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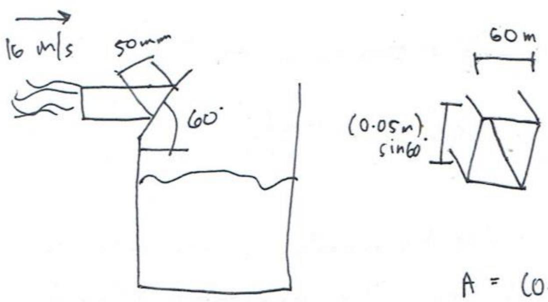
2018101135, CE-3

CE142P-1, E02

MODULE 2, CW8

F4-1 to F413, pp. 186 - 188

F4-1. Water flows into the tank through a rectangular tube. If the average velocity of the flow is 16 m/s, determine the mass flow. Take $\rho_w = 1000\ kg/m^3$.



mass flow $= \rho_w VA$

$= (1000\ \frac{kg}{m^3})(16\ \frac{m}{s})(0.06m)(0.043m)$

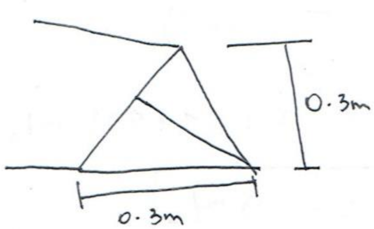
$= 41.56921938\ kg/s$

$A = (0.05m)(\sin 60°)$

$A = 0.04330127019\ m$

$\boxed{\text{mass flow} = 41.569\ kg/s}$

F4-2. Air flows through the triangular duct at 0.7 kg/s when the temperature is 15°C and the gage pressure is 70 kPa. Determine its average velocity. Take $P_{atm} = 101\ kPa$.



$P = \rho RT$

$P = 101\ kPa + 70\ kPa = 171\ kPa$ or $171 \times 10^3\ N/m^2$

$171 \times 10^3\ N/m^2 = \rho\ (286.9\ \frac{J}{kg})\ (15 + 273K)$

$\rho = 2.069536424\ kg/m^3$

$A = \frac{1}{2}(0.3m)(0.3m)$

$A = 0.045\ m$

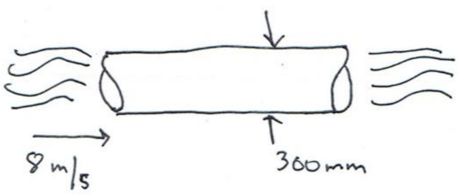
$m = \rho VA$

$0.7\ \frac{kg}{s} = (2.06953642\ \frac{kg}{m^3})(V)(0.045m)$

$V = 7.516444444\ m/s$

$\boxed{V = 7.516\ m/s}$

F4-3. Water has an average velocity of 8 m/s through the pipe. Determine the volumetric flow and mass flow.



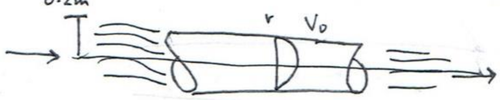
$$Q = VA$$
$$= (8\ \text{m/s})(0.07068583471\ \text{m})$$
$$= 0.565486677\text{6}\ \text{m}^3/\text{s}$$

$$A = \pi(0.15\ \text{m})^2$$
$$A = 0.07068583471\ \text{m}$$

$$\boxed{\dot{m} = 565.487\ \text{kg/s}}$$

$$\dot{m} = \rho_w Q$$
$$= \left(1000\ \frac{\text{kg}}{\text{m}^3}\right)\left(0.5654866776\ \text{m}^3/\text{s}\right)$$
$$\dot{m} = 565.4866776\ \text{kg/s}$$

F4-4. Crude oil flows through the pipe at 0.02 m³/s. If the velocity profile is assumed to be as shown, determine the maximum velocity V_o of the oil and the average velocity.

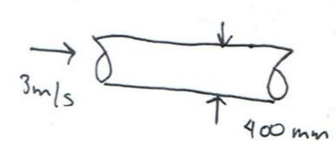


$V = V_o(1 - 25r^2)$ m/s

$$Q = V_o A$$
$$0.02\ \text{m}^3/\text{s} = V_o\left[\tfrac{1}{2}\pi(0.2\ \text{m})^2\right]$$
$$0.02\ \text{m}^3/\text{s} = V_o(0.06283185307)$$
$$V_o = 0.3183098862\ \text{m/s}$$
$$\boxed{V_o = 0.318\ \text{m/s}}$$

$$V_{avg} = \frac{Q}{A}$$
$$= \frac{0.02\ \text{m}^3/\text{s}}{\pi(0.2\ \text{m}^2)}$$
$$V_{avg} = 0.1591549431\ \text{m/s}$$
$$\boxed{V_{avg} = 0.159\ \text{m/s}}$$

F4-5. Determine the mass flow of air having a temperature of 20 °C and the pressure of 80 kPa as it flows through the circular duct with an average velocity of 3 m/s.



$$P = \rho RT$$
$$181\times10^3\ \text{N/m}^2 = \rho\left(286.9\ \frac{\text{J}}{\text{kg}\cdot\text{K}}\right)(20 + 273\ \text{K})$$
$$181\times10^3\ \text{N/m}^2 = \rho\left(286.9\ \frac{\text{J}}{\text{kg}\cdot\text{K}}\right)(293\ \text{K})$$
$$\rho = 2.153180343\ \text{kg/m}^3$$

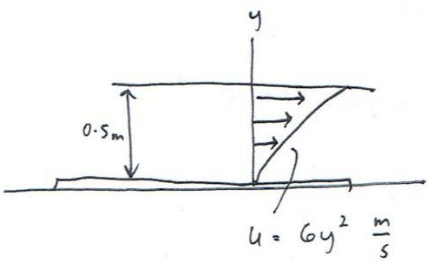
$$P = 80\ \text{kPa} + 101\ \text{kPa}$$
$$= 181\ \text{kPa}$$
$$= 181\times10^3\ \text{N/m}^2$$

$$\dot{m} = \rho V A$$
$$= \left(2.153\ \frac{\text{kg}}{\text{m}^3}\right)\left(3\ \frac{\text{m}}{\text{s}}\right)(0.12567\ \text{m}^2)$$
$$\dot{m} = 0.8117298657\ \text{kg/s}$$

$$A = \pi(0.2\ \text{m})^2$$
$$= 0.1256637061\ \text{m}^2$$

$$\boxed{\dot{m} = 0.812\ \frac{\text{kg}}{\text{s}}}$$

F4-6. If the velocity for a very viscous liquid as it flows through a 0.5 m-wide rectangular channel is approximated as $u = 6y^2 \frac{m}{s}$, where y is in meters, determine the volumetric flow.

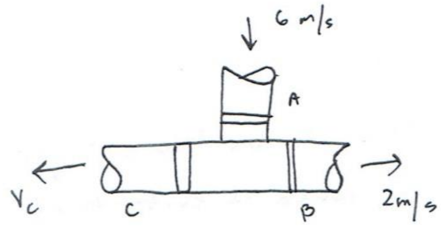


$$Q = VA$$

$$= \frac{1}{3}(0.5\,m)\left[6(0.25)\,\frac{m}{s}\right]\left[0.5\,m\right]$$

$$\boxed{Q = 0.125\ m^3/s}$$

F4-7. The average velocity of the steady flow at A and B is indicated. Determine the average velocity at C. The pipes have cross-sectional areas of $A_A = A_C = 0.1\,m^2$ and $A_B = 0.2\,m^2$.



$$\frac{\partial}{\partial t}\int_{cv} \rho\, dV + \int_{cs} \rho V\, dA = 0$$

$$0 - V_A A_A + V_B A_B + V_c A_c = 0$$

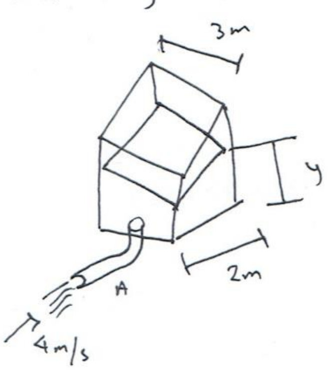
$$0 - (6\,\tfrac{m}{s})(0.1\,m^2) + (2\,m/s)(0.2\,m^2) + V_c\,(0.1\,m^2) = 0$$

$$0 - 0.6\ m^3/s + 0.4\ m^3/s + V_c(0.1\,m^2) = 0$$

$$\frac{\cancel{0.1\,m^2}\,V_c}{\cancel{0.1\,m^2}} = + \frac{0.2\ m^3/s}{0.1\,m^2}$$

$$\boxed{V_c = 2\ m/s \quad \text{or} \quad 2.000\ m/s}$$

F4-8. A liquid flows into the tank A at $4\,\frac{m}{s}$. Determine the rate, $\frac{dy}{dt}$, at which the level of the liquid is rising in the tank. The cross sectional area of the pipe at A is $A_A = 0.1\,m^2$



$$V = (3m)(2m)(y)$$

$$V = 6y\ m^3$$

$$\frac{\partial}{\partial t} = 6\,\frac{\partial y}{\partial t}$$

$$\frac{\partial}{\partial t}\int_{cv} \rho_1\, dV + \int_{cs} \rho_1 V\, dA = 0$$

$$\rho_1 \frac{\partial V}{\partial t} - \rho_1 V_A A_A = 0$$

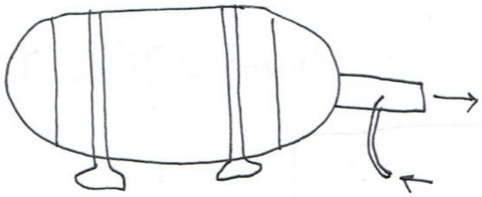
$$\frac{\partial V}{\partial t} = V_A A_A$$

$$\frac{\cancel{6}\,\frac{\partial y}{\partial t}}{\cancel{6}} = \frac{(4\,m/s)(0.1\,m^2)}{6}$$

$$= 0.0667\ m/s$$

$$\boxed{\frac{\partial y}{\partial t} = 0.067\ m/s}$$

F4-9. As air exits the tank at 0.05 kg/s, it is mixed with water at 0.002 kg/s. Determine the average velocity of the mixture as it exits the 20 mm-diameter pipe if the density of the mixture is 1.45 kg/m³.



$$\frac{\partial}{\partial t}\int_{cv} \rho \, dV + \int_{cs} \rho \mathbf{V} \cdot d\mathbf{A} = 0$$

$$A = \pi (0.01 m^2) = 3.141592654 \times 10^{-4}$$

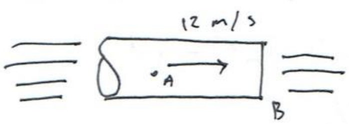
$$0 - m_a - m_w + \rho_m V_A = 0$$

$$0 - 0.05 \frac{kg}{s} - 0.02 \frac{kg}{s} + \left(1.45 \frac{kg}{m^3}\right) V \left(3.141 m^2\right) = 0$$

$$0 - 0.05 \frac{kg}{s} - 0.02 \frac{kg}{s} + 4.555 \times 10^{-4} V = 0$$

$$\boxed{V = 114 \ m/s}$$

F4-10. Air at a temperature of 16°C and gage pressure of 200 kPa flows through the pipe at 12 m/s when it is at A. Determine its average velocity when it exits the pipe at B if its temperature there is 70°C.



$$P = 200 \text{ kPa} + 101 \text{ kPa}$$

$$= 301 \text{ kPa}$$

$$= 301 \times 10^3 \ N/m^2$$

$$P = \rho_A R T_A$$

$$301 \times 10^3 \ N/m^2 = \rho_A \left(286.9 \frac{J}{kg} \cdot K\right)(16 + 273 K)$$

$$\rho_A = 3.6303 \ kg/m^3$$

$$P = \rho_B R T_B$$

$$301 \times 10^3 \ N/m^2 = \rho_B \left(286.9 \frac{J}{kg} \cdot K\right)(70 + 273 K)$$

$$\rho_B = 3.0587 \ kg/m^3$$

$$\frac{\partial}{\partial t}\int_{cv} \rho \, dV + \int_{cs} \rho \mathbf{V} \cdot d\mathbf{A} = 0$$

$$0 - \rho_A V_A A_A + \rho_B V_B A_B = 0$$

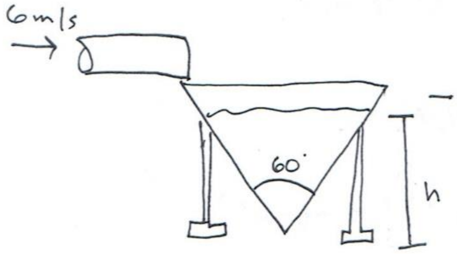
since $A_A = A_B$

$$0 - \rho_A V_A + \rho_B V_B = 0$$

$$\boxed{V_B = 14.243 \ m/s}$$

$$V_B = V_A \left(\frac{\rho_A}{\rho_B}\right) = \left(12 \frac{m}{s}\right)\left(\frac{3.6303 \ kg/m^3}{3.0587 \ kg/m^3}\right) = 14.24252133 \ m/s$$

F4-11. Determine the rate at which water is rising in the triangular container when $t = 10\,s$ if the water flows from the 50-mm diameter pipe with an average speed of 6 m/s. The container is 1m long. At $t = 0\,s$, $h = 0.1\,m$.



