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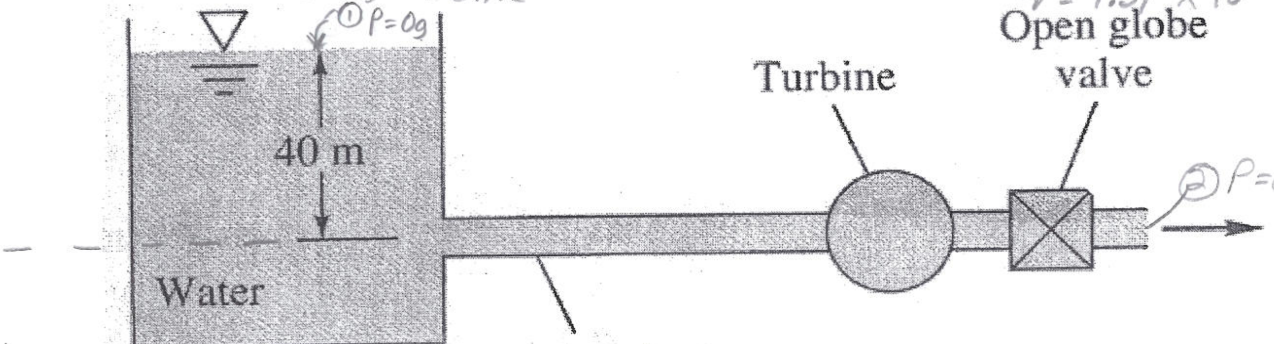
ENCE 3318
Fluid Mechanics for Civil Engineering
TEST 4

1. In the Figure below, the pipe entrance is sharp-edged. If the flow rate is 0.004 m^3/s, what power, in W, is extracted by the turbine?

Assume Large Tank   Assume $T = 10°C$ $\gamma = 9810\ N/m^2$ $\nu = 1.31 \times 10^{-6}\ m^2/s$



Cast iron:
$L = 125$ m, $D = 5$ cm

$A_{pipe} = \frac{\pi d^2}{4} = \frac{\pi (.05m)^2}{4} = 0.00196\ m^2$

$g = 9.81\ m/s^2$

$\gamma = 9810\ N/m^2$

$Q = 0.004\ m^3/s$ $Q = VA \therefore V = \frac{Q}{A} \therefore V_2 = \frac{0.004\ m^3/s}{0.00196\ m^2} = 2.041\ m/s$

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$h_{L_{entrance}} = K_e V^2/2g = (0.5)(2.041)^2 \div 2(9.81) = 0.1062\ m$

$h_{L_{exit}} = K_{ex} \frac{V^2}{2g} = (1)(2.041)^2 \div 2(9.81) = 0.2123\ m$

$h_{L_{valve}}\ K_v\ V^2/2g = (10)(2.041)^2 \div 2(9.81) = 2.1232 m$

$h_{L_{minor}} = 0.1062m + 0.2123m + 2.1232m = 2.4417m$

pipe $R_n = \frac{VD}{\nu} = \frac{(2.041\ m/s)(125m)}{1.31 \times 10^{-6}\ m^2/s} = 1.947 \times 10^8$

$\frac{k_s}{d} = \frac{0.00026m}{.05m} = 0.0052 \quad \therefore f = 0.032$

$h_f = f \frac{L}{D} \frac{V^2}{2g} = (0.032)\left(\frac{125m}{0.05m}\right)\left(\frac{(2.041\ m/s)^2}{2(9.81\ m/s^2)}\right) = 16.98\ m$

$\frac{P_1}{\gamma} + Z_1 + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + Z_2 + \frac{V_2^2}{2g} + h_{L_{minor}} + h_{L_{pipe}} + h_t$ ($P_1, V_1, P_2, Z_2 \to 0$)

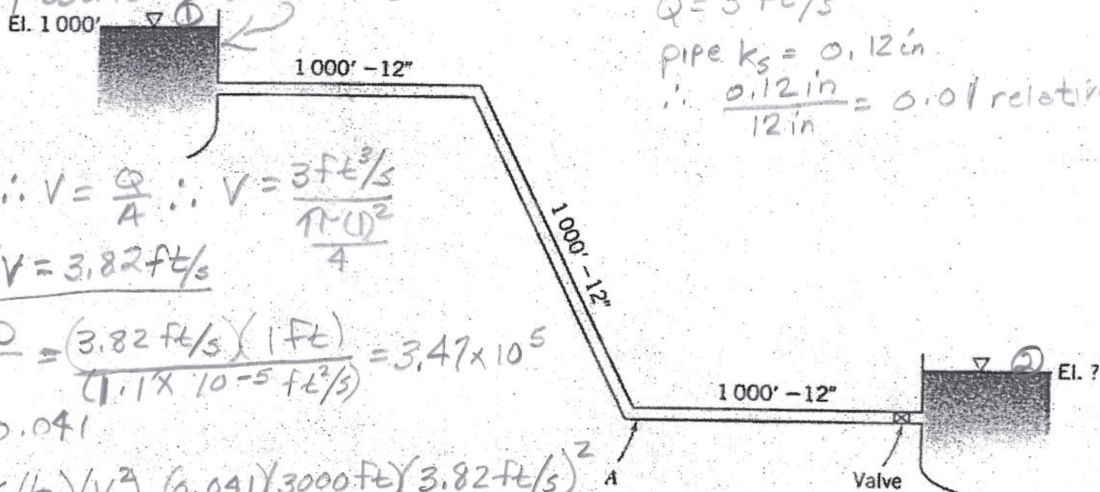
$40 - \frac{(2.041\ m/s)^2}{2(9.81\ m/s^2)} - 2.4417m - 16.98m = h_t = 20.366m$

Power   Watts $= Q\gamma h_t = (0.004\ m^3/s)(9810\ N/m^2)(20.366\ m)$

799.2 watts or **.799 kw**

2. A concrete pipeline ($k_s = 0.12$ in.) 3000 feet long conveys water ($\nu = 1.1 \times 10^{-5}$ ft^2/s) between two reservoirs. If the discharge is 3.0 cfs, find the elevation of the lower reservoir. A partially open valve near the lower reservoir has a loss coefficient of 6.0. The entrance loss coefficient is 0.3. Neglect minor losses for pipe bends. The diameter of the pipe is 12 inches.

