CANKAYA UNIVERSITY
FACULTY OF ENGINEERING
MECHANICAL ENGINEERING DEPARTMENT
ME 313 HEAT TRANSFER

Fall 2016

HW 6

1) Consider laminar forced convection inside a circular tube of inside radius r_0 and subjected to a uniform heat flux at the tube wall. In the region where the velocity and temperature profiles are fully developed, the dimensionless temperature $\theta(r)$, defined is given in the form

$$\theta(r) = \frac{T(r,z) - T_w(z)}{T_m(z) - T_w(z)} = \frac{96}{11}\left[\frac{3}{16} + \frac{1}{16}\left(\frac{r}{r_0}\right)^4 - \frac{1}{4}\left(\frac{r}{r_0}\right)^2\right]$$

Develop an expression for the heat transfer coefficient.

$$h = -k\left(\frac{d\theta}{dr}\right)_{r=r_0}$$

$$\left(\frac{d\theta}{dr}\right)_{r=r_0} = \frac{96}{11}\left[-\frac{1}{2r_0} + \frac{1}{4r_0}\right] = -\frac{24}{11r_0} = -\frac{48}{11D} \qquad D = r_0(z)$$

$$h = \frac{48}{11}\frac{k}{D} \quad \text{or} \quad Nu_D = \frac{hD}{k} = \frac{48}{11}$$

2) In a particular application involving airflow over a heated surface, the boundary layer temperature distribution may be approximated as

$$\frac{T - T_w}{T_\infty - T_w} = 1 - \exp\left[-\Pr\left(\frac{yU_\infty}{\upsilon}\right)\right]$$

where *y* is the distance normal to the surface and the Prandtl number, $\Pr = \frac{\mu c_p}{k} = 0.7$, is a dimensionless fluid property. If $T_\infty = 400\,\mathrm{K}, T_w = 300\,\mathrm{K}$, and $\frac{U_\infty}{\upsilon} = 5000\,\mathrm{m}^{-1}$, what is the surface heat flux?

$$q_w'' = -k\left(\frac{\partial T}{\partial y}\right)_{y=0} = -k(T_\infty - T_w)\left[\Pr\frac{U_\infty}{\nu}\right] \exp\left[-\Pr\frac{U_\infty y}{\nu}\right]_{y=0}$$

$$= -k(T_\infty - T_w)\Pr\frac{U_\infty}{\nu}$$

$$= (-)(0.0263)(100)(0.7)(5000)$$

$$= -9205\ \mathrm{W/m^2}$$

3) P6.12 From the text book

$$h = \frac{-k\left(\frac{\partial T}{\partial y}\right)_{y=0}}{T_w - T_\infty}$$

$$= \frac{k(70)(600x)}{T_w - T_\infty}$$

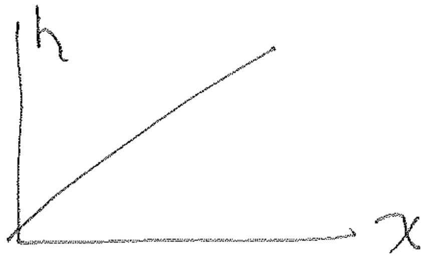
$T_w = T(x,0) = 90°C$

evaluate k at $T_f = \frac{T_w + T_\infty}{2} = \frac{20+90}{2} = 55°C$

$= 328\,K \longrightarrow k = 0.0284\ W/mK$

$T_w - T_\infty = 70°C = 70K$

$$h = \frac{0.0284(42000x)}{70} = 17x \quad (W/m^2K)$$



$$\bar{h} = \frac{1}{L}\int_0^L h\,dx = \frac{17}{5}\int_0^5 x\,dx = 42.5\ W/m^2K$$

4) The experimental data shown tabulated were obtained by passing *n*-butyl alcohol at a bulk temperature of 15°C over a heated flat plate 0.3-m long, 0.9-m wide, and with a surface temperature of 60°C. Correlate the experimental data using appropriate dimensionless numbers and compare the line that best fits the data with