$$V = \frac{1}{2}(2h\tan 30^\circ)(h)(1m)$$

$$V = h^2 \tan 30^\circ$$

$$\frac{\partial V}{\partial t} = 2\tan 30^\circ h \frac{\partial h}{\partial t}$$

$$\frac{\partial}{\partial t}\int_{cv} \rho_w \, dV + \int_{cs} \rho_w V \, dA = 0$$

$$\rho_w \frac{\partial V}{\partial t} - \rho_v VA = 0$$

$$\frac{\partial V}{\partial t} = VA$$

$$\frac{\partial V}{\partial t} = VA$$

$$2\tan 30^\circ h \frac{\partial h}{\partial t} = (6\,\tfrac{m}{s})(\pi\,(0.025\,m)^2)$$

$$\frac{\partial h}{\partial t} = \frac{0.01020}{h} \quad \text{— Eq. 1}$$

$$\int_{0.1}^{h} h\,dh = 0.01020\int_0^t dt$$

$$h^2 - (0.1\,m)^2 = 0.020405$$

$$h = \sqrt{0.020405t + 0.01}$$

$t = 10s$;

$$h = \sqrt{0.020405(10) + 0.01}$$

$$h = 0.46266$$

Eq. 1

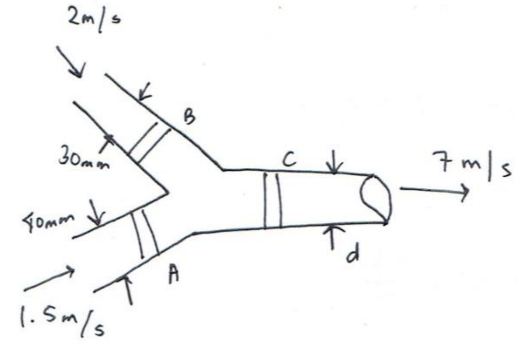
$$\frac{\partial h}{\partial t} = \frac{0.01020}{h}$$

$$\frac{\partial h}{\partial t} = \frac{0.01020}{0.46266}$$

$$\frac{\partial h}{\partial t} = 0.0220464271 8\,m/s$$

$$\boxed{\frac{\partial h}{\partial t} = 0.022\,m/s}$$

F4-12. Determine the required diameter of the pipe at C so that water flows through the pipe at rates shown.



$$\frac{\partial}{\partial t}\int_{cv} \rho\, dV + \int_{cs} \rho V dA = 0$$

$$0 - V_A A_A - V_B A_B + V_C A_C = 0$$

$$0 - (1.5\tfrac{m}{s})(1.256\, m^2) - (2\tfrac{m}{s})(7.069\, m^2) + (7\tfrac{m}{s})(\tfrac{\pi}{4}d^2) = 0$$

$A_A = \pi(0.02\,m)^2 = 1.256637061 \times 10^{-3}$

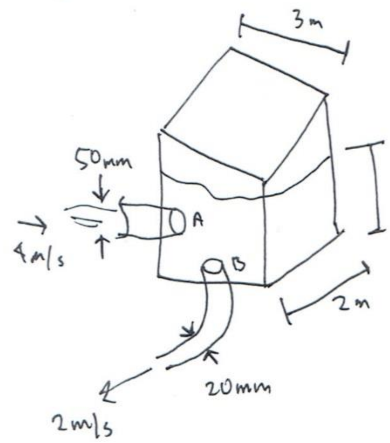
$A_B = \pi(0.015\,m)^2 = 7.068583471 \times 10^{-4}$

$A_C = \frac{\pi}{4}d^2$

$d = 0.02449\ m$

$$\boxed{d = 24.5\ m}$$

F4-13. Oil flows into the tank with an average velocity of 4 m/s through the 50 mm-diameter pipe at A. It flows out of the tank at 2 m/s through the 20 mm-diameter pipe at B. Determine the rate at which the depth y of the oil in the tank is changing.



$$\frac{\partial}{\partial t}\int_{cv} \rho_o\, dV + \int_{cs} \rho_o V dA = 0$$

$$\rho_o \frac{\partial}{\partial t} V - \rho_o V_A A_A + \rho_o V_B A_B = 0$$

$$\rho_o \frac{\partial}{\partial t}\left[y(2m)(3m)\right] - \rho_o (4\tfrac{m}{s})(\pi(0.025\,m)^2) + \rho_o (2\tfrac{m}{s})(\pi(0.01\,m)^2) = 0$$

$$(6m^2)\frac{\partial y}{\partial t} = 7.226\times10^{-3}\ m^3/s$$

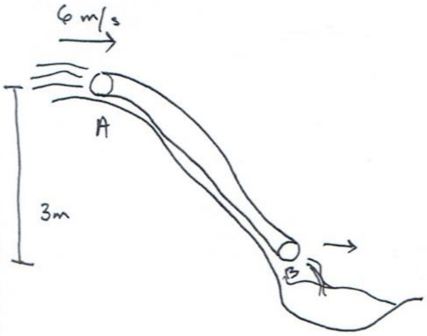
$$V_y = \frac{\partial y}{\partial t} = \frac{7.226\times10^{-3}\ m^3/s}{6m^2}$$

$V_y = 1.20433333\times10^{-3}\ m/s$

$$\boxed{V_y = 1.204\ m/s}$$

F5-1 to F5-12, pp. 248 - 250

F5-1. Water flows through the pipe at A at 6 m/s. Determine the pressure at A and the velocity of the water as it exits the pipe at B.



$$V_B = V_A = 6\ \frac{m}{s}$$

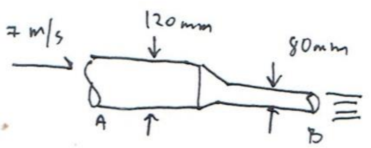
$$\boxed{V_B = 6\ m/s}$$

$$\frac{P_A}{\rho_w} + \frac{V_A^2}{2} + gz_A = \frac{P_B}{\rho_w} + \frac{V_B^2}{2} + gz_B$$

$$\frac{P_A}{1000\ \frac{kg}{m^3}} + \cancel{\frac{V^2}{2}} + (9.81\ \tfrac{m}{s^2})(3\ m) = 0 + \cancel{\frac{V^2}{2}} + 0 \quad ; \quad P_A = -29.430 \times 10^{-3}\ Pa$$

$$\boxed{P_A = -29.430\ kPa}$$

F5-2. Oil is subjected to a pressure of 300 kPa at A, where its velocity is 7 m/s. Determine its velocity and the pressure at B. $\rho_o = 940\ kg/m^3$.



$$\frac{\partial}{\partial t}\int_{cv} \rho\, dV + \int_{cs} \rho V\, dA = 0$$

$$0 - V_A A_A + V_B A_B = 0$$

$$A_A = \pi(0.06\ m)^2 = 0.011309733355\ m^2$$
$$A_B = \pi(0.04\ m)^2 = 5.026548 \times 10^{-3}\ m^2$$

$$0 - (7\ \tfrac{m}{s})(0.0113) + V_B(5.02 \times 10^{-3}) = 0$$

$$\boxed{V_B = 15.757\ m/s}$$

$$\frac{P_A}{\rho_o} + \frac{V_A^2}{2} + gz_A = \frac{P_B}{\rho_o} + \frac{V_B^2}{2} + gz_B$$

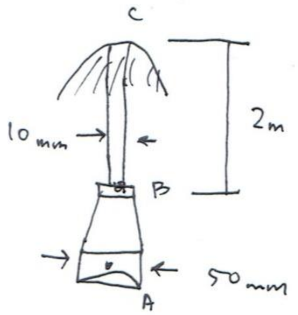
$z_A = z_B = z$;

$$\frac{300 \times 10^3\ N/m^2}{940\ kg/m^3} + \frac{(7\ m/s)^2}{2} + gz = \frac{P_B}{940\ kg/m^3} + \frac{(15.75\ m/s)^2}{2} + gz$$

$$P_B = 206.44 \times 10^3\ Pa$$

$$\boxed{P_B = 206.441\ kPa}$$

F5 - 3. The fountain is to be designed so that water is ejected from the nozzle and reaches a maximum elevation of 2m. Determine the required water pressure in the pipe at A, a short distance AB from the nozzle exit.



$$P_c = P_B = 0$$

$$V_c = 0$$

$$\frac{P_B}{\rho_w} + \frac{V_B^2}{2} + g z_B = \frac{P_c}{\rho_w} + \frac{V_c^2}{2} + g z_c$$

$$0 + \frac{V_B^2}{2} + 0 = 0 + 0 + (9.81\ m/s^2)(2m)$$

$$V_B = 6.264\ m/s$$

$$\frac{\partial}{\partial t}\int_{cv} \rho\, dV + \int_{cs} \rho V dA = 0$$

$$0 - V_A A_A + V_B A_B = 0$$

$$0 - V_A \left[\pi (0.025 m)^2\right] + (6.264\ m/s)\left[\pi (0.005 m)^2\right] = 0$$

$$V_A = 0.2506\ m/s$$

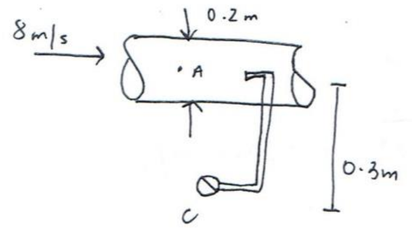
$$\frac{P_A}{\rho_w} + \frac{V_A^2}{2} + g z_A = \frac{P_B}{\rho_w} + \frac{V_B^2}{2} + g z_B$$

$$\frac{P_A}{1000\ \frac{kg}{m^3}} + \frac{(0.2506\ m/s)^2}{2} + 0 = 0 + \frac{(6.264\ m/s)^2}{2} + 0$$

$$P_A = 19.59 \times 10^3\ Pa$$

$$\boxed{P_A = 19.593\ kPa}$$

F5-4. Water flows through the pipe at 8 m/s. Determine the pressure reading on the gage C if the pressure at A is 80 kPa.



$$V_A = 8 \text{ m/s} \qquad z_A = z_B = 0$$

$$V_B = 0$$

$$\frac{P_A}{\rho_w} + \frac{V_A^2}{2} + g z_A = \frac{P_B}{\rho_w} + \frac{V_B^2}{2} + g z_B$$

$$\frac{80 \times 10^3 \text{ N/m}^2}{1000 \text{ kg/m}^3} + \frac{(8 \text{ m/s})^2}{2} + 0 = \frac{P_B}{1000 \frac{\text{kg}}{\text{m}^3}} + 0 + 0$$

$$P_B = 112 \times 10^3 \text{ Pa}$$

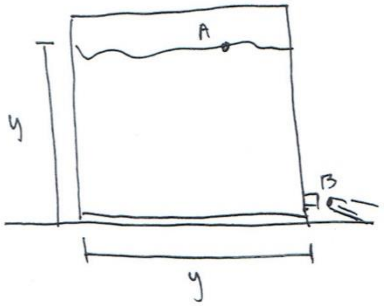
$$P_B + \rho_w g h_w = P_C$$

$$112 \times 10^3 \text{ Pa} + (1000 \text{ kg/m}^3)(9.81 \text{ m/s}^2)(0.3 \text{ m}) = P_C$$

$$P_C = 114.943 \times 10^3 \text{ Pa}$$

$$\boxed{P_C = 114.943 \text{ kPa}}$$

F5-5. The tank has a square base and is filled with water to the depth of y = 0.4 m. If the 20 mm-diameter drain pipe is opened, determine the initial volumetric flow of the water and the volumetric flow when y = 0.2 m



$$V = (2\text{m})(2\text{m})\, y = 4y$$

$$\frac{\partial V}{\partial t} = 4 \frac{\partial y}{\partial t}$$

$$4 \frac{\partial y}{\partial t} = V_B A_B$$

$$4 \frac{\partial y}{\partial t} = V_B \left[\pi (0.01 \text{m})^2\right]$$

$$V_A = \frac{\partial y}{\partial t} = 25\pi \times 10^{-6} V_B$$

$$\frac{\partial}{\partial t} \int_{cv} \rho_w \, dV + \int_{cs} \rho_w V \, dA = 0$$

$$\rho_w \frac{\partial V}{\partial t} + \rho_w V_B A_B = 0$$

$$\frac{\partial V}{\partial t} = V_B A_B$$

$P_A = P_B = 0$

$$\frac{P_A}{\rho_w} + \frac{V_A^2}{2} + gz_A = \frac{P_B}{\rho_w} + \frac{V_B^2}{2} + gz_B$$

$$0 + 0 + (9.81\ m/s^2)\,y = 0 + \frac{V_B^2}{2} + 0$$

$$V_B = \sqrt{19.62y}$$

At $y = 0.4m$,

$$V_B = \sqrt{19.62(0.4)} = 2.801\ m/s$$

$$Q = V_B A_B$$

$$= (2.801\ m/s)\left[\pi(0.01m)^2\right]$$

$$\boxed{Q = 8.7996 \times 10^{-4}\ m^3/s}$$

At $y = 0.2m$,

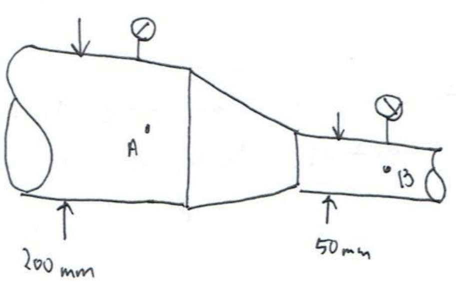
$$V_B = \sqrt{19.62(0.2)} = 1.981\ m/s$$

$$Q = V_B A_B$$

$$= (1.981\ m/s)\left[\pi(0.01m)^2\right]$$

$$\boxed{Q = 0.622 \times 10^{-3}\ m^3/s}$$

F5-6. Air at a temperature of 80 °C flows through the pipe. At A, the pressure is 20 kPa, and the average velocity is 4 m/s. Determine the pressure reading at B. Assume the air is incompressible.



