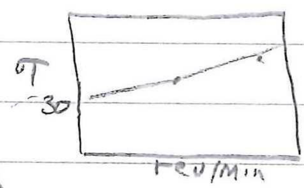
ta 3220 Re-Exam June 2012

1. a) For a Bingham plastic, τ is linear (with (du_x/dy)), and τ_o is the intercept at $(-du_x/dy) = 0$ (which means "rev/min" $= 0$).



$\tau_o = 30$ Pa

b) For a power-law fluid $\tau \propto \left(\frac{du_x}{dy}\right)^n$

(if one doesn't worry about the sign of $\left(\frac{du_x}{dy}\right)$.

$$\frac{50}{40} = \frac{(600)^n}{300^n} \; ; \; n = \frac{\ln(50/40)}{\ln(600/300)} = 0.321$$

2. In highly turbulent flow, friction factor f is indep. of Re. f doesn't change as D_o changes. $D_h = 2D_o$ (hydraulic dia.)

$$f = \frac{1}{4}\frac{D_h}{L}\frac{\Delta \mathcal{P}}{\frac{1}{2}\rho v^2} = \text{const.}$$

with Q fixed, $v \propto \frac{1}{D_o} \propto \frac{1}{D_h}$

$\therefore$ $f = \text{const} \propto \frac{D_h}{v^2}\frac{\Delta P}{L} \propto (D_h^3)\frac{\Delta \mathcal{P}}{L}$

If D_o doubles, $(\Delta P/L)_1 \rightarrow \left(\frac{\Delta P}{L}\right)_o\left(\frac{1}{8}\right)$

3. As in problem 2, $v \propto \frac{1}{D_o}$. $Re = \frac{Dv\rho}{\mu} = \text{const.}$, independent of D_o at fixed Q. For highly turbulent flow (Eq. 3.120, FT), $Nu = 0.027\, Re^{0.8} Pr^{0.33} = \text{constant}$

$Nu = \frac{h D_h}{k}$; since Nu doesn't change, $h \propto \frac{1}{D_h} \propto \frac{1}{D_o}$

$h_1 = \frac{1}{2} h_o$.

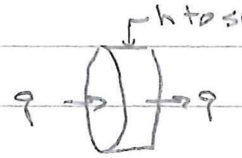
4. $P_o = 10^7$ Pa $\quad P_L = 1.01 \cdot 10^5$ Pa

$$\frac{\Delta \mathcal{P}}{L} = \frac{(10^7 - 1.01\cdot 10^5) - 850\,(9.81)\,1000}{1020} = \frac{1.56 \cdot 10^6 \text{ Pa}}{1020 \text{ m}} = 1530 \frac{\text{Pa}}{\text{m}}$$

note gravity reduces potential gradient driving flow up well.

This problem is similar to the "cooling fin" problem done in class.
Because problem statement says T does not vary with r, our control volume can extend across cross-section

5. a) Control volume: whole cross-section; thickness Δx



heat flux in: $q_z|_z \pi R^2$

out $q_z|_{z+\Delta z} \pi R^2$

heat lost to surroundings: $2\pi R \Delta z h(T-T_1)$

no convection, no generation, no accumulation

$\pi R^2 (q_z|_z - q_z|_{z+\Delta z}) - 2\pi R \Delta z h(T-T_1) = 0$, Divide by $\pi R \Delta z$

$$R \frac{(q_z|_z - q_z|_{z+\Delta z})}{\Delta z} - 2h(T-T_1) = 0$$

$$-R \frac{d q_z}{dz} = 2h(T-T_1)$$

Plug in Fourier's law

$$-R \frac{d}{dz}\left(-k\frac{dT}{dz}\right) = Rk\frac{d^2T}{dz^2} = 2h(T-T_1)$$

[one could group the parameters together if desired.]

b) BC: 1) $T = T_0$ at $z = L$

2) $\frac{dT}{dx} = 0$ at $z = 0$ (from $q_x = 0$ at $z = 0$)

6. a) Energy balance on pot

heat in = heat out.

$$Q = \frac{650 \cdot 60}{60 \cdot 15} = 43.3\ W$$

(650 W averaged over 1 minute every 15')

b) $Q = hA(T - T_{air}) = U_0(\pi(0.1)(0.1) + 2\pi(0.05)^2)(60-20)$:

$43.3 = U_0(0.0471)(40) = 1.885 U_0$

$U_0 = 23.0\ W/m^2K$

c) Some heat, at least (probably most heat) is lost by evaporation + loss of water vapor. Less heat is lost through the walls. $U_0 \leq 27.6\ W/m^2K$

7. The problem is the product of 3 slabs: one w/ $D=0.1$ (Left-right), one w/ $D=0.2$ (Back-front), + one slab does not participate (top-bottom).

$$\alpha = \frac{k}{\rho C_p} = \frac{230}{2700 \cdot 938} = 9.08 \cdot 10^{-5}\ m^2/s$$

For L-R, $\frac{\alpha t}{D^2} = F_o = 0.0908$ $\quad \frac{T_1 - T_c}{T_1 - T_o} = 0.55$ $\quad$ Fig 3.17, FT

B-F : $\frac{\alpha t}{D^2} = F_o = 0.0227$ $\quad 0.93$

Fig 3.17 applies:

$$\frac{T_1 - T_c}{T_1 - T_c} = (0.55)(0.93) = 0.512 = \frac{100 - T_c}{100}$$

$$T_c = 48.8$$

(Could also use Fig 12.1-1 of BSL. $\frac{\alpha t}{b^2} = 0.363$ and 0.0908

$\frac{T_1 - T}{T_1 - T_0} \approx 0.53$ and 0.97