CH EN 3453 – Heat Transfer

Internal Flow
Heat Transfer Correlations

Sections 8.4 to 8.8, 8.10

Reminders…

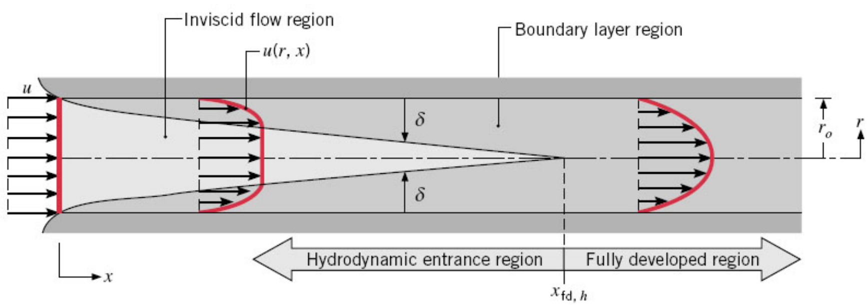
- Experimental writeup due Wednesday next week
  – Check www.che.utah.edu/projects_lab/
- Homework #7 due Friday
- Help session today 4:30 pm
  – Room MEB 2325

Experimental Writeup

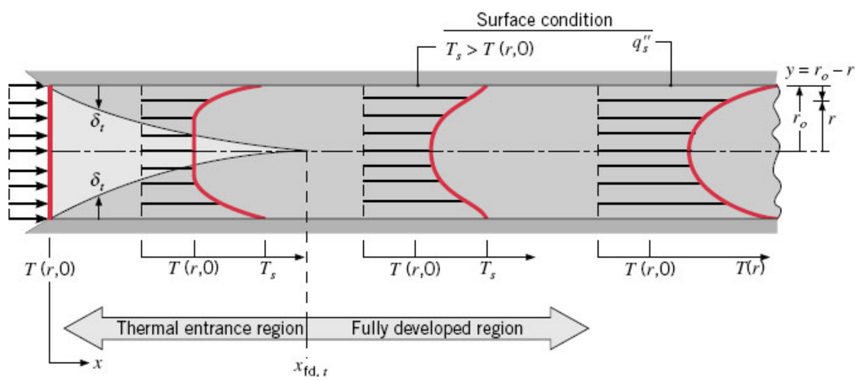
- Apparatus
  - Check www.che.utah.edu/projects_lab/
  - Include <u>key</u> specifications, preferably as a table
  - Include a schematic of the system
    - Reference appropriately if "borrowed"
- Procedure
  - Describe how the system was operated
  - Describe how data was acquired/recorded
  - Do not simply tick off step-by-step
- Do not include any of our results from Friday
  - Those are available on the web site

Entrance Regions / Boundary Layers

Flow (velocity):



Thermal:



Heat Transfer Coefficient

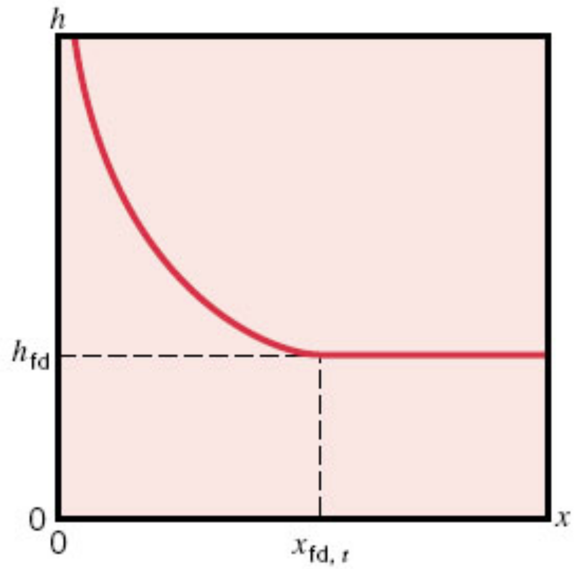
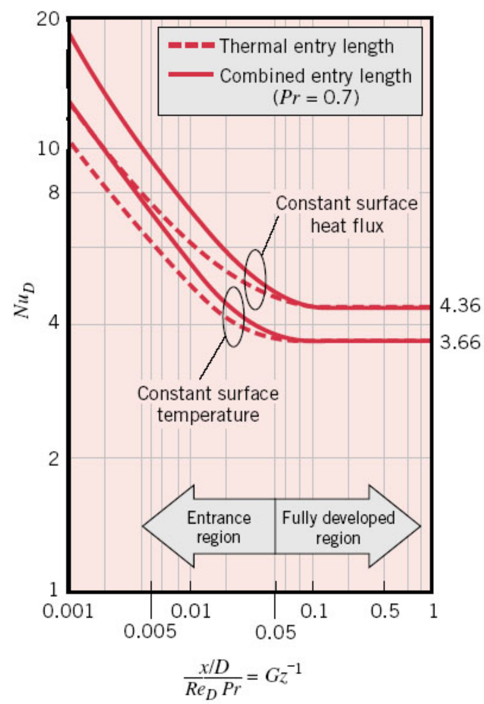