$$\frac{\partial}{\partial t}\int_{cv} \rho\, dV + \int_{cs} \rho V dA = 0$$

$$0 - V_A A_A + V_B A_B = 0$$

$$0 - (4\ m/s)\left[\pi(0.1m)^2\right] + V_B\left[\pi(0.025m)^2\right] = 0$$

$$V_B = 64\ m/s$$

Between A & B,

$z_A = z_B = 0$

$\rho_a = 1.000\ kg/m^3$

$T = 80°C$

$$\frac{P_A}{\rho_a} + \frac{V_A^2}{2} + gz_A = \frac{P_B}{\rho_a} + \frac{V_B^2}{2} + gz_B$$

$$\frac{20\times10^3\ N/m^3}{1000\ kg/m^3} + \frac{(4\ m/s)^2}{2} + 0 = \frac{P_B}{1000\ kg/m^3} + \frac{(64\ m/s)^2}{2} + 0$$

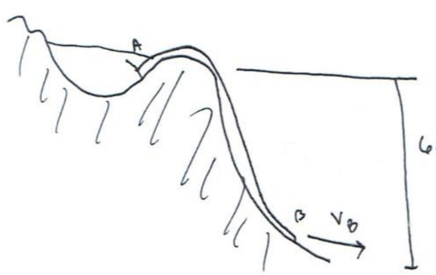
$$P_B = 17.961 \times 10^3\ Pa$$

$$\boxed{P_B = 17.961\ kPa}$$

F5-7. Water flows from the reservoir through the 100 mm-diameter pipe. Determine the discharge at B. Draw the energy grade line and the hydraulic grade line for the flow from A to B.

$$P_A = P_B = 0 \qquad z_A = 6\,\text{m}$$

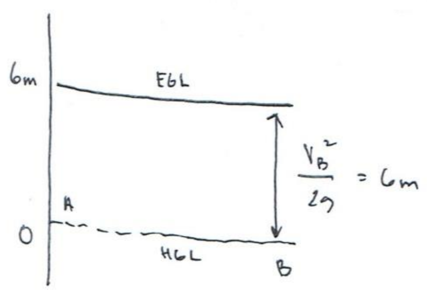
$$V_A = 0 \qquad z_B = 0$$



$$\frac{P_A}{\gamma_w} + \frac{V_A^2}{2g} + z_A = \frac{P_B}{\gamma_w} + \frac{V_B^2}{2g} + z_B$$

$$0 + 0 + 6\,\text{m} = 0 + \frac{V_B^2}{2(9.81\,\text{m/s}^2)} + 0$$

$$V_B = 10.85\,\text{m/s}$$



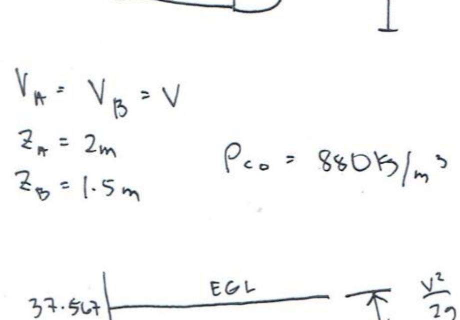
$$Q = V_B A_B$$

$$= (10.85\,\text{m/s})\left[\pi(0.05\,\text{m})^2\right]$$

$$\boxed{Q = 0.0852\,\text{m}^3/\text{s}}$$

$$\frac{V_B^2}{2g} = \frac{(10.85\,\text{m/s})^2}{2(9.81\,\text{m/s}^2)} = 6\,\text{m}$$

F5-8. Crude oil flows through the 50 mm-diameter pipe such that at A its average velocity is 4 m/s and the pressure is 300 kPa. Determine the pressure of the oil at B. Draw the energy grade line and the hydraulic grade line for the flow from A to B.



$$\frac{P_A}{\gamma_{co}} + \frac{V_A^2}{2g} + z_A = \frac{P_B}{\gamma_{co}} + \frac{V_B^2}{2g} + z_B$$

$$\frac{300\times10^3\,\text{N/m}^2}{(880\,\text{kg/m}^3)(9.81\,\text{m/s}^2)} + \frac{V^2}{2g} + 2\,\text{m} = \frac{P_B}{(880\,\text{kg/m}^3)(9.81\,\text{m/s}^2)} + \frac{V^2}{2g} + 1.5\,\text{m}$$

$$P_B = 304.32\times10^3\,\text{Pa}$$

$$\boxed{P_B = 304.321\,\text{kPa}}$$

$V_A = V_B = V$

$z_A = 2\,\text{m}$

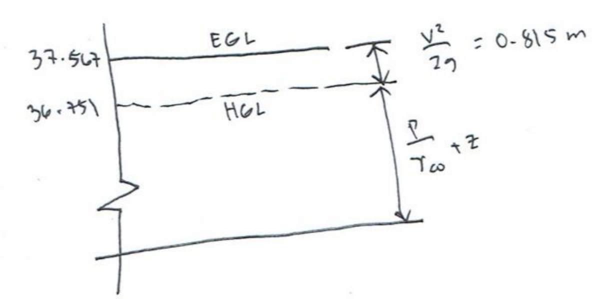
$z_B = 1.5\,\text{m}$

$\rho_{co} = 880\,\text{kg/m}^3$

$$H = \frac{P_A}{\gamma_{co}} + \frac{V_A^2}{2g} + z_A$$

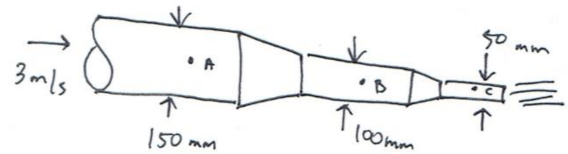
$$= \frac{300\times10^3\,\text{N/m}^2}{(880\,\text{kg/m}^3)(9.81\,\text{m/s}^2)} + \frac{(4\,\text{m/s})^2}{2(9.81\,\text{m/s}^2)} + 2\,\text{m}$$

$$H = 37.567\,\text{m}$$



$$\frac{V^2}{2g} = \frac{(4\,\text{m/s})^2}{2(9.81\,\text{m/s}^2)} = 0.815\,\text{m}$$

F5-9. At A, the water pressure of 400 kPa and a velocity of 3 m/s flows through the transitions. Determine the pressure and velocity at B and C. Draw the energy grade line and the hydraulic grade line for the flow from A to C.



$$\frac{\partial}{\partial t}\int_{cv}\rho\, dV + \int_{cs}\rho V\, dA = 0$$

$$0 - V_A A_A + V_B A_B = 0$$

$$0 - (3\text{ m/s})\left[\pi(0.075\text{ m})^2\right] + V_B\left[\pi(0.05\text{ m})^2\right] = 0$$

$$\boxed{V_B = 6.753\text{ m/s}}$$

$$0 - V_A A_A + V_C A_C = 0$$

$$-(3\text{ m/s})\left[\pi(0.075\text{ m})^2\right] + V_c\left[\pi(0.025\text{ m})^2\right] = 0$$

$$\boxed{V_c = 27\text{ m/s}}$$

Between A & B,

$$\frac{P_A}{\gamma_w} + \frac{V_A^2}{2g} + z_A = \frac{P_B}{\gamma_w} + \frac{V_B^2}{2g} + z_B$$

$$\frac{400\times10^3\text{ N/m}^2}{9810\text{ N/m}^3} + \frac{(3\text{ m/s})^2}{2(9.81\text{ m/s}^2)} + 0 = \frac{P_B}{9810\text{ N/m}^3} + \frac{(6.75\text{ m/s})^2}{2(9.81\text{ m/s}^2)} + 0$$

$$P_B = 381.724\times10^3\text{ Pa}$$

$$\boxed{P_B = 382.724\text{ kPa}}$$

Between A & C,

$$\frac{P_A}{\gamma_m} + \frac{V_A^2}{2g} + z_A = \frac{P_c}{\gamma_w} + \frac{V_c^2}{2g} + z_c$$

$$\frac{400\times10^3\text{ N/m}^2}{9810\text{ N/m}^3} + \frac{(3\text{ m/s})^2}{2(9.81\text{ m/s}^2)} + 0 = \frac{P_c}{9810\text{ N/m}^3} + \frac{(27\text{ m/s})^2}{2(9.81\text{ m/s}^2)} + 0$$

$$P_c = 40.0\times10^3\text{ Pa} = \boxed{P_c = 40.000\text{ kPa}}$$

$$H = \frac{P_A}{\gamma_w} + \frac{V_A^2}{2g} + z_A$$

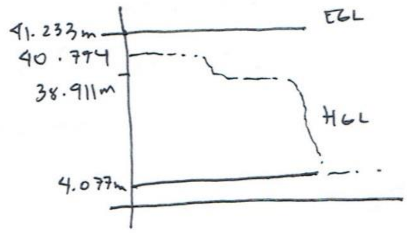
$$= \frac{400\times10^3\text{ N/m}^2}{9810\text{ N/m}^3} + \frac{(3\text{ m/s})^2}{2(9.81\text{ m/s}^2)} = 0$$

$$H = 41.233\text{ m}$$

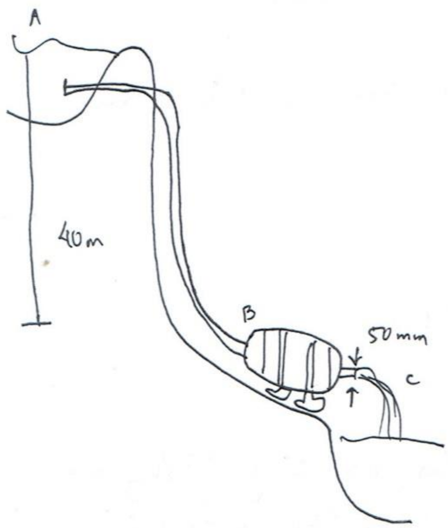
Velocity heads at A, B, and C are:

$$\frac{V_A^2}{2g} = \frac{(3\ m/s)^2}{2(9.81\ m/s^2)} = 0.459\ m \qquad \frac{V_C^2}{2g} = \frac{(27\ m/s)^2}{2(9.81\ m/s^2)} = 37.156\ m$$

$$\frac{V_B^2}{2g} = \frac{(6.75\ m/s)^2}{2(9.81\ m/s^2)} = 2.322\ m$$



F5-10. Water from the reservoir flows through the 150m-long, 50mm-diameter pipe into the turbine at B. If the head loss in the pipe is 1.5m for every 100-m length of pipe, and the water exits the pipe at C with an average velocity of 8 m/s, determine the power output of the turbine. The turbine operates with 60% efficiency.