Assume Large Tank



$Q = 3\ ft^3/s$

pipe $k_s = 0.12$ in

$\therefore \dfrac{0.12\ in}{12\ in} = 0.01$ relative roughness

$Q = AV \therefore V = \dfrac{Q}{A} \therefore V = \dfrac{3\ ft^3/s}{\frac{\pi (1)^2}{4}}$

$V = 3.82\ ft/s$

$R_n = \dfrac{VD}{\nu} = \dfrac{(3.82\ ft/s)(1\ ft)}{(1.1 \times 10^{-5}\ ft^2/s)} = 3.47 \times 10^5$

$\therefore f = 0.041$

$h_f = f\left(\dfrac{L}{D}\right)\left(\dfrac{V^2}{2g}\right) = \dfrac{(0.041)(3000\ ft)(3.82\ ft/s)^2}{(1\ ft) \times 2 \times 32.2\ ft/s^2}$

$h_f = 27.87\ ft$

$h_{L\,entrance} = K_e \dfrac{V^2}{2g} = 0.3\dfrac{(3.82\ ft/s)^2}{2(32.2\ ft/s^2)} = 0.06798\ ft$

$h_{L\,valve} = K_v \dfrac{V^2}{2g} = \dfrac{6.0\,(3.82\ ft/s)^2}{2(32.2\ ft/s^2)} = 1.35954\ ft$

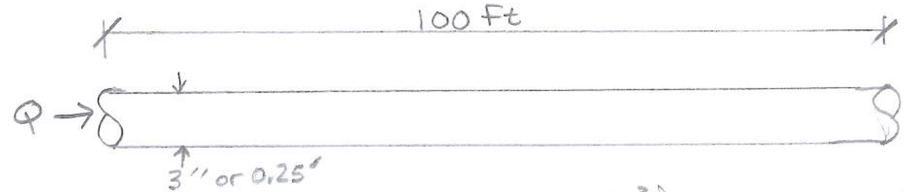
$h_{L\,exit} = K_{ex}\dfrac{V^2}{2g} = \dfrac{1.0\,(3.82\ ft/s)^2}{2(32.2\ ft/s)} = 0.22659\ ft$

$\dfrac{P_1}{\gamma}^{\nearrow 0} + Z_1 + \dfrac{V_1^2}{2g}^{\nearrow 0} = \dfrac{P_2}{\gamma}^{\nearrow 0} + Z_2 + \dfrac{V_2^2}{2g}^{\nearrow 0} + h_f + h_{L\,ent} + h_{L\,valve} + h_{L\,exit}$

$1{,}000\ ft - 27.87\ ft - 0.06798\ ft - 1.35954\ ft - 0.22659\ ft = Z_2$

$\boxed{Z_2 = 970.48\ ft}$

3. A 3 in. Smooth pipeline 100 ft long carries 100 gpm of crude oil. Calculate the head loss when the oil is at (a) 80°F, (b) 110 °F.



1 gallon = 0.13368 ft³

$A = \frac{\pi d^2}{4} = \frac{\pi(.25)^2}{4} = 0.049\ ft^2$

$\nu_{@80°F} = 1.59 \times 10^{-4}\ lb\text{-}s/ft^2$

$\nu_{@110°F} = 1.15 \times 10^{-4}\ lb\text{-}s/ft^2$

$Q = (100\ gal/min)\left(\frac{1\ min}{60\ sec}\right)\left(\frac{0.13368\ ft^3}{1\ gal}\right) = 0.2228\ ft^3/sec$

$Q = VA \therefore V = \frac{Q}{A} \therefore V = \frac{0.2228\ ft^3/s}{0.049\ ft^2} = \boxed{4.547\ ft/s}$

a.) $T = 80°F$

$h_f = f\frac{L}{D}\frac{V^2}{2g} = (0.008952)\left(\frac{100\ ft}{0.25\ ft}\right)\left(\frac{(4.547\ ft/s)^2}{2(32.2\ ft/s^2)}\right)$

$R_n = \frac{Vd}{\nu} = \frac{(4.547\ ft/s)(0.25')}{1.59 \times 10^{-4}\ lb\text{-}s/ft^2}$

$R_n = 7.149 \times 10^3$ (Laminar Flow)

$f = \frac{64}{R_n} = 0.008952$

$\boxed{h_f = 1.15\ ft\ @\ 80°F}$

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b) $T = 110°F$

$h_f = f\frac{L}{D}\frac{V^2}{2g} = (0.006475)\left(\frac{100\ ft}{0.25\ ft}\right)\left(\frac{(4.547\ ft/s)^2}{2(32.2\ ft/s^2)}\right)$

$R_n = \frac{Vd}{\nu} = \frac{(4.547\ ft/s)(0.25')}{1.15 \times 10^{-4}\ lb\text{-}s/ft^2}$

