Homework 3 CM3110 Morrison

Numbered problems are from the Text; Lettered problems are on the next page.

Module	Number	Topics	Assigned Problems	Stretch Problems
3	1	pipe flow: pressure drop from Q	A	
3	2	pipe flow: flow rate from pressure drop	B	
3	3	friction from fittings vs from long pipe	9.12	
3	4	friction from laminar flow	9.8	
3	5	flow through a slit Q given		E
3	6	hydraulic diameter	7.21	
3	7	non-circular cross-section (note typo: "isosceles" should be "equilateral."	7.33	
3	8	packed beds	G	
3	9	terminal velocity	8.3	
3	10	drag coefficient	2.13	
3	11	drag coefficient		2.14
3	12	boundary layers	2.30	
3	13	boundary layers		2.31
3	14	packed bed	F	
3	15	fluidized bed incipient fluidization	H	
3	16	drag coefficient	8.47	
3	17	drag coefficient	8.49	
3	18	flow around a sphere (sketch)	8.6	
3	19	creeping flow around sphere	8.11	
3	20	creeping flow around sphere	8.12	
3	21	falling sphere with drag (see ex 8.8)		8.19
3	22	throw a ball (see example 8.8)		8.20
3	23	momentum boundary layer (words)	8.33	
3	24	streamlining, pressure drag (words)	8.46	
3	25	macro versus micro momentum bal	9.4	
3	26	60^o expanding bend-macro momentum	9.20 (getting the vector)	9.20
3	27	compare str & U tube-macro momentm		9.24
3	28	90^o expanding bend-macro momentum	9.19 (getting the vector)	9.19

A. What is the pressure drop in 200.0 meters of smooth horizontal copper tubing of inner diameter $1.5\ cm = 0.015\ m$? Water at 25^oC is flowing at $1.31 \times 10^{-2}\ m/s$ average velocity. Please give your answer in Pa. Answer: $330\ Pa$

B. What is the average velocity $\langle v \rangle\ (m/s)$ for water (25^oC) flowing in a horizontal straight pipe under a driving pressure difference of $\Delta p = 1.83 \times 10^6 Pa$? (inner diameter is $0.020m$, length is $2.0 \times 10^2\ m$). Answer: $4.5\ m/s$

E. (STRETCH) Water at 25^oC is forced through a narrow slit that is $1.0\ mm$ by $50.\ mm$ in cross section and $50.0\ cm$ long. The flow rate through the slit is $96\ cm^3/s$. What is the driving pressure? Answer: $3.0\ psig$. (Hint: The Poiseuille number may be taken to be that of an infinite slit.)

F. Please answer the following (no calculations required)

a. When fluid flows at volumetric flow rate Q through a cylindrical packed bed reactor (height L and diameter D) explain how we can calculate the expected pressure drop across the length of the bed.
b. What quantities would we need to know about the bed to determine the pressure drop? Please be specific and complete.

G. (Example 7.16 for 8mm diameter column; page 564 Morrison). An 8.0 mm diameter chromatography column consists of a packing with a void fraction $\varepsilon = 0.39$ and a specific surface area $a_v = 720cm^{-1}$. What pressure drop per unit length ($\Delta p/L$) must be applied to drive toluene through the column at 1.0 ml/min?

H. Pulverized coal is to be burned at atmospheric pressure in a fluidized bed. The density of the coal is approximately $1.0 \times 10^3 \frac{kg}{m^3}$. The mean particle diameter is $0.074mm$ and the gas, mostly air, has a viscosity of $1.0 \times 10^{-4} Pa\ s$. What is a reasonable estimate of the minimum fluidization velocity? Note that if a fluidized bed's void fraction ε is not known, Denn (*Process Fluid Mechanics*, Prentice Hall, 1980, p72) recommends the approximation $\left(\frac{\varepsilon^3}{1-\varepsilon}\right) \approx 0.091$. Answer: $v_0 = 3.2 \times 10^{-4} m/s$