$V_A = 0$

$P_A = P_C = 0$

$z_A = 40\ m$

$z_C = 0$

$$\frac{P_A}{\gamma_w} + \frac{V_A^2}{2g} + z_A + h_{pump}$$

$$0 + 0 + 40m + 0 = 40m$$

$$40m = \frac{P_C}{\gamma_w} + \frac{V_C^2}{2g} + z_C + h_{turb} + h_L$$

$$40m = 0 + \frac{(8\ m/s)^2}{2(9.81\ m/s^2)} + 0 + h_{turb} + \left(\frac{150}{100}\right)(1.5m)$$

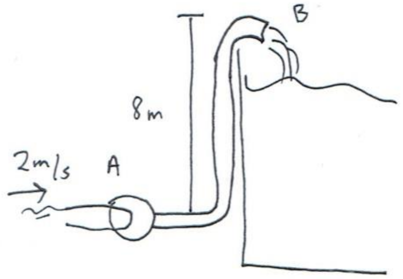
$$h_{turb} = 34.488\ m$$

$Q = V_C A_C = (8\ m/s)(\pi(0.025m)^2) = 5\pi \times 10^{-3}\ m^3/s$

$\dot{W}_i = Q\gamma_w h_s = [5\pi \times 10^{-3}\ m^3/s](9810\ N/m^3)(34.488m) = 5314.43\ W = 5.314\ kW$

$$\varepsilon = \frac{\dot{W}_o}{\dot{W}_i} = \quad 0.6 = \frac{\dot{W}_o}{5.314\ kW} \qquad \dot{W}_o = \frac{0.6}{5.314\ kW} \qquad \boxed{\dot{W}_o = 3.1884\ kW}$$

F5-11. Water is supplied to the pump at a pressure of 80 kPa and a velocity of $V_A = 2\ m/s$. If the discharge is required to be $0.02\ m^3/s$ through the 50 mm-diameter pipe, determine the power that the pump must supply to the water to lift it 8m. The total head loss is 0.75 m.



$$Q = V_B A_B$$

$$0.02\ m^3/s = V_B \left[\pi (0.025\ m)^2\right]$$

$$V_B = 10.19\ m/s$$

$$P_B = 0$$

$$z_A = 0$$

$$z_B = 8m$$

$$\frac{P_A}{\gamma_w} + \frac{V_A^2}{2g} + z_A + h_{pump} = \frac{P_B}{\gamma_w} + \frac{V_B^2}{2g} + z_B + h_{turb} + h_L$$

$$\frac{80 \times 10^3\ N/m^2}{9810\ N/m^3} + \frac{(2\ m/s)^2}{2(9.81\ m/s^2)} + 0 + h_{pump} = 0 + \frac{(10.19\ m/s)^2}{2(9.81\ m/s^2)} + 8m + 0 + 0.75m$$

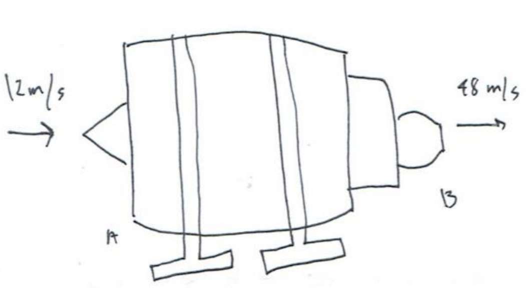
$$h_{pump} = 5.6793\ m$$

$$\dot{W} = Q\gamma_w h_{pump} = (0.02\ m^3/s)(9810\ N/m^2)(5.6793\ m) = 1.114 \times 10^3\ W$$

$$\boxed{W = 1.114\ kW}$$

F5-12. The jet engine takes in air and fuel having an enthalphy of 600 kJ/kg at 12 m/s. At the exhaust, the enthalphy is 450 kJ/kg and the velocity is 48 m/s. If the mass flow is 2 kg/s, and the rate of heat loss is 1.5 kJ/s, determine the power output of the engine.

$$Q_m = -1.5\ kJ/s$$



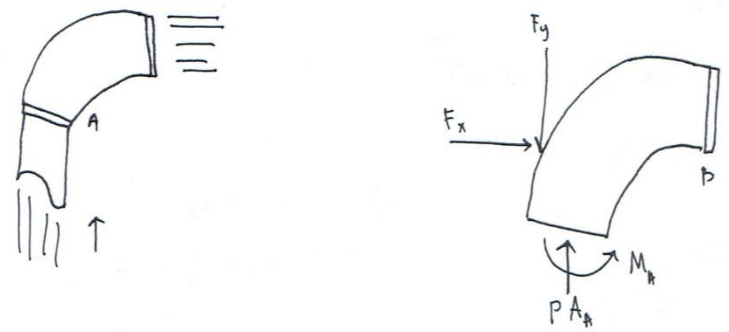
$$Q_{in} - W_{out} = \left[\left(h_B + \frac{V_B^2}{2} + gz_B\right) - \left(h_A + \frac{V_A^2}{2} + gz_A\right)\right]_{in}$$

$$-1.5 \times 10^3\ \frac{J}{s} - W_{out} = \left[\left(450 \times 10^3\ \frac{J}{kg} + \frac{(48\ m/s)^2}{2} + 0\right) - \left(600 \times 10^3\ \frac{J}{kg} + \frac{(12\ m/s)^2}{2} + 0\right)\right]\left(2\ \frac{kg}{s}\right)$$

$$\boxed{W_{out} = 298\ kW}$$

F6-1 to F6-6, pp. 304-305

F6-1. Water is discharged through the 40-mm-diameter elbow at 0.012 m³/s. If the pressure at A is 160 kPa, determine the resultant force the elbow exerts on the water.



$$Q = VA$$

$$0.012\ m^3/s = V\left[\pi(0.02\ m)^2\right]$$

$$V = 9.549\ m/s$$

$$V_A = V_B = V = 9.549\ m/s$$

$$P_B = 0$$

$$\Sigma F = \frac{\partial}{\partial t}\int_{cv} V\rho\, dV + \int_{cs} V\rho V\, dA$$

$$\Sigma F_x = 0 + \uparrow$$

$$= 0 + V_B \rho_w (V_B A_B)$$

$$F_x = (9.549\ m/s)(1000\ kg/m^3)(0.012\ m^3/s) = 114.59\ N \rightarrow$$

$$\Sigma F_y = 0 \uparrow +$$

$$= 0 + V_A(-\rho_w V_A A_A)$$

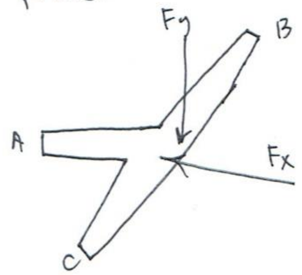
$$(160\times10^3\ N/m^2)(\pi(0.02\ m)^2) - F_y = (9.549\ m/s)\left[-(1000\ kg/m^3)(0.012\ m^3/s)\right]$$

$$F_y = 315.65\ N \downarrow$$

$$F = \sqrt{F_x^2 + F_y^2} = \sqrt{(114.59\ N)^2 + (315.65)^2} = \boxed{336\ N}$$

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{315.65\ N}{114.59\ N}\right) = \boxed{70^\circ}$$

F6-2. The 5 kg shield is held at an angle of 60° to deflect the 40 mm-diameter water stream, which is discharged at 0.02 m³/s. If the measurements show that 30% of the discharge is deflected upwards, determine the resultant force needed to hold the shield in place.



$$Q_A = V_A A_A$$

$$0.02\ m^3/s = V_A\left[\pi (0.02\ m)^2\right]$$

$$V_A = 15.915\ m/s$$

$$Q_B = 0.3\,Q_A$$
$$= 0.3(0.02\ m^3/s)$$
$$Q_B = 0.006\ m^3/s$$

$$Q_C = 0.7\,Q_A$$
$$= 0.7(0.02\ m^3/s)$$
$$Q_C = 0.014\ m^3/s$$

$$V_B = V_C = V_A = 15.915\ m/s$$

$$P_A = P_B = P_C = 0$$

$$\Sigma F = \frac{\partial}{\partial t}\int_{cv} V\rho\, dV + \int_{cs} V_\rho V dA$$

$$\Sigma F_x = 0 \quad \xrightarrow{+}$$

$$= 0 + V_A\left[-(\rho_w V_A A_A)\right] + V_B\cos 60^\circ(\rho_w V_B A_B) + (-V_c\cos 60^\circ)(\rho_w V_c A_c)$$

$$-F_x = (15.915\ m/s)\left[-(1000\ kg/m^3)(0.02\ m^3/s)\right] + (15.915\ m/s)(\cos 60^\circ)(1000\ kg/m^3)(0.006\ \tfrac{m^3}{s})$$
$$+ (-15.915\ m/s)(\cos 60^\circ)(1000\ kg/m^3)(0.014\ m^3/s)$$

$$F_x = 381.97\ N$$

$$\Sigma F_y = 0 \quad +\uparrow$$

$$= 0 + V_B\sin 60^\circ(\rho_w V_B A_B) + (V_c\sin 60^\circ)\left[-(\rho_w V_c A_c)\right]$$

$$-F_y = (15.915\ m/s)\sin 60\,(1000\ kg/m^3)(0.006\ m^3/s) + (15.915\ m/s)\sin 60^\circ\left[-(1000\ \tfrac{kg}{m^3})(0.014\ \tfrac{m^3}{s})\right]$$

$$F_y = 110.27\ N$$

$$F = \sqrt{F_x^2 + F_y^2}$$

$$= \sqrt{(381.97N)^2 + (110.27N)^2}$$

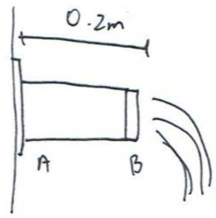
$$\boxed{F = 397.57N}$$

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$$

$$= \tan^{-1}\left(\frac{110.27\ N}{381.97\ N}\right)$$

$$\boxed{\theta = 16.1^\circ}$$

F6-3. Water is flowing at 10 m/s from the 50 mm-diameter open pipe AB. If the flow is increasing at 3 m/s², determine the pressure in the pipe at A.



$$\Sigma F = \frac{\partial}{\partial t}\int_{cv} V \rho \, dV + \int_{cs} V \rho V \, dA$$

$$\Sigma F_x = 0 \quad \xrightarrow{+}$$

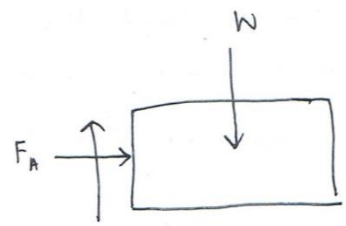
$$= \frac{dV}{dt} \rho_w V_o + V_A\left[-(\rho_w V_A A_A)\right] + V_B(\rho_w V_B A_B)$$

$$F_A = p_A A_A = p_A\left[\pi (0.025\,m)^2\right] = 0.625\pi \times 10^{-3}\, p_A$$

$$F_B = 0$$

$$V_o = \left[\pi (0.025\,m)^2\right](0.2\,m) = 0.125\pi \times 10^{-3}\, m^3$$

$$A_A = A_B \quad ; \quad V_A = V_B$$



$$F_x = 0 \quad \xrightarrow{+}$$

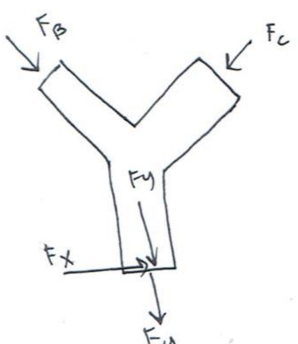
$$= \frac{dV}{dt} \rho_w V_o$$

$$0.625 \times 10^{-3}\pi\, P_A = \left(3\,\frac{m}{s^2}\right)\left(1000\,\frac{kg}{m^3}\right)\left[0.125\pi \times 10^{-2}\, m^3\right]$$

$$P_A = 600\ Pa$$

F6-4. Crude oil flows at the same rate out of each branch of the wye fitting. If the pressure at A is 80 kPa, determine the resultant force at A to hold the fitting to the pipe.

$$Q_A = V_A A_A = (6\,m/s)\left[\pi (0.015\,m)^2\right] = 1.35 \times 10^{-3}\pi\ m^3/s$$



$$Q_B = Q_C = \frac{1}{2} Q_A = \frac{1}{2}\left[1.35 \times 10^{-3}\pi\ m^3/s\right] = 0.675 \times 10^{-3}\pi\ m^3/s$$

$$Q_B = V_B A_B$$

$$0.675\pi \times 10^{-3}\ m^3/s = V_B\left[\pi (0.01\,m)^2\right]$$

$$V_B = 6.75\ m/s$$

$$V_C = V_B = 6.75\ m/s$$

$$\Sigma F_x = 0 \quad \xrightarrow{+}$$

$$= 0 + (V_C \cos 45^\circ)(\rho_{co} V_C A_C) + (-V_B \cos 45^\circ)(\rho_{co} V_B A_B)$$

$$F_x = \cancel{(V_C \cos 45^\circ)\rho_{co} Q_C - (V_B \cos 45^\circ)\rho_{co} Q_B}$$

$$F_x = 0$$

$\Sigma F_y = 0 \quad +\uparrow$

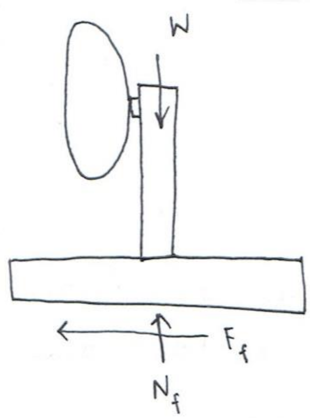
$$= 0 + V_A(-\rho_{co} V_A A_A) + V_B \sin 45°(\rho_{co} V_B A_B) + V_c \sin 45°(\rho_{co} V_c A_c)$$

$$[80\times10^3 \text{ N/m}^2](\pi(0.015\text{ m})^2) - F_y = (6\text{ m/s})\left[-(880\tfrac{\text{kg}}{\text{m}^3})(1.35\pi\times10^{-3}\text{ m}^3/\text{s})\right]$$
$$+ 2(6.75\text{ m/s})\sin 45°\left[(880\text{ kg/m}^3)\,0.675\pi\times10^{-3}\text{ m}^3/\text{s}\right]$$

$F_y = 61.1\text{ N}$

$F_x = 0$; $\boxed{F = F_y = 61.1\text{ N}\downarrow}$

F6-5. The table fan develops a slipstream that has a diameter of 0.25 m. If the air is moving horizontally at 20 m/s as it leaves the blades, determine the horizontal friction force that the table must exert on the fan to hold it in place. Assume that the air has a constant density of 1.22 kg/m3. and that the air just to the right of the blade is essentially at rest.



$$\Sigma F = \frac{\partial}{\partial t}\int_{cv} V \rho\, dV + \int_{cs} V \rho\, V\, dA$$

$\Sigma F_x = 0 \quad \xrightarrow{+}$

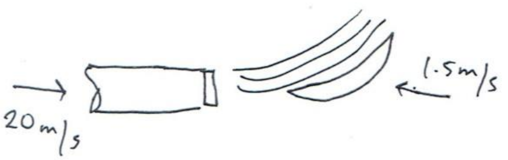
$$= 0 + (-V_{out})[\rho_a V_{out} A_{out}]$$

$$-F_f = (-20\text{ m/s})\left[(1.22\text{ kg/m}^3)(20\text{ m/s})\pi(0.125\text{ m})^2\right]$$

$F_f = 23.95464398$

$$\boxed{F_f = 23.955\text{ N}}$$

F6-6. As water flows out the 20-mm-diameter pipe, it strikes the vane, which is moving to the left at 1.5 m/s. Determine the resultant force on the vane needed to deflect the water 90° as shown.

