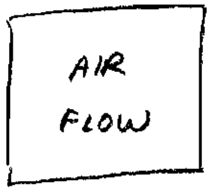
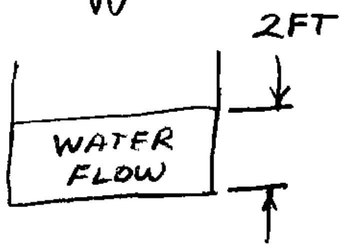
10.115 GIVEN: AIR FLOW AND WATER FLOW AS SHOWN BELOW.

A



4 FT SQUARE DUCT

W



4 FT WIDE OPEN CHANNEL

FIND: R_A, R_W, AND R_A/R_W

SOLUTION: $R_A = \dfrac{A_A}{P_A} = \dfrac{4 \times 4}{4+4+4+4} = 1$

$R_W = \dfrac{A_W}{P_W} = \dfrac{2 \times 4}{2+4+2} = 1$

$\boxed{\text{(a)} \quad R_A = R_W}$

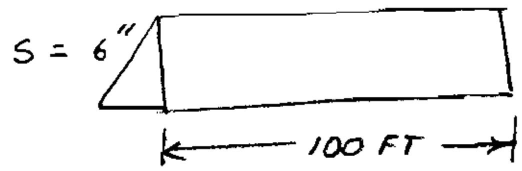
10.116

GIVEN: AIR AT 60°F

FLOW THROUGH A DUCT

WITH AN EQUILATERAL

TRIANGLE CROSS SECTION.



$$A = \frac{sh}{2}$$

$k_s = 0.0005$ FT & $\overline{V} = 12$ FT/s

FIND: PRESSURE DROP OVER 100 FOOT LENGTH.

SOLUTION: $$Re = \frac{\frac{4A}{P}\overline{V}}{\nu} \qquad A = \frac{\sqrt{3}\,S^2}{4}, \quad P = 3S$$

TABLE A.3 $\rightarrow$ $\nu = 1.58 \times 10^{-4}\ \frac{FT^2}{s}$, $\rho = .00237\ \frac{SLUGS}{FT^3}$

$$\frac{4A}{P} = \frac{\sqrt{3}\,S^2}{3S} = \frac{\sqrt{3}}{3}S$$

$$Re = \frac{\frac{\sqrt{3}}{3}\left(\frac{6}{12}\right)12}{1.58 \times 10^{-4}} = 22{,}000$$

RELATIVE ROUGHNESS: $$\frac{k_s}{\frac{4A}{P}} = \frac{.0005}{\left(\frac{\sqrt{3}}{3}\right)\left(\frac{6}{12}\right)} = .0017$$

ENTER MOODY DIAGRAM WITH $Re = 2 \times 10^4$

AND R.R. $= .0017 \Rightarrow f = 0.030$

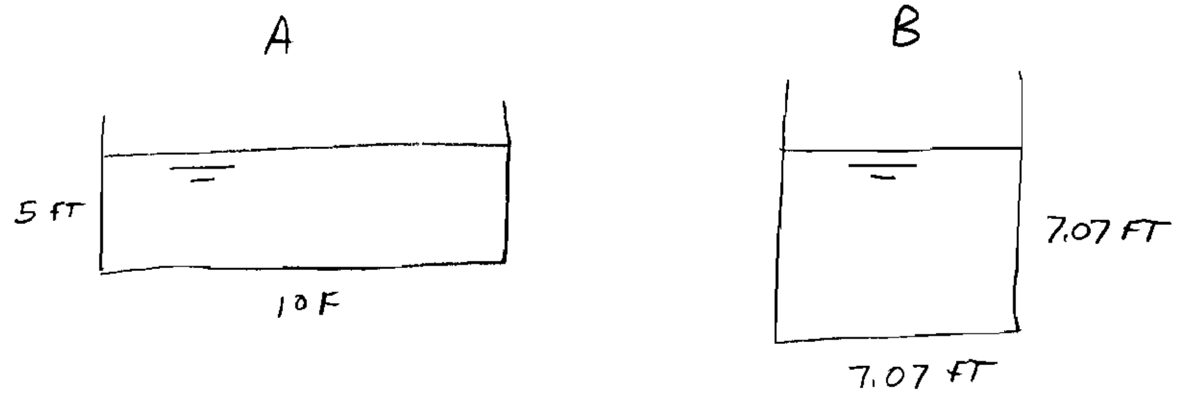
$$p_1 - p_2 = \gamma h_L = \gamma f \frac{L}{(4A/P)} \frac{V^2}{2g}, \quad \gamma = \rho g$$

$$p_1 - p_2 = \frac{1}{2}\rho V^2 f \frac{L}{\sqrt{3}\,S}$$

$$p_1 - p_2 = \frac{1}{2}(.00237)(12)^2(0.030)\frac{100}{\frac{\sqrt{3}}{3}\left(\frac{6}{12}\right)}$$

$$\boxed{p_1 - p_2 = 1.77 \text{ PSF}}$$

10.117



GIVEN: TWO CHANNELS WITH SAME SLOPE, SAME WALL ROUGHNESS, AND SAME CROSS SECTIONAL FLOW AREA.