Velocity (m/s)	Average Heat Transfer Coefficient ($W/m^2\,°C$)
0.089	121
0.305	218
0.488	282
1.14	425

$$Nu_L = C\,Re_L^n$$

$$Nu_L = \frac{\bar{h}L}{k} \qquad Re_L = \frac{\rho L U_\infty}{\mu}$$

Hint: You can obtain C and n using polyfit command in Matlab

$T_m = 15°C$
$T_w = 60°C$

$L = 0.3\,m$
$W = 0.9\,m$

for n-butyl alcohol

$T_f = \frac{(15+60)}{2} = 37.5°C \rightarrow$

$\mu = 1.92 \times 10^{-3}\ \frac{N.s}{m^2}$

$k = 0.166\ W/mK$

$\rho = 796\ kg/m^3$

$Pr = 294$

U_∞ (m/s)	$Re_L \times 10^4$	$\bar{h}$	$\overline{Nu_L}$
0.089	1.11	121	218.7
0.305	3.79	218	394
0.488	6.07	282	509.6
1.14	14.2	425	768.1

Generate a log-log plot

see next page

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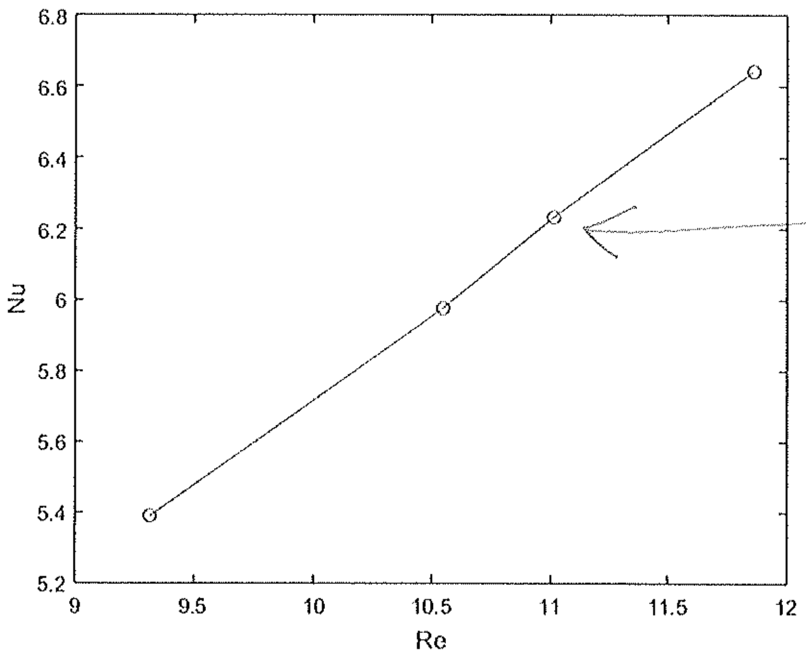
```
>> Re= [1.11 3.79 6.07 14.2 ]*(10^(4))

Re =

  1.0e+05 *

   0.1110    0.3790    0.6070    1.4200

>>  Nu=[218.7 394 509.6 768.1]

Nu =

  218.7000  394.0000  509.6000  768.1000

>> plot(log(Re),log(Nu),'o',log(Re),log(Nu))

>>xlabel('Re')

>> ylabel('Nu')
```



straight line so we use n=1 in polyfit i.e. polyfit(log Re, log Nu, 1)

Noe we can use polyfit command

```
>> polyfit(log(Re),log(Nu),1)

ans =

   0.4944    0.7787
```

This means that

Log(Nu)=0.4994Log(Re)+0.7787

$$\log\left(\frac{\mathrm{Nu}}{\mathrm{Re}^{0.4944}}\right) = 0.7787$$

$$\frac{\mathrm{Nu}}{\mathrm{Re}^{0.4944}} = \exp(0.7787)$$

or

$$\mathrm{Nu} = 2.17\,\mathrm{Re}^{0.4944}$$