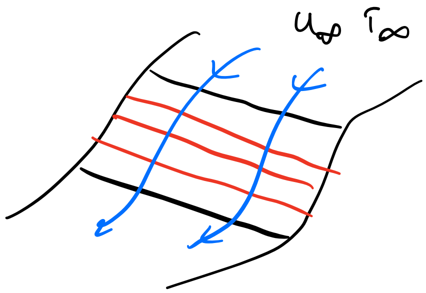
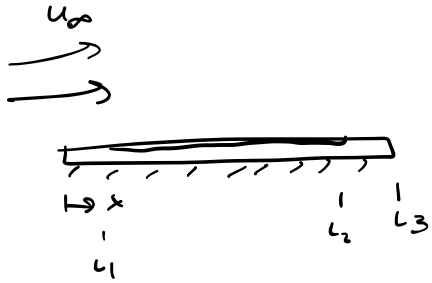
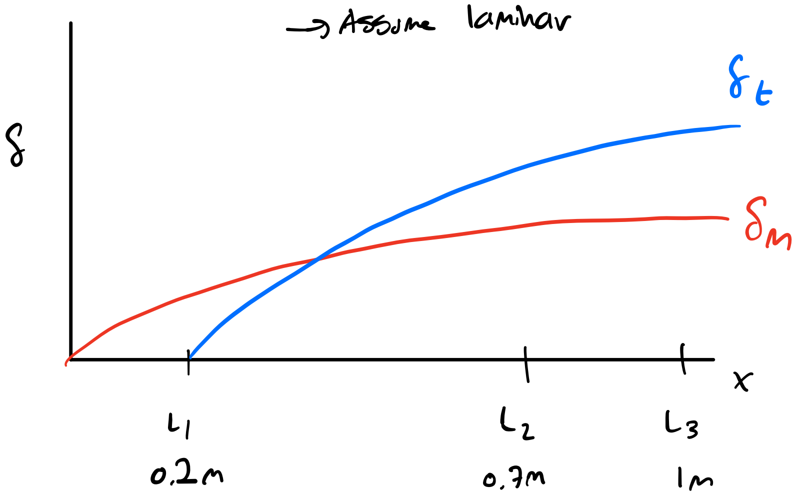




a) $Re_{crit} = 5 \times 10^5$ $\qquad Re_{crit} = \dfrac{\rho u_\infty x_{crit}}{\mu}$

$$\rightarrow \boxed{x_{crit} = \frac{Re_{crit}\,\mu}{\rho\, u_\infty} = 0.7933\ [m]}$$

b) $\rightarrow$ Assume laminar



$P_r = \dfrac{\mu c}{k} = 0.825$

$P_r < 1 \rightarrow \delta_t > \delta_M$

c) Assume laminar, δ_t starts @ $x=0$

Total power required to keep heated region $> 0°C$

T lowest at $x=0$, so condition $T(x=L_1) > 0°C$

$q'' = const = h_x(T_s - T_\infty)$ $\qquad \dot{q} = h_x A_s (T_s - T_\infty)$

$Nu_x = \dfrac{h_x \cdot x}{k}$, $\qquad Nu_x = 0.332\, Re_x^{0.5}\, P_r^{1/3}$

$Re_x = \dfrac{\rho u_\infty x}{\mu}$, $\qquad P_r = \dfrac{\mu c}{k} = 0.825$

$\rightarrow \dot{q}$ in EES

d) T largest @ $x = L_2$

$\rightarrow$ T in EES

e) Reynolds analogy $Nu_x \approx Pr^{1/3} C_f \, Re/2$

$\tau = 75$ mPa @ $x = L_3/2$

$$\tau = \frac{1}{2} \rho u_\infty^2 C_f$$

$\rightarrow h_{x = L_3/2}$ in EES

f) $u_\infty = 30$ m/s all turbulent

$$\delta_{vs,x} = \frac{5 \mu}{\rho \cdot u_\infty \sqrt{\frac{C_{fx}}{2}}} \qquad C_{f_x} = \frac{0.0594}{Re_x^{0.2}} \text{ (turbulent)}$$

$$\dot{q}_{turb} \approx A_s \cdot \frac{k (T_s - T_\infty)}{\delta_{vs}} \qquad T_s = 0°C$$