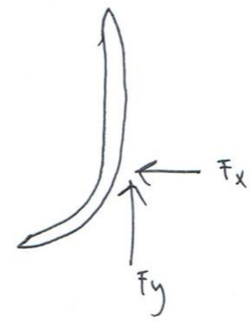


$\overset{+}{\rightarrow}$ $V_f = V_{cv} + V_{f/cs}$

$20 \text{ m/s} = 1.5 \frac{\text{m}}{\text{s}} + V_{f/cs}$

$V_{f/cs} = 21.5 \text{ m/s}$

$$\Sigma F = \frac{\partial}{\partial t}\int_{cv} V\rho\, dV + \int_{cs} V\rho\, \mathbf{V}\cdot d\mathbf{A}$$



$\Sigma F_x = 0 \quad \overset{+}{\rightarrow}$

$= 0 + (V_{f/cs})_{in}\left[-\rho (V_{f/cs})_{in} A_{in}\right]$

$-F_x = (21.5 \text{ m/s})\left[-(1000 \text{ kg/m}^3)(21.5 \text{ m/s})\,\pi\,(0.01 \text{ m})^2\right]$

$F_x = 145.2 \text{ N}$

$\Sigma F_y = 0 \quad +\uparrow$

$= 0 + (V_{f/cs})_{out}\left[\rho (V_{f/cs})_{out}(A_{out})\right]$

$F_y = (21.5 \text{ m/s})\left[(1000 \text{ kg/m}^3)(21.5 \text{ m/s})\,\pi\,(0.01 \text{ m})^2\right]$

$F_y = 145.2 \text{ N}$

$F = \sqrt{F_x^2 + F_y^2}$

$= \sqrt{(145.2)^2 + (145.2)^2}$

$F = 205.3438093 \text{ N}$

$\boxed{F = 205.344 \text{ N}}$

$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$

$= \tan^{-1}\left(\frac{145.2}{145.2}\right)$

$\boxed{\theta = 45°}$

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MODULE 2, CW9

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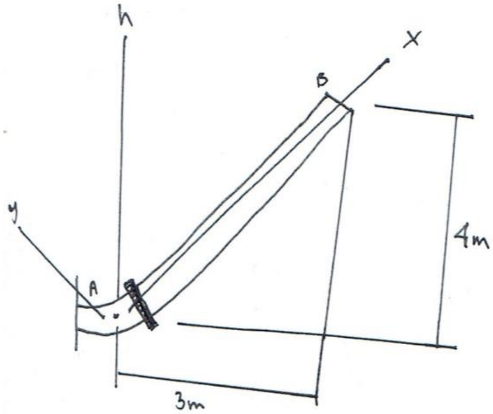
Problem Set 5

E9.4 (p. 453)

Oil flows through the 100-mm-diameter pipe in the figure. If the pressure at A is 34.25 kPa, determine the discharge at B. Take ρ_o = 870 kg/m² and μ_o = 0.0360 N·s/m².



$$\frac{d}{dx}(p + \rho g h)$$

$$= \frac{P_B - P_A}{L} + \frac{\rho g (h_B - h_A)}{L}$$

$$Q = -\frac{\pi R^4}{8\mu_o}\left[\frac{d}{dx}(p + \rho g h)\right]$$

$$Q = -\frac{\pi R^4}{8\mu_o}\left[\frac{P_B - P_A}{L} + \frac{\rho g (h_B - h_A)}{L}\right]$$

$$Q = -\frac{\pi (0.05\ m)^4}{8(0.0360\ N\cdot s/m^2)}\left[\frac{0 - 34.25\times10^3\ \frac{N}{m^2}}{5\ m} + \frac{(870\ \frac{kg}{m^3})(9.81\ \frac{m}{s^2})(4m - 0m)}{5\ m}\right]$$

$$Q = -6.817692391\times10^{-5}(-6850 + 6827.76)$$

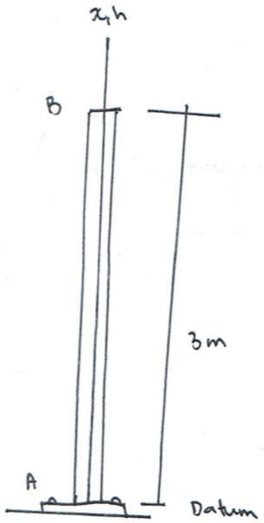
$$Q = -6.81\times10^{-5}(-22.24)$$

$$Q = 0.001516254788\ m^3/s$$

$$\boxed{Q = 0.002\ m^3/s}$$

E9.5 (p. 454)

Determine the maximum pressure at A so that the flow of water through the vertical standpipe in the figure remains laminar. The pipe has an inner diameter of 80 mm. Take $\rho_w = 1000\ kg/m^3$ and $\mu_w = 1.52 \times 10^{-3}\ N \cdot s/m^2$.



$$Re = \frac{\rho_w V D}{\mu_w}$$

$$\frac{Re\, \mu_w}{\rho_w D} = \frac{\rho_w V D}{\rho_w D}$$

$$V = \frac{Re\, \mu_w}{\rho_w D}$$

$$V = \frac{(2300)(1.52 \times 10^{-3}\ N \cdot s/m^2)}{(1000\ kg/m^3)(0.08\ m)}$$

$$V = 0.0437\ m/s$$

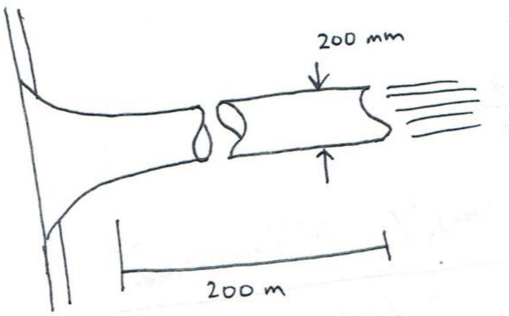
$$V = -\frac{R^2}{8\mu}\left[\frac{d}{dx}(p + \rho g h)\right] = -\frac{R^2}{8\mu}\left[\frac{P_B - P_A}{L} + \frac{\rho g (h_B - h_A)}{L}\right]$$

$$0.0437\ m/s = \frac{(0.04\ m)^2}{8\left(1.52 \times 10^{-3}\ \frac{N \cdot s}{m^2}\right)}\left[\frac{0 - P_A}{3m} + \frac{(1000\ \frac{kg}{m^3})(9.81\ \frac{m}{s^2})(3m - 0)}{3m}\right]$$

$$\boxed{P_A = 29.432\ kPa}$$

E10.1 (p. 485)

The 200-mm-diameter galvanized iron pipe in the figure transports water from a reservoir at a temperature of 20°c. Determine the head loss and pressure drop in 200 m of the pipe if the flow is $Q = 90$ liters/s.



$$V = \frac{Q}{A} = \frac{\left(90 \frac{\text{liters}}{s}\right)\left(\frac{1 m^3}{1000 \text{ liters}}\right)}{\pi (0.1 m)^2} = 2.865 \, m/s$$

$$Re = \frac{VD}{\nu_w} = \frac{(2.865 \, m/s)(0.2m)}{1.00 \times 10^{-6} \, m^2/s} = 5.73 \times 10^5 > 2300$$

(turbulent)

$f = 0.019$;

$$h_L = f \frac{L}{D} \frac{V^2}{2g} = (0.019)\left(\frac{200 \, m}{0.2 \, m}\right)\left[\frac{(2.865 \, m/s)^2}{2 \, (9.81 \, m/s)}\right]$$

$$= (0.019)(1000)(0.418360091 7)$$

$$h_L = 7.948841743 \, m$$

$$\boxed{h_L = 7.949 \, m}$$

$$\frac{P_{in}}{\gamma} + \frac{V_{in}^2}{2g} + \cancel{z_{in}}^{0} + \cancel{h_{pump}}^{0} = \frac{P_{out}}{\gamma} + \frac{V_{out}^2}{2g} + \cancel{z_{out}}^{0} + \cancel{h_{turb}}^{0} + h_L$$

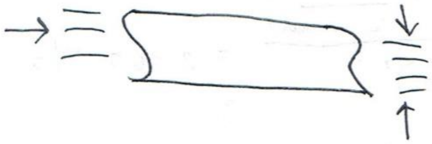
$$h_L = \frac{\Delta P}{\gamma_W}$$

$$7.949 = \frac{\Delta P}{(998.3 \, kg/m^3)(9.81 \, m/s^2)}$$

$$\boxed{\Delta P = 77.828 \, kPa}$$

E10. 2 (p. 486)

Heavy fuel oil flows through 3km of cast iron pipe having a diameter of 250 mm, If the volumetric flow is 40 liter/s, determine the head loss in the pipe. Take $\nu_o = 0.120 \times 10^{-3}\ m^2/s$.



250 mm

$$V = \frac{Q}{A}$$

$$= \frac{(40\ \text{liter}/s)(1\ m^3/1000\ \text{liter})}{\pi\,(0.125\ m)^2}$$

$$V = 0.8149\ m/s$$

$$Re = \frac{VD}{\nu_o}$$

$$= \frac{(0.8149\ m/s)(0.250m)}{(0.120 \times 10^{-3}\ m^2/s)}$$

$$= 1698$$

$1698 < 2300$ (laminar)

Since laminar,

$$f = \frac{64}{Re} = \frac{64}{1698} = 0.0377$$

$$f = 0.0377$$

$$h_L = f\,\frac{L}{D}\,\frac{V^2}{2g}$$

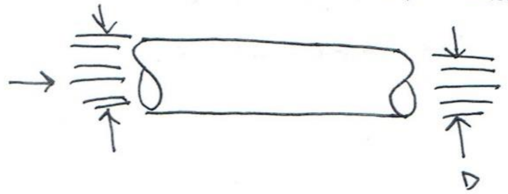
$$= (0.0377)\left(\frac{3000\ m}{0.250m}\right)\left[\frac{(0.8149\ m/s)^2}{2(9.81\ m/s^2)}\right]$$

$$h_L = 15.32763537\ m$$

$$\boxed{h_L = 15.328\ m}$$

E10.5 (p. 489)

The cast iron pipe in the figure is used to transport water at 0.30 m^3/s. If the head loss is to be no more than 0.006 m for every 1m length of pipe, determine the smallest diameter D of pipe that can be used. Take $\nu_w = 1.15 \times 10^{-6}$ m^2/s.



$$h_L = f \frac{L}{D} \frac{V^2}{2g}$$

$$\frac{h_L D\, 2g}{h_L\, 2g} = \frac{f L V^2}{h_L\, 2g} \qquad D = \frac{f L V^2}{h_L\, 2g}$$

$$D = \frac{f\,(1m)\left(\frac{0.3\ m^3/s}{(\pi/4) D^2}\right)^2}{(0.006m)(2)(9.81\ m/s^2)}$$

$$D^5 = 1.2394 f$$

$$Re = \frac{VD}{\nu_w} = \frac{\left[\frac{0.3\ m^3/s}{(\pi/4) D^2}\right] D}{(1.15 \times 10^{-6}\ m^2/s)} = \frac{3.3215 \times 10^5}{D}$$

for cast iron pipes,

$\varepsilon = 0.00026$ m

$\frac{\varepsilon}{D} = 0.000521$

$f \cong 0.0176$

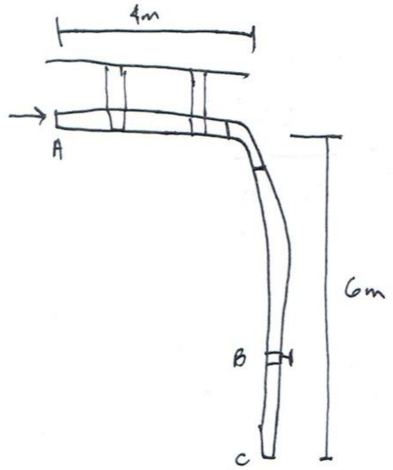
$$D^5 = 1.2394 f = 1.2394(0.0176)$$

$$\boxed{D = 0.4653\ m}$$

E10.6 (p. 497)

When the globe value at B in the figure is fully opened, it is observed that water flows out through the 65-mm-diameter cast iron pipe with an average velocity of 2 m/s. Determine the pressure in the pipe at A. take