FIND: $Q_A < = > Q_B$?

SOLUTION: THE CHANNEL WITH THE LOWEST FRICTIONAL LOSSES WILL HAVE THE GREATEST FLOW RATE.

$$h_{fA} = f_A \frac{L}{(4Rh)_A} \frac{V^2}{2g} \qquad (4Rh)_A = \frac{4A}{P} = \frac{4(50)}{20}$$

$$(4Rh)_A = 10 \text{ FT}$$

$$h_{fB} = f_B \frac{L}{(4Rh)_B} \frac{V^2}{2g} \qquad (4Rh)_B = \frac{4(50)}{3 \times 7.07} = 9.43 \text{ FT}$$

$f_A \approx f_B$ SINCE f IS A WEAK FUNCTION OF Re.

$$Rh_A > Rh_B \Rightarrow h_{fA} < h_{fB}$$

$$\Rightarrow \boxed{(c)\ Q_A > Q_B}$$

15.1 (1) GIVEN: WATER FLOWS AT A DEPTH OF 4 IN. WITH A VELOCITY OF 28 FT/S IN A RECTANGULAR CHANNEL.

FIND: (a) IS THE FLOW SUBCRITICAL OR SUPERCRITICAL? (b) WHAT IS THE ALTERNATE DEPTH?

SOLUTION: (a) THE CRITICAL DEPTH IS: $y_c = \left(\frac{q^2}{g}\right)^{\frac{1}{3}} = \left[\frac{(y_1 V_1)^2}{g}\right]^{\frac{1}{3}}$

$$y_c = \left[\frac{(\frac{4}{12}\ 28)^2}{32.2}\right]^{\frac{1}{3}} \qquad y_c = 1.39 \text{ FT}$$

4 IN < 1.39 FT SO THE FLOW IS <u>SUPERCRITICAL</u>.

(b) THE SPECIFIC ENERGY OF THE FLOW IS:

$$E = y_1 + \frac{V_1^2}{2g} = \frac{4}{12} + \frac{28^2}{64.4}$$

$$E = 12.5 \text{ FT}$$

THE ALTERNATE DEPTH IS GIVEN BY:

$$y_2 + \frac{V_2^2}{2g} = 12.5 \text{ FT} \qquad (1)$$

ALSO NEED CONTINUITY:

$$y_1 V_1 = y_2 V_2 \qquad (2)$$

15.1 (2)

$$\left(\frac{4}{12}\right)(28) = y_2 V_2$$

$$y_2 V_2 = 9.33 \Rightarrow V_2 = \frac{9.33}{y_2}$$

PUT $V_2 = \frac{9.33}{y_2}$ INTO EQN. (1)

$$y_2 + \frac{\left(\frac{9.33}{y_2}\right)^2}{2g} = 12.5$$

$$y_2 + \frac{1.353}{y_2^2} = 12.5$$

$$y_2^3 - 12.5\, y_2^2 + 1.353 = 0$$

Root solver to find alternate depth.

$g(y) := y^3 - 12.5y^2 + 1.353$ First guess: $y := .5$ (units of feet)

$h := \mathrm{root}(g(y), y)$ $h = 0.3335$

The first guess yields the original supercritical depth of .333 feet or 4 inches.

Second guess: $y := 10$

$h := \mathrm{root}(g(y), y)$ $h = 12.4913$

The second guess yields the alternate depth of 12.5 feet. The is the subcritical flow depth.

$$\boxed{y_2 = 12.5 \text{ FT}}$$

$$V_2 = 0.75 \ \frac{\text{FT}}{\text{S}}$$

15.2 GIVEN: WATER FLOW IN A RECTANGULAR CHANNEL AT 900 CFS. THE CHANNEL IS 16 FT WIDE AND THE WATER DEPTH IS 3 FT.

FIND: IS THE FLOW SUBCRITICAL OR SUPERCRITICAL?

SOLUTION: THE CRITICAL DEPTH IS $y_c = \left(\frac{q^2}{g}\right)^{\frac{1}{3}}$

$$q = y_1 V_1$$

BUT WE ARE GIVEN: $Q = y_1 V_1 w_1$

$$y_1 V_1 = \frac{Q}{w} = \frac{900}{16} = 56.25 \ \frac{FT^2}{S}$$

$$y_c = \left(\frac{56.25^2}{32.2}\right)^{\frac{1}{3}} = 4.61 \text{ FT}$$

$y_1 < y_c$, SO THE FLOW IS SUPERCRITICAL