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ME109 **Midterm #2 (3 problems – 40 points)** 11/7/14

Problem 1 (15 pts)

Consider an industrial fluid pumped through a pipe of diameter D=0.4 m, length L= 200 m that is immersed in water. The bulk mean velocity and inlet temperature of the fluid are u_m=2 m/s and T_{mi}=50°C. The temperature of the lake water is T_∞=5°C. The pipe is thin and the conductive thermal resistance of the pipe wall neglected.

Industrial fluid properties: density ρ=900 kg/m^3, specific heat C_p=2kJ/kgK, kinematic viscosity ν=6.9x10^{-6} m^2/s; Pr=74, thermal conductivity k=0.26 W/mK; water properties: volumetric thermal expansion coefficient β=320X10^{-6} K^{-1}, dynamic viscosity μ=769x10^{-6} Ns/m^2, density ρ=1000 kg/m^3, Pr=7, thermal conductivity k=0.6 W/mK

a) find the internal forced convection heat transfer coefficient, $\bar{h}_i$ (5pts)
b) assuming an average pipe wall temperature, T_s=30°C, find the average free convection heat transfer coefficient to the water, $\bar{h}_o$ (5pts)*
c) give the overall heat transfer coefficient, $\bar{U}$ (2 pts)
d) evaluate the outlet temperature of the fluid, T_{mo} using the results in a,b,c (3 pts)

* $\overline{Nu}_D = CRa_D^n$

TABLE 9.1 Constants of Equation 9.33 for free convection on a horizontal circular cylinder [22]

Ra_D	C	n
10^{-10}–10^{-2}	0.675	0.058
10^{-2}–10^{2}	1.02	0.148
10^{2}–10^{4}	0.850	0.188
10^{4}–10^{7}	0.480	0.250
10^{7}–10^{12}	0.125	0.333

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Problem 2 (15 pts)

Consider a plate of length, L=2 m and temperature $T_s=40^oC$. Air flows parallel to the plate at free stream velocity $u_\infty=1$ m/s and temperature $T_\infty=20^oC$.

Air properties: density $\rho=1.16$ (Kg/m^3), specific heat $C_p=1$ kJ/kgK, kinematic viscosity $\nu=16X10^{-6}$ m^2/s, thermal conductivity $k=16x10^{-3}$ W/mK, Pr=0.7

The critical Reynolds number for transition to turbulence, $Re_{cr}=5X10^5$

a) find the heat transfer from the plate to the air stream per unit width of the plate (5 pts)
b) find the local heat flux at x=1 m (5 pts).
c) find the heat transfer from the plate to the air stream per unit width of the plate if the free stream velocity is raised to $u_\infty=20$ m/s (5 pts)

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Problem 2 (10 pts)

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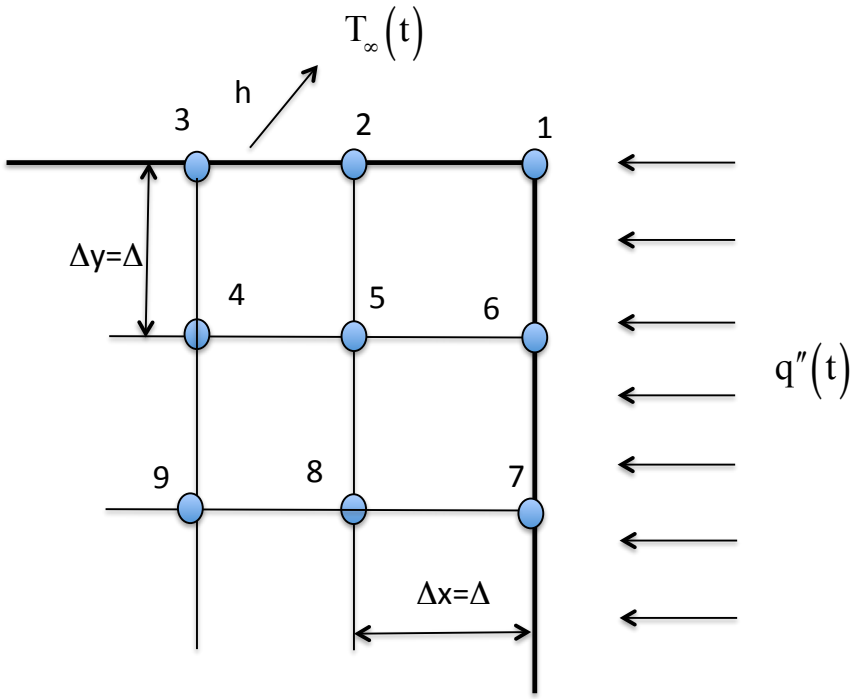
Problem 3 (10 pts)

Consider transient heat transfer in a 2-D corner. The right side receives an external heat flux $q''(t)$ and the upper side is subjected to convective heat transfer as shown in the schematic below. Assuming that $\Delta x=\Delta y=\Delta$,

(a) derive the explicit finite difference nodal temperature equation for node 1 (7 pts)
(b) give the stability criterion for node 1 (3 pts)



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