$\rho_w = 998 \text{ kg/m}^3$ and $\nu_w = 0.8 \times 10^{-6} \text{ m}^2/\text{s}$



$$Re = \frac{VD}{\nu_w} = \frac{(2 \frac{m}{s})(0.065 m)}{0.8 \times 10^{-6} m^2/s} = 1.625 \times 10^5$$

$$f = 0.0290.$$

$$h_L = f \frac{L}{D} \frac{V^2}{2g} + 0.9 \left(\frac{V^2}{2g}\right) + 10 \left(\frac{V^2}{2g}\right)$$

$$= 0.0290 \left(\frac{10 m}{0.065 m}\right) \left[\frac{(2 m/s)^2}{2(9.81 m/s^2)}\right] + (0.9 + 10) \left[\frac{(2 m/s)^2}{2(9.81 m/s^2)}\right]$$

$$= 0.9096 m + 2.222 m$$

$$h_L = 3.132 m$$

$V_A A = V_C A$

$V_A = V_C = 2 m/s$

$$\frac{P_A}{\gamma_w} + \frac{V_A^2}{2g} + z_A + h_{pump} = \frac{P_C}{\gamma_w} + \frac{V_C^2}{2g} + z_C + h_{turb} + h_L$$

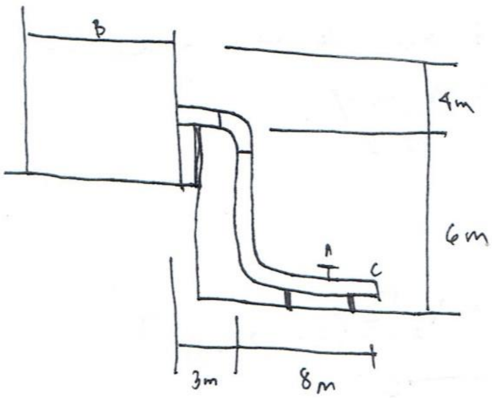
$$\frac{P_A}{(998 \frac{kg}{m^3})(9.81 \frac{m}{s^2})} + \frac{(2 m/s)^2}{2(9.81 m/s^2)} + 6 m + 0 = 0 + \frac{(2 m/s)^2}{2(9.81 m/s^2)} + 0 + 0 + 3.132 m$$

$$P_A = -28.081 \times 10^3 \text{ Pa}$$

$$\boxed{P_A = -28.081 \text{ kPa}}$$

E 10.8 (p. 500)

Determine the required diameter of the galvanized iron pipe in the figure. If the discharge at C is to be 0.475 m³/s when the gate valve at A is fully opened. The reservoir is filled with water to the depth shown. Take $\nu_w = 1 \times 10^{-6}\ m^2/s$.



$$Q = VA$$

$$0.475\ m^3/s = V\left(\frac{\pi}{4}D^2\right)$$

$$V = \frac{0.6048}{D^2} \quad \text{—— (1)}$$

$$\frac{P_B}{\gamma_w} + \frac{V_B^2}{2g} + z_B + h_{pump} = \frac{P_C}{\gamma_w} + \frac{V_C^2}{2g} + z_C + h_{turb} + h_L$$

$$0 + 0 + (4m + 6m) + 0 = 0 + \frac{V^2}{2g} + 0 + 0$$

$$+ \left[f\left(\frac{17m}{D}\right)\left(\frac{V^2}{2g}\right) + 0.5\left(\frac{V^2}{2g}\right) + 2\left[0.9\left(\frac{V^2}{2g}\right)\right] + 0.19\left(\frac{V^2}{2g}\right)\right]$$

$$10 = \left[f\left(\frac{17}{D}\right) + 3.49\right]\left[\frac{V^2}{2(9.81\ m/s^2)}\right] \quad \text{—— (2)}$$

Combining (1) & (2);

$$536.40D^5 - 3.49D - 17f = 0 \quad \text{—— (3)}$$

Assume $D = 0.3\ m$,

$f = 0.01508$

$V = 6.72\ m/s$

$Re = 2.02 \times 10^6$

$$536.40D^5 - 3.49D - 17f = 0$$

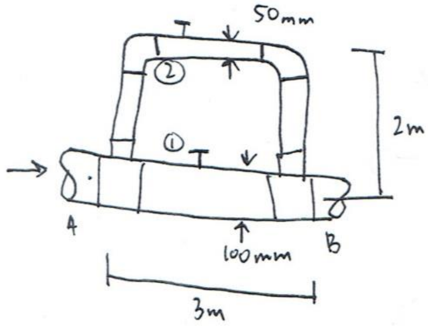
$$536.40D^5 - 3.49D - 17(0.017) = 0$$

$$\boxed{D = 0.3017602426\ m}$$

$D = 300\ mm$

E10.10 (p. 506)

Water flows at a rate of 0.03 m³/s through the branch piping system shown in the figure. The 100-mm-diameter pipe has a filter and globe valve on it, and the 50-mm-diameter diverter pipe has a gate valve. The pipes are made of galvanized iron. Determine the flow through each pipe, and the pressure drop bet. A & B when both valves are fully opened. The head loss due to the filter is $K_L = 1.6\left(\frac{V^2}{2g}\right)$. Take $\gamma_w = 9810\ N/m^3$ and $\nu_w = 1\times10^{-6}\ m^2/s$.



$$Q = V_1 A_1 + V_2 A_2$$

$$0.03\ m^3/s = V_1\left[\pi(0.05\ m)^2\right] + V_2\left[\pi(0.025m)^2\right]$$

$$15.279 = 4V_1 + V_2 \quad \text{---}(1)$$

$$(h_L)_1 = f_1\left(\frac{3m}{0.1m}\right)\left(\frac{V_1^2}{2g}\right) + 2(0.9)\left(\frac{V_1^2}{2g}\right) + 1.6\left(\frac{V_1^2}{2g}\right) + 10\left(\frac{V_1^2}{2g}\right)$$

$$= (30f_1 + 12.4)\frac{V_1^2}{2g} \quad \text{---}(2)$$

$$(h_L)_2 = f_2\left(\frac{7m}{0.05m}\right)\left(\frac{V_2^2}{2g}\right) + 2(1.8)\left(\frac{V_2^2}{2g}\right) + 2(0.9)\left(\frac{V_2^2}{2g}\right) + 0.19\left(\frac{V_2^2}{2g}\right)$$

$$= (140f_2 + 5.59)\frac{V_2^2}{2g} \quad \text{---}(3)$$

$$(h_L)_1 = (h_L)_2\ ;\quad (30f_1 + 12.4V_1^2) = (140f_2 + 5.59)V_2^2 \quad \text{---}(4)$$

Assume $f_1 = 0.02$; $V_1 = 2.941\ m/s$

$f_2 = 0.025$; $V_2 = 3.517\ m/s$

$$Q_1 = V_1A_1 = (2.95\ m/s)\left[\pi(0.05\ m)^2\right] = \boxed{0.0232\ m^3/s}$$

$$Q_2 = V_2A_2 = (3.48\ m/s)\left[\pi(0.025m)^2\right] = \boxed{0.0068\ m^3/s}$$

$z_A = z_B = 0$

$V_A = V_B = V$

$$\frac{P_A}{\gamma_w} + \frac{V_A^2}{2g} + \cancel{z_A}^{0} + \cancel{h_{pump}}^{0} = \frac{P_B}{\gamma_w} + \frac{V_B^2}{2g} + \cancel{z_B}^{0} + \cancel{h_{turb}}^{0} + h_L$$

$$P_A - P_B = \gamma_w h_L$$

using (2);

$$P_A - P_B = (9810 \ N/m^3)\left[30(0.022) + 12.4\right]\left[\frac{(2.95 \ m/s)^2}{2(9.81 \ m/s^2)}\right]$$

$$= 56.841 \times 10^3 \ Pa$$

$$\boxed{\Delta P = 56.841 \ kPa}$$

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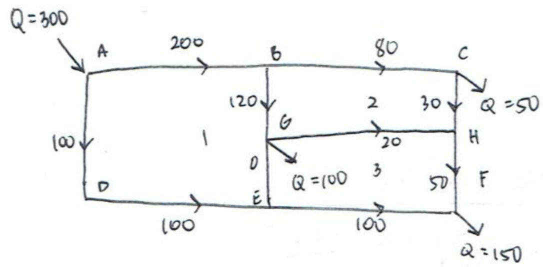
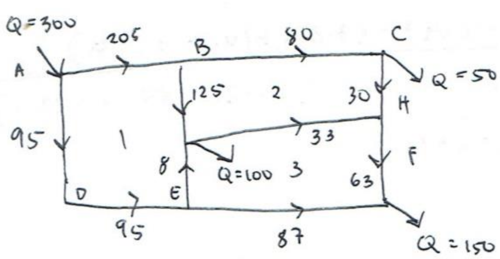
2018101135, CE-3
CE142P-2, E02

Module 2, CW 11

Example 4.8 (p. 113)

A water supply distribution system for an industrial park is schematically shown in the Figure. The demands on the system are currently at junctions C, G, and F with flow rates given in liters per second. Water enters the system at junction A from a water storage tank on a hill. The water surface elevation in the tank is 50 m above the elevation of point A in the industrial park. All the junctions have the same elevation as point A. All pipes are aged ductile iron (e = 0.26 mm) with lengths and diameters provided in the table. Calculate the flow rate in each pipe. Also determine if the pressure at junction F will be high enough to satisfy the customer there. The required pressure is 185 kPa.





Pipe	flow	L	D	$\frac{e}{D}$	f	K
AB	0.20	300	0.30	0.00087	0.019	194
AD	0.10	250	0.25	0.00104	0.020	423
BC	0.08	350	0.20	0.00130	0.021	1900
BG	0.12	125	0.20	0.00130	0.021	678
GH	0.02	350	0.20	0.00130	0.021	1900
CH	0.03	125	0.20	0.00130	0.021	678
DE	0.10	300	0.20	0.00130	0.021	1630
GE	0.00	125	0.15	0.00173	0.022	2990
EF	0.10	350	0.20	0.00130	0.021	1900
HF	0.05	125	0.15	0.00173	0.022	2990

LOOP 1:

Pipe	Q	K	h_f	h_f/Q	New Q
AB	0.20	194	7.76	38.8	0.205
BG	0.12	678	9.76	81.3	0.125
GE	0.00	2990	0.00	0.00	0.005
AD	0.10	423	4.23	42.3	0.095
DE	0.10	1630	16.30	163.00	0.095

$$h_f = KQ^2$$

$$h_{f_{AB}} = 194(0.2)^2 = 7.76$$

$$h_{f_{BG}} = 678(0.12)^2 = 9.76$$

$$h_{f_{GE}} = 2990(0.0)^2 = 0$$

$$h_{f_{AD}} = 423(0.10)^2 = 4.23$$

$$h_{f_{DE}} = 1630(0.10)^2 = 16.30$$

$$\Delta Q = \frac{\Sigma h_{f_c} - \Sigma h_{f_{cc}}}{2\left[\Sigma\left(\frac{h_{f_c}}{Q_c}\right) + \Sigma\left(\frac{h_{f_c}}{Q_{cc}}\right)\right]}$$

$$= \frac{(7.76 + 9.76) - (4.23 + 16.3)}{2((38.8 + 81.3) + (42.3 + 163))}$$

$\Delta Q = -0.05\ m^3/s$ (clockwise direction)

LOOP 2:

$$\Delta Q = \frac{\Sigma h_{fc} - \Sigma h_{fcc}}{2\left[\Sigma\left(\frac{h_{fc}}{Q_c}\right) + \Sigma\left(\frac{h_{fcc}}{Q_{cc}}\right)\right]} = \frac{(12.2 + 0.61) - (10.6 + 0.76)}{2[(152.5 + 20.3) + (84.8 + 38)]} = +0.002 \text{ m}^3/\text{s}$$

Pipe	Q	K	h_f	h_f/Q	New Q
BC	0.08	1900	12.2	152.5	0.078
CH	0.03	678	0.61	20.3	0.028
BG	0.125	678	10.6	84.8	0.127
GH	0.02	1900	0.76	38.0	0.022

LOOP 3:

$$\Delta Q = \frac{\Sigma h_{fc} - \Sigma h_{fcc}}{2\left[\Sigma\left(\frac{h_{fc}}{Q_c}\right) + \Sigma\left(\frac{h_{fcc}}{Q_{cc}}\right)\right]} = \frac{(0.92 + 7.48) - (0.07 + 19)}{2[(41.8 + 149.6) + (14 + 190)]} = -0.013 \text{ m}^3/\text{s}$$

2ND ITERATION

LOOP 1:

Pipe	Q	K	h_f	h_f/Q	New Q
AB	0.205	194	8.15	39.8	0.205
BG	0.127	678	10.9	85.8	0.127
AD	0.095	423	3.82	40.2	0.095
DE	0.095	1630	14.7	154.7	0.095
EG	0.008	2990	0.19	23.8	0.008

$$\Delta Q = \frac{\Sigma h_{fc} - \Sigma h_{fcc}}{2\left[\Sigma\left(\frac{h_{fc}}{Q_c}\right) + \Sigma\left(\frac{h_{fcc}}{Q_{cc}}\right)\right]}$$

$$= \frac{(8.15 + 10.9) - (3.82 + 14.7 + 0.19)}{2[(39.8 + 85.8) + (40.2 + 154.7 + 23.8)]}$$

$$\Delta Q = 0.0005 \text{ m}^3/\text{s}$$

LOOP 2:

Pipe	Q	K	h_f/Q	h_f	New Q
BC	0.078	1900	148.7	11.6	0.080
CH	0.028	678	18.9	0.53	0.030
BG	0.127	678	85.8	10.9	0.125
GH	0.035	1900	66.6	2.33	0.033

$$\Delta Q = \frac{\Sigma h_{fc} - \Sigma h_{fcc}}{2\left[\Sigma\left(\frac{h_{fc}}{Q_c}\right) + \Sigma\left(\frac{h_{fcc}}{Q_{cc}}\right)\right]} = \frac{(11.6 + 0.53) - (10.9 + 2.33)}{2[(148.7 + 18.9) + (85.8 + 66.6)]} = -0.002 \text{ m}^3/\text{s}$$

LOOP 3:

Pipe	Q	K	h_f	h_f/Q	New Q
GH	0.033	1900	2.07	62.7	0.033
HF	0.063	2990	11.9	188.9	0.063
EG	0.008	2990	0.19	23.8	0.008
EF	0.087	1900	14.4	165.5	0.087

$$\Delta Q = \frac{\Sigma h_{fc} - \Sigma h_{fcc}}{2\left[\Sigma\left(\frac{h_{fc}}{Q_c}\right) + \Sigma\left(\frac{h_{fcc}}{Q_{cc}}\right)\right]} = \frac{(2.07 + 11.9 + 0.19) - (14.4)}{2[(62.7 + 188.9 + 23.8) + (165.5)]} = -0.000 \text{ m}^3/\text{s}$$

Pipe	Q	L	D	h_f	ΔP
AB	205	300	30	8.2	80.3
AD	95	250	25	3.8	37.2
BC	80	350	20	12.2	119.4
BG	125	125	20	10.6	103.8
GH	33	350	20	2.1	20.6
CH	30	125	20	0.6	5.9
DE	95	300	20	14.7	143.9
EG	8	125	15	0.2	2.0
EF	87	350	20	14.4	141.0
HF	63	125	15	11.9	116.5

Determining pressure at Junction F;

At Junction A:

$$P = \gamma h = \rho g h = (9790\ N/m^3)(50m) = 489.5\ kPa$$

$$P_F = P_A - \Delta P_{AD} - \Delta P_{DE} - \Delta P_{EF}$$

$$= 489.5 - 37.2 - 143.9 - 141.0$$

$$\boxed{P_F = 167.4\ kPa}$$

$167.4 < 185$ kPa, customer is not likely satisfied.

Example 4.11 (p. 131)

A steel pipe 5000 ft. long laid on a uniform slope has an 18-in. diameter and a 2-in. wall thickness. The pipe carries water from a reservoir and discharges it into the air at an elevation 150 ft below the reservoir free surface. A valve installed at the downstream end of the pipe permits a flow rate of 25 cfs. If the valve is completely closed in 1.4s, calculate the maximum water hammer pressure at the valve. Assume the longitudinal stresses in the pipeline are negligible.

$$\frac{1}{E_c} = \frac{1}{E_b} + \frac{D}{E_p e}$$

$E_b = 3.2 \times 10^5$ psi

$E_p = 2.8 \times 10^7$ psi

$D = 18$

$$\frac{1}{E_c} = \frac{1}{3.2 \times 10^5 \text{ psi}} + \frac{18}{(2.8 \times 10^7 \text{psi})(2.0)}$$

$$E_c = 2.90 \times 10^5 \text{ psi}$$

$$C = \sqrt{\frac{E_c}{\rho}} = \sqrt{\frac{2.90 \times 10^5 \text{ psi } (144)}{1.94}} = 4{,}640 \text{ ft/s}$$

$$t = \frac{2L}{C} = \frac{2(5000)}{4640} = 2.16 s$$

since $1.4 s < 2.16 s$;

$$V_0 = \frac{25}{\frac{\pi}{4}(1.5)^2} = 14.14710605 \text{ ft/s}$$

$$\Delta P = \rho C V_0 = (1.94)(4640)(14.147) = 127346.5898 \text{ lb/ft}^2$$

$$\boxed{\Delta P = 127346.5898 \text{ lb/ft}^2}$$

Example 4.13

A simple surge tank 8.00m in diameter is located at the downstream end of a 1500-m long pipe, 2.20 m in diameter. The head loss between the upstream reservoir and the surge tank is 15.1 m when the Flow rate is 20.0 m^3/s. Determine the maximum elevation of the water in the surge tank if a value downstream suddenly closes.

$$h_L = h_f = K_f V^2$$

$$\frac{h_f}{V^2} = \frac{K_f \cancel{V^2}}{\cancel{V^2}}$$

$$K_f = \frac{h_f}{V^2} = \frac{15.1}{(5.26)^2} = 0.5457647212 \ s^2/m$$

$$\beta = \frac{LA}{2gK_f A_s} = \frac{(1500)(3.80)}{2(9.81)(0.546)(50.3)} = 10.6m \quad \text{or } 10.57928406 m$$

$$\frac{Y_{max} + h_L}{\beta} = \ln\left(\frac{\beta}{\beta - y_{max}}\right)$$

$$\frac{y_{max} + 15.1}{10.6} = \ln\left(\frac{10.578}{10.578 - y_{max}}\right)$$

by Iteration:

y_{max}	left hand side	Right hand side
9.50	2.32	2.27
9.60	2.33	2.36

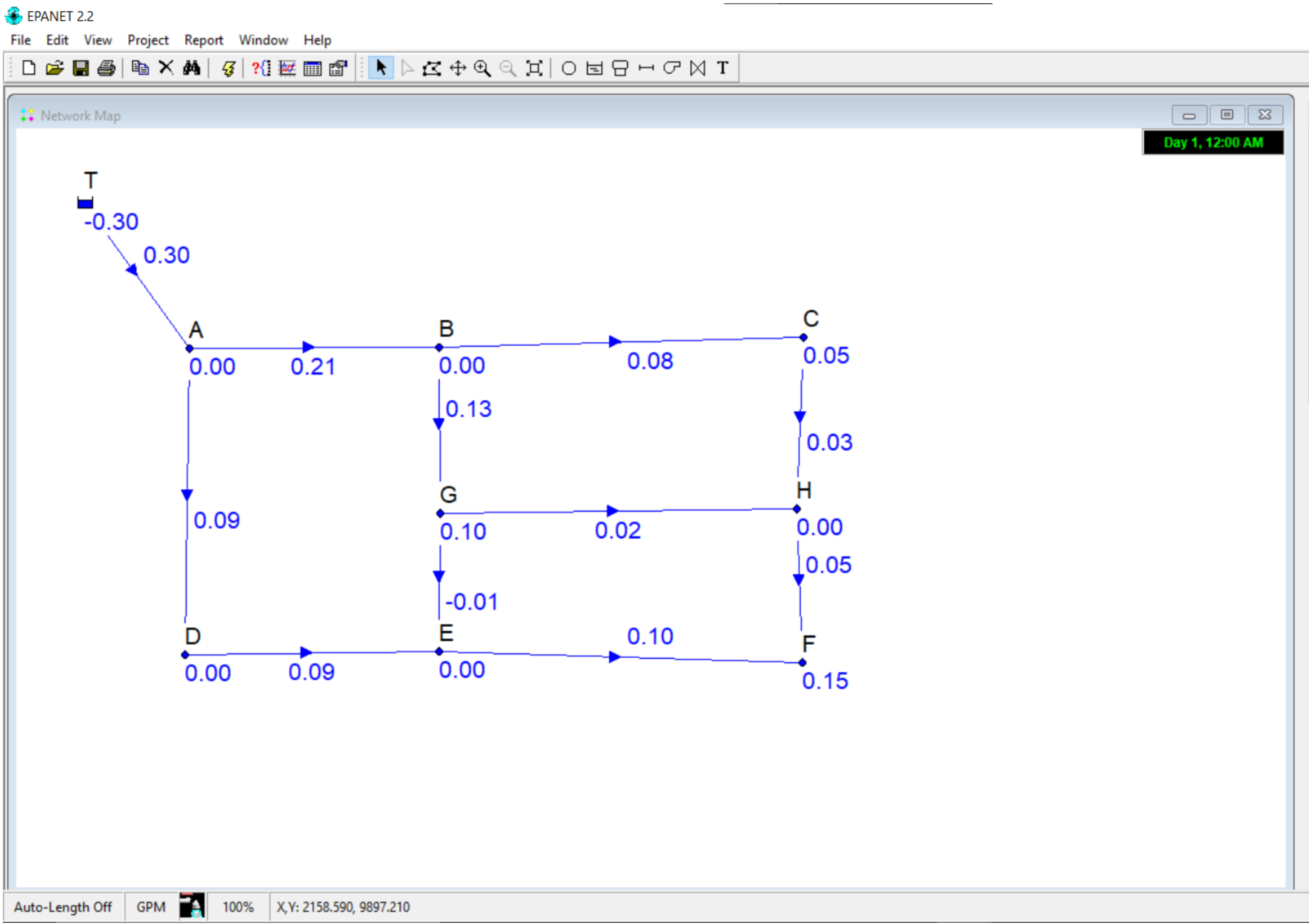
Assuming $y_{max} = 9.57$;

$$\frac{9.57 + 15.1}{10.6} = \ln\left(\frac{10.578}{10.578 - 9.57}\right)$$

$$2.33 \overset{\checkmark}{=} 2.33$$

$$\boxed{y_{max} = 9.57}$$

4.) Validate Example 4.8 using EPANET (screenshot model showing Q)



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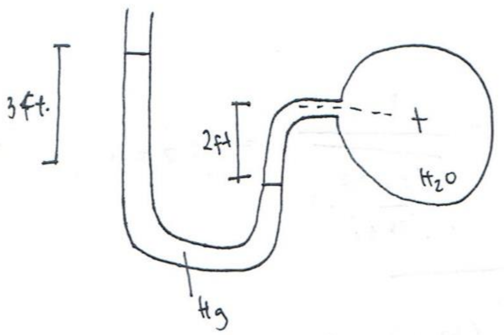
PROBLEM SET 7

Example 9.1

In the figure, water is flowing in the pipe, and mercury (sp. gr. = 13.6) is the manometer fluid. Determine the pressure in the pipe in psi and in inches of Hg.



$$(3\text{ ft})(\gamma_{Hg}) = P + (2\text{ ft})(\gamma)$$

$$(3\text{ ft})(\rho g)_{Hg} = P + (2\text{ ft})(\rho g)$$

$$(3\text{ ft})(13.6)(62.3\text{ lb/ft}^3) = P + (2\text{ ft})(62.3\text{ lb/ft}^3)$$

$$P = 2417.24\text{ lb/ft}^2$$

$$\boxed{P = 16.8\text{ psi}}$$

$$h = \frac{P}{\gamma_{Hg}} = \frac{2417.24\text{ lb/ft}^2}{(13.6)(62.3\text{ lb/ft}^2)} = 2.852941176$$

$$\boxed{h = 2.853\text{ ft} = 34.3\text{ in.}}$$

Example 9.2

A Pitot tube is used to measure velocity at a certain location in a water pipe. The manometer indicates a pressure difference (column height) of 14.6 cm. The indicator fluid has a specific gravity of 1.95. Compute the velocity.

$$P_1 - \gamma x + \gamma_m \Delta h - \gamma \Delta h + \gamma x = P_0$$

$$P_0 - P_1 = \Delta P = \Delta h(\gamma_m - \gamma)$$

$$V^2 = 2g\Delta h\left(\frac{\gamma_m - \gamma}{\gamma}\right) = 2g\Delta h[1.95 - 1]$$

$$V^2 = 2(9.81)\left(\frac{14.6}{100}\right)[1.95 - 1.0]$$

$$V^2 = 2.721294$$

$$V = 1.649634505\text{ m/s}$$

$$\boxed{V = 1.650\text{ m/s}}$$

Example 9.3 (p. 353)

A 6 cm (throat) Venturi meter is installed in a 12 cm - diameter horizontal water pipe. A differential (mercury - water) manometer installed between the throat and the entry section registers a mercury (sp-gr. = 13.6) column reading of 15.2 cm. Calculate the discharge.

$$\Delta P = \Delta h \, (\gamma_{Hg} - \gamma)$$

$$\frac{\Delta P}{\gamma} = \Delta h \left(\frac{\gamma_{Hg} - \gamma}{\gamma} \right)$$

$$A_1 = \frac{\pi}{4}(12)^2 = 113 \text{ cm}^2$$

$$A_2 = \frac{\pi}{4}(6)^2 = 28.3 \text{ cm}^2$$

$$\Delta P = \Delta h \left[(\text{sp.gr.})_{Hg} - 1 \right]$$

$$= (15.2 \text{ cm})(13.6 - 1.0)$$

$$C_d = \frac{1}{\sqrt{\left(\frac{A_1}{A_2}\right)^2 - 1}} = \frac{1}{\sqrt{\left(\frac{113}{28.3}\right)^2 - 1}} = 0.259$$

$$Q = C_d A_1 \sqrt{2g\left(\frac{\Delta P}{\gamma}\right)} = (0.259)\left(\frac{113}{10000}\right)\sqrt{2(9.81)\left(\frac{15.2}{100}\right)(12.6)} = 0.0179405096 2$$

$$\boxed{Q = 0.018 \text{ m}^3/\text{s}}$$

Example 9.4

The Venturi meter in Ex. 9.3 is replaced with an ASME flow nozzle meter. During operation, the attached differential (mercury - water) manometer registers a mercury column reading of 15.2 cm. The water in the pipeline is 20°C. Determine the discharge.