FIGURE 8.5
Axial variation of the convection heat transfer coefficient for flow in a tube.

Nu_D Development (Fig 8.10a)



$\overline{Nu}_D$ as per 8.56 and 8.57

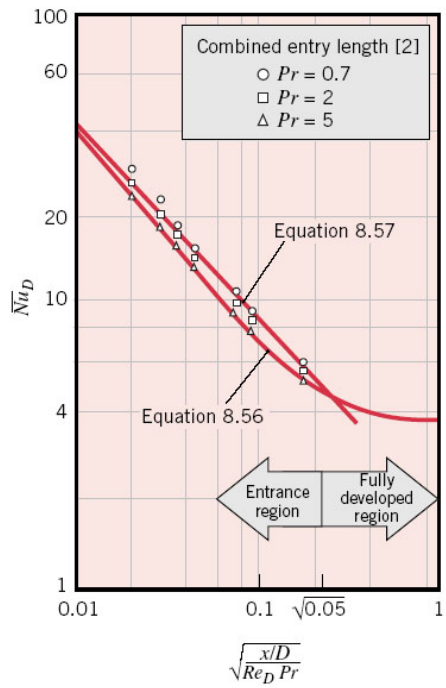
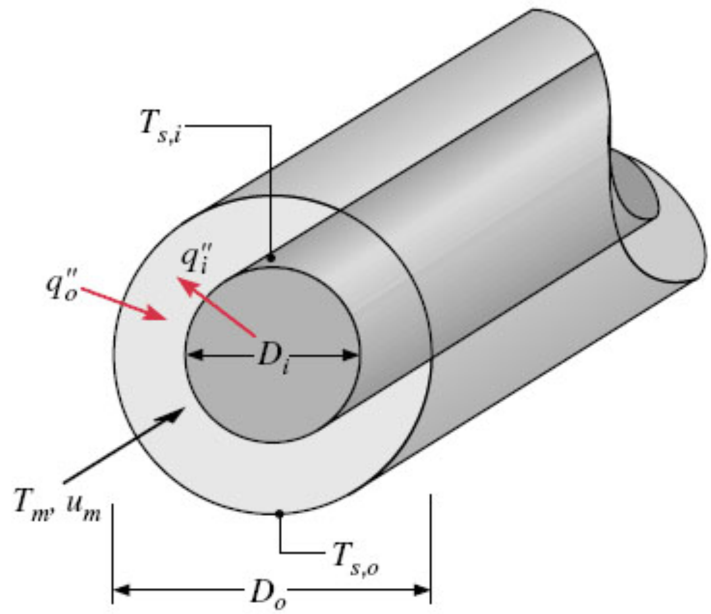


TABLE 8.1 Nusselt numbers and friction factors for fully developed laminar flow in tubes of differing cross section

Cross Section	$\frac{b}{a}$	$Nu_D \equiv \frac{hD_h}{k}$ (Uniform q_s'')	(Uniform T_s)	$f\,Re_{D_h}$
	—	4.36	3.66	64
a b	1.0	3.61	2.98	57
a b	1.43	3.73	3.08	59
a b	2.0	4.12	3.39	62
a b	3.0	4.79	3.96	69
a b	4.0	5.33	4.44	73
b	8.0	6.49	5.60	82
	∞	8.23	7.54	96
Heated / Insulated	∞	5.39	4.86	96
	—	3.11	2.49	53

Used with permission from W. M. Kays and M. E. Crawford, *Convection Heat and Mass Transfer,* 3rd ed. McGraw-Hill, New York, 1993.

