a}$

Find Reynolds numbers

$Re_{a,1} = \rho_a \cdot U_{\infty} \cdot \frac{x_1}{\mu_a}$

$Re_{a,2} = \rho_a \cdot U_{\infty} \cdot \frac{x_2}{\mu_a}$

$Re_{a,3} = \rho_a \cdot U_{\infty} \cdot \frac{x_3}{\mu_a}$

The boundary layer will be laminar in all three points. therefore

$\delta_{a,1} = 5 \cdot \frac{x_1}{\sqrt{Re_{a,1}}}$

$$\frac{\delta_{th,a,1}}{\delta_{a,1}} = Pr_a^{\left[\frac{-1}{3}\right]}$$

$$\delta_{a,2} = 5 \cdot \frac{x_2}{\sqrt{Re_{a,2}}}$$

$$\frac{\delta_{th,a,2}}{\delta_{a,2}} = Pr_a^{\left[\frac{-1}{3}\right]}$$

$$\delta_{a,3} = 5 \cdot \frac{x_3}{\sqrt{Re_{a,3}}}$$

$$\frac{\delta_{th,a,3}}{\delta_{a,3}} = Pr_a^{\left[\frac{-1}{3}\right]}$$

Part c

$$T_{s,c} = 450$$

$$T_{\infty,c} = 400$$

$$T_{ref,c} = 0.5 \cdot \left[T_{s,c} + T_{\infty,c}\right]$$

$$U_{\infty,c} = 2$$

First, find the properties of Sodium. For simplicity use properties at 370 K

$$\rho_c = 929$$

$$k_c = 86.2$$

$$C_{P,c} = 1380$$

$$\nu_c = 7.5 \times 10^{-7}$$

$$\mu_c = \rho_c \cdot \nu_c$$

$$Pr_c = 0.011$$

$$\alpha_c = \mu_c \cdot \frac{C_{P,c}}{k_c}$$

Find Reynolds numbers

$$Re_{c,1} = \rho_c \cdot U_{\infty,c} \cdot \frac{x_1}{\mu_c}$$

$$Re_{c,2} = \rho_c \cdot U_{\infty,c} \cdot \frac{x_2}{\mu_c}$$

$$Re_{c,3} = \rho_c \cdot U_{\infty,c} \cdot \frac{x_3}{\mu_c}$$

The boundary layers at x=0.01 and x=0.1 are all laminar, but it is turbulent at x=0.3 m. Therefore,

$$\delta_{c,1} = 5 \cdot \frac{x_1}{\sqrt{Re_{c,1}}}$$

$$\frac{\delta_{th,c,1}}{\delta_{c,1}} = Pr_c^{\left[\frac{-1}{2}\right]}$$

$$\delta_{c,2} = 5 \cdot \frac{x_2}{\sqrt{Re_{c,2}}}$$

$$\frac{\delta_{th,c,2}}{\delta_{c,2}} = Pr_c^{\left[\frac{-1}{2}\right]}$$

For the turbulent boudary layer the thermal and velocity boundary layers are approximately of the same thickness. We cna use an empirical correlation
for estimating the thickness of the turbulent boundary layer

$$\delta_{c,3} = 0.37 \cdot \frac{x_3}{Re_{c,3}^{[1/5]}}$$

$$\frac{\delta_{th,c,3}}{\delta_{c,3}} = 1$$

SOLUTION

Unit Settings: SI K Pa J mass deg

α_a = 0.7217	α_c = 0.01115	$C_{P,a}$ = 1006
$C_{P,c}$ = 1380	$\delta_{a,1}$ = 0.002144	$\delta_{a,2}$ = 0.006781
$\delta_{a,3}$ = 0.01175	$\delta_{c,1}$ = 0.0003062	$\delta_{c,2}$ = 0.0009682
$\delta_{c,3}$ = 0.007323	$\delta_{th,a,1}$ = 0.002391	$\delta_{th,a,2}$ = 0.00756
$\delta_{th,a,3}$ = 0.01309	$\delta_{th,c,1}$ = 0.002919	$\delta_{th,c,2}$ = 0.009232
$\delta_{th,c,3}$ = 0.007323	k_a = 0.02749	k_c = 86.2
μ_a = 0.00001972	μ_c = 0.0006968	ν_c = 7.500E-07
Pr_a = 0.7217	Pr_c = 0.011	P_∞ = 100000
$Re_{a,1}$ = 543.7	$Re_{a,2}$ = 5437	$Re_{a,3}$ = 16310
$Re_{c,1}$ = 26667	$Re_{c,2}$ = 266667	$Re_{c,3}$ = 800000
ρ_a = 1.072	ρ_c = 929	T_∞ = 300
$T_{\infty,c}$ = 400	T_{ref} = 325	$T_{ref,c}$ = 425
T_s = 350	$T_{s,c}$ = 450	U_∞ = 1
$U_{\infty,c}$ = 2	x_1 = 0.01	x_2 = 0.1
x_3 = 0.3		

4 potential unit problems were detected.