$$\frac{d_2}{d_1} = \frac{6}{12} = 0.5$$

$$C_d = 0.259$$

Assume $C_v = 0.99$

$$Q = C_v C_d A_1 \sqrt{2g\left(\frac{\Delta P}{\gamma}\right)}$$

$$Q = (0.99)(0.259)\left(\frac{113}{10000}\right)\sqrt{2(9.81)\left[\frac{15.2}{100}\right](12.6)} = 0.0178 \text{ m}^3/\text{s}$$

Verify; $N_R = \frac{V_2 d_2}{\nu} = \frac{\left(0.0178 / \frac{\pi}{4}(0.06)^2\right)(0.06)}{(1 \times 10^{-6})} = 3.78 \times 10^5$

Thus, use $C_v = 0.986$;

$$Q = \left(\frac{0.986}{0.99}\right)(0.0178) = 0.0177280808 1 \text{ m}^3/\text{s}$$

$$\boxed{Q = 0.177 \text{ m}^3/\text{s}}$$

Example 9.5

Laboratory measurements are made on a contracted (both sides) horizontal weir with a crest length of 1.56 m. The measured discharge is 0.25 m^3/s under a head of H = 0.2m. Determine the discharge coefficient in the given SI units.

$$Q = C\left(L - \frac{nH}{10}\right)H^{3/2}$$

L = 1.56 m

H = 0.2 m

n = 2

$$0.25 = C\left(1.56 - \frac{2(0.2)}{10}\right)(0.2)^{3/2}$$

$$C = 1.84\ m^{0.5}/s \quad \text{or} \quad 1.838871692\ m^{0.5}/s$$

$$\boxed{C = 1.839\ m^{0.5}/s}$$

Example 9.6

A 4ft Parshall flume is installed in an irrigation Channel to monitor the rate of flow. The readings at gauges H_a and H_b are 2.5 ft and 2.0 ft, respectively. Determine the channel discharge.

H_a = 2.5 ft

H_b = 2.0 ft

$$\frac{H_b}{H_a} = 80\%$$

$$Q_u = 4WH_a^{1.522 \cdot W^{0.026}}$$

$$= 4(4)(2.5)^{1.522(4)^{(0.026)}}$$

$$= 67.92243345 \text{ cfs}$$

Corrected flow rate;

$$Q_c = 3.1(1.8) = 5.58 \text{ cfs}$$

$$Q = Q_u - Q_c$$

$$Q = 67.92243345 - 5.58$$

$$Q = 62.34243345 \text{ cfs}$$

$$\boxed{Q = 62.342 \text{ cfs}}$$

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PROBLEM SET 8

Example 6.1
A 3m wide rectangular irrigation channel carries a discharge of 25.3 m^3/s at a uniform depth of 1.2m. Determine the slope of the channel if manning's coefficient is n = 0.022.

$A = by = (3)(1.2) = 3.6\ m^2$

$P = b + 2y = 3 + 2(1.2) = 5.4m$

$R_h = \frac{A}{P} = \frac{3.6}{5.4} = \frac{2}{3} = 0.667\ m$

$S_0 = S_e = \left(\frac{Qn}{AR_h^{2/3}}\right)$

$= \left(\frac{25.3(0.022)}{(3.6)(0.667)^{2/3}}\right)^2$

$= 0.04101854873$

$\boxed{S_0 = 0.041}$

Example 6.2
A 6 ft diameter, concrete pipe is flowing with a free surface (i.e. not under pressure), if the pipe is laid on a slope of 0.001 and carries a uniform flow at a depth of 4 ft (y in table 6.1), what is the discharge?

$\theta = 90° + \alpha$

$= 90° + \sin^{-1}\left(\frac{1\ ft}{3\ ft}\right) = 19.5°$

$\theta = 109.5°$

$= \left(\frac{109.5°}{360°}\right)(2\pi)$

$\theta = 0.608\pi$ radians

$A = \frac{1}{8}(2\theta - \sin 2\theta)d_0^2$

$= \frac{1}{8}[2(0.608\pi) - \sin 2(0.608\pi)](6ft)^2$

$A = 20.0\ ft^2$

$P = \theta d_0 = (0.608\pi)(6ft) = 11.5\ ft$

$R_h = \frac{A}{P} = \frac{(20.0\ ft^2)}{(11.5\ ft)} = 1.74\ ft$

$S_0 = S_e$
$n = 0.013$

$Q = \frac{1.49}{n} AR_h^{2/3} S_0^{1/2}$

$= \frac{1.49}{0.013}(20)(1.74)^{2/3}(0.001)^{1/2}$

$Q = 104.8670563\ ft^3/s$

$\boxed{Q = 104.867\ ft^3/s}$

Example 6.3

If the discharge in the channel in Example 6.1, is increased to 40 m^3/s, what is the normal depth of the flow?

$A = by = 3y$

$P = b + 2y = 3 + 2y$

$R_h = \frac{A}{P} = \frac{3y}{3+2y}$

$S_0 = S_e$

$Q = \frac{1}{n} A R_h^{2/3} S_0^{1/2}$

$40 = \frac{1}{0.022} (3y)\left(\frac{3y}{3+2y}\right)^{2/3} (0.041)^{1/2}$

$AR_h^{2/3} = 3y\left(\frac{3y}{3+2y}\right)^{2/3} = \frac{(0.022)(40)}{(0.041)^{1/2}} = 4.346$

$y = y_n = 1.69 m$

$\frac{nQ}{(1.0 S_0^{1/2} b^{8/3}} = \frac{(0.022)(40)}{(1.0)(0.041)^{1/2}(3)^{8/3}} = 0.23$

$\frac{y_n}{b} = 0.56$

$y_n = 0.56\ (3.0)$

$\boxed{y_n = 1.680 m}$

Example 6.4

Prove that the best hydraulic trapezoidal section is a half-hexagon.

$A = by + my^2$ — ①

$P = b + 2y\sqrt{1+m^2}$ — ②

$b = \frac{A}{y - my}$

① to ②;

$P = \frac{A}{y} - my + 2y\sqrt{1+m^2}$

$\frac{dP}{dy} = -\frac{A}{y^2} - m + 2\sqrt{1+m^2} = 0$

subt. A from ①;

$\frac{by + my^2}{y^2} = 2\sqrt{1+m^2} - m$

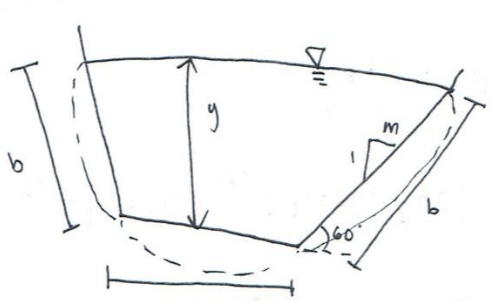
$b = 2y(\sqrt{1+m^2} - m)$ — ③

Sub ③ to ② to get P;

$P = 2y(2\sqrt{1+m^2} - m)$ — ④

$m = \frac{\sqrt{3}}{3} = \cot 60°$ — ⑤

$b = 2y\left(\sqrt{1+\frac{1}{3}} - \frac{\sqrt{3}}{3}\right) = 2\frac{\sqrt{3}}{3}y$ or $y = \frac{\sqrt{3}}{2}b = b\sin 60°$



$M = \frac{1}{\tan 60°} = \frac{\sqrt{3}}{3}$

$y = b\sin 60° = \frac{\sqrt{3}}{3}b$

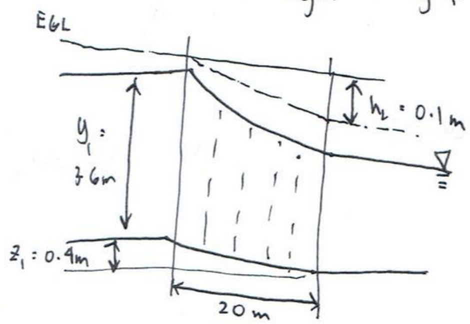
$R_h = \frac{A}{P} = \frac{by + my^2}{b + 2y\sqrt{1+m^2}}$

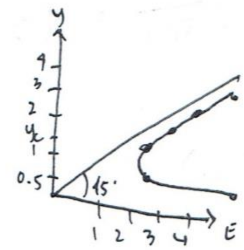
Sub b from ③; $R_h = \frac{y}{2}$

Example 6.5

A hydraulic transition is designed to connect two rectangular channels of the same width by a sloped floor, Assume the channel is 3m wide and is carrying a discharge of 15 m³/s at 3.6 m depth. Also assume a 0.1m energy loss uniformly distributed through the transition. Determine the water surface profile in the transition.

$$E = y + \frac{Q^2}{2gA^2} = y + \frac{(15)^2}{2(9.81)(3y)^2} = y + \frac{1.27}{y^2}$$





$$y_c = 3\sqrt{\frac{52}{9.81}} = 1.37\ m$$

$$V_i = \frac{Q}{A_i} = \frac{15}{(3.6)(3)} = 1.39\ m/s$$

$$\frac{V_i^2}{2g} = \frac{(1.39)^2}{2(9.81)} = 0.10m$$

$$H_1 = z_i + y_i + \frac{V_i^2}{2g}$$

$$= 0.40 + 3.60 + 0.10$$

$$H_i = 4.10m$$

$$H_e = z_e + y_e + \frac{V_e^2}{2g}$$

$$= H_i - 0.1$$

$$H_e = 4.00m$$

$$E_e = H_e = 4.00m$$

Example 6.6

A trapezoidal channel has a bottom width of 5m and side slopes m = 2. If the flow rate is 20 m³/s, what is the critical depth?

$$\frac{Q^2}{g} = DA^2 = \frac{A^3}{T} = \frac{[(b+my)y]^3}{b+2my}$$

$$\frac{20^2}{9.81} = 40.8 = \frac{[(5+2y)y]^3}{5+2(2)y}$$

$$y = 1.02m$$

$$y_c = y = 1.02m$$

$$\frac{Q\,m^{3/2}}{g^{1/2}\,b^{5/2}} = \frac{(20)(2)^{3/2}}{(9.81)^{1/2}(5)^{5/2}}$$

$$= 0.3230840175$$

$$\frac{my_c}{b} = \frac{(2)(1.02)}{5} = 0.408$$

$$y_c = \frac{0.408(5)}{2} = \boxed{1.020m}$$

Example 6.7

A 10 ft-wide rectangular channel carries 500 cfs of water at a 2 ft depth before entering a jump. Compute the downstream water depth and the critical depth.

$$q = \frac{500}{10} = 50 \ \frac{ft^3}{s} \cdot ft$$

$$y_c = \sqrt[3]{\frac{Q^2}{g b^2}} = \sqrt[3]{\frac{q^2}{g}}$$

$$V_1 = \frac{q}{y_1}$$

$y_1 = 2.0$;

$$y_c = \sqrt[3]{\frac{50^2}{32.2}} = 4.266070671 \ ft$$

$$= \frac{50}{2}$$

$$V_1 = 25 \ ft/s$$

$$N_{F_1} = \frac{V_1}{\sqrt{g y_1}} = 3.12$$

$$\frac{y_2}{y_1} = \frac{1}{2}\left(\sqrt{1 + 8 N_{F_1}^2} - 1\right)$$

$$\frac{y_2}{2} = \frac{1}{2}\left(\sqrt{1 + 8(3.12)^2} - 1\right) = 7.881171094 \ ft$$

$$\boxed{y_2 = 7.881 \ ft}$$

Example 6.8

A long, rectangular open channel 3m wide carries a discharge of 15 m³/s. The Channel slope is 0.004, and the Mannig's coefficient is 0.01. At a certain point in the channel, flow reaches normal depth.

a.) determine the flow classification at normal depth. Is it supercritical or subcritical?

b.) If a hydraulic jump takes place at normal depth, what is the sequent depth?

c.) Estimate the energy head loss through the jump.

For A;

$$Q = \frac{1}{n} A_1 R_{h_1}^{2/3} S^{1/2}$$

$$A = y_1 b$$

$$R_h = \frac{A_1}{P_1} = \frac{y b}{2 y_1 + b}$$

$b = 3m$

$$15 = \frac{1}{0.01}(3 y_1)\left(\frac{3 y_1}{2 y_1 + 3}\right)^{2/3} (0.004)^{1/2}$$

$$y_1 = 1.08 m$$

$$V_1 = \frac{Q}{3 y_1} = \frac{15}{3(1.08)} = 4.63 \ m/s$$

$$N_{F_1} = \frac{V_1}{\sqrt{g y_1}} = \frac{4.63}{\sqrt{(9.81)(1.08)}} = 1.42$$

$N_{F_1} > 1$; Flow is $\boxed{\text{SUPERCRITICAL}}$

For B;

$$y_2 = \frac{y_1}{2}\left(\sqrt{1 + 8 N_{F_1}^2} - 1\right) = 1.57 y_1 = 1.57(1.08)$$

$$\boxed{y_2 = 1.6956 \ m}$$

For C;

$$\Delta E = \frac{(y_2 - y_1)^3}{4 y_1 y_2} = \frac{(0.62)^3}{4(1.70)(1.08)} = \boxed{0.032 \ m}$$