$x = L_1$

$\rightarrow$ IN EES

```
$unitsystem SI C J kg Pa

"ME 364 - Fall 2023
Homework 6
Convection with conceptual model"

"Given information"
T_inf = -15 [C]
T_ice = 0 [C]
u_inf = 8 [m/s]
rho = 1.3 [kg/m^3]
k = 0.02 [W/m-C]
mu = 1.65e-5 [Pa-s]
c = 1000 [J/kg-C]

L_1 = 0.2 [m]
L_2 = 0.7 [m]
L_3 =  1 [m]
W = 1.6 [m]
A_s = W*(L_2-L_1)

"part c"
x = L_1
T_s = T_ice
q_dot = h_x*A_s*(T_s-T_inf)
Nus_x = h_x*x/k
Nus_x = 0.332*Re_x^0.5*Pr^(1/3)
Re_x = rho*u_inf*x/mu
Pr = mu*c/k

"part d"
x2 = L_2
//T_s = T_ice
q_dot = h_x2*A_s*(T_s2-T_inf)
Nus_x2 = h_x2*x2/k
Nus_x2 = 0.332*Re_x2^0.5*Pr^(1/3)
Re_x2 = rho*u_inf*x2/mu

"part e"
tau = 75E-3 [Pa]
tau = 0.5*rho*u_inf^2*C_f
Nus_d = Pr^(1/3)*C_f* (rho*u_inf*(L_3/2)/mu)/2
Nus_d = h_xd*(L_3/2)/k

"part f"
u_inf_f = 30 [m/s]
x_f = L_1
T_s_f = T_ice
delta_vs_x = 5*mu/(rho*u_inf_f*sqrt(C_f_x/2))
C_f_x = 0.0594/(rho*u_inf_f*x_f/mu)^0.2
q_dot_f = A_s*k*(T_s_f-T_inf)/delta_vs_x
```

SOLUTION

Unit Settings: SI C Pa J mass deg

A_s = 0.8 [m^2]	c = 1000 [J/kg-C]
C_f = 0.001803 [-]	$C_{f,x}$ = 0.004354 [-]

$\delta_{vs,x}$ = 0.00004534 [m]
h_x = 11.06 [W/m^2-C]
h_{x2} = 5.909 [W/m^2-C]
h_{xd} = 10.66 [W/m^2-K]
k = 0.02 [W/m-C]
L_1 = 0.2 [m]
L_2 = 0.7 [m]
L_3 = 1 [m]
μ = 0.0000165 [Pa-s]
Nus_d = 266.4 [-]
Nus_x = 110.6 [-]
Nus_{x2} = 206.8 [-]
Pr = 0.825 [-]
$\dot{q}$ = 132.7 [W]
$\dot{q}_f$ = 5293 [W]
Re_x = 126061 [-]
Re_{x2} = 441212 [-]
ρ = 1.3 [kg/m^3]
τ = 0.075 [Pa]
T_{ice} = 0 [C]
T_{inf} = -15 [C]
T_s = 0 [C]
T_{s2} = 13.06 [C]
$T_{s,f}$ = 0 [C]
u_{inf} = 8 [m/s]
$u_{inf,f}$ = 30 [m/s]
W = 1.6 [m]
x = 0.2 [m]
x2 = 0.7 [m]
x_f = 0.2 [m]

No unit problems were detected.

KEY VARIABLES

$\dot{q}$ = 132.7 [W]	*c) heater power required*
T_{s2} = 13.06 [C]	*d) highest heater temperature*
h_{xd} = 10.66 [W/m^2-K]	*e) heat transfer coefficient at x = L_3/2*
$\dot{q}_f$ = 5293 [W]	*f) heater power required at turbulence with u_inf = 30*