Annular Flow



Annular Flow – One Surface Insulated

TABLE 8.2 Nusselt number for fully developed laminar flow in a circular tube annulus with one surface insulated and the other at constant temperature

D_i/D_o	Nu_i	Nu_o	Comments
0	—	3.66	See Equation 8.55
0.05	17.46	4.06	
0.10	11.56	4.11	
0.25	7.37	4.23	
0.50	5.74	4.43	
≈1.00	4.86	4.86	See Table 8.1, $b/a \rightarrow \infty$

Used with permission from W. M. Kays and H. C. Perkins, in W. M. Rohsenow and J. P. Hartnett, Eds., *Handbook of Heat Transfer,* Chap. 7, McGraw-Hill, New York, 1972.

Annular Flow – Heat Flux at Both Surfaces

$$Nu_i = \frac{Nu_{ii}}{1 - (q_o'' / q_i'')\theta_i^*} \qquad Nu_o = \frac{Nu_{oo}}{1 - (q_i'' / q_o'')\theta_o^*}$$

TABLE 8.3 Influence coefficients for fully developed laminar flow in a circular tube annulus with uniform heat flux maintained at both surfaces

D_i/D_o	Nu_{ii}	Nu_{oo}	θ_i^*	θ_o^*
0	—	4.364	∞	0
0.05	17.81	4.792	2.18	0.0294
0.10	11.91	4.834	1.383	0.0562
0.20	8.499	4.833	0.905	0.1041
0.40	6.583	4.979	0.603	0.1823
0.60	5.912	5.099	0.473	0.2455
0.80	5.58	5.24	0.401	0.299
1.00	5.385	5.385	0.346	0.346

Heat Transfer Enhancement

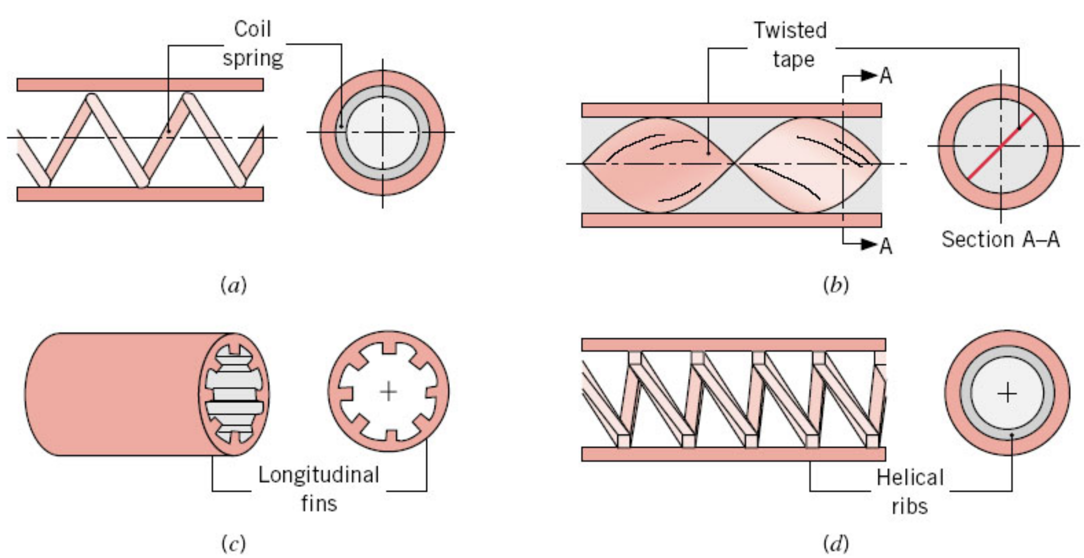


FIGURE 8.12 Internal flow heat transfer enhancement schemes: (*a*) longitudinal section and end view of coil-spring wire insert, (*b*) longitudinal section and cross-sectional view of twisted tape insert, (*c*) cut-away section and end view of longitudinal fins, and (*d*) longitudinal section and end view of helical ribs.

Example Problem

(6th edition 8.22)

Engine oil is heated by flowing through a circular tube of diameter D = 50 mm and length L = 25m and whose surface is maintained at 150°C. If the flow rate and inlet temperature are 0.5 kg/s and 20°C, what is the outlet temperature $T_{m,o}$? What is the total heat transfer rate q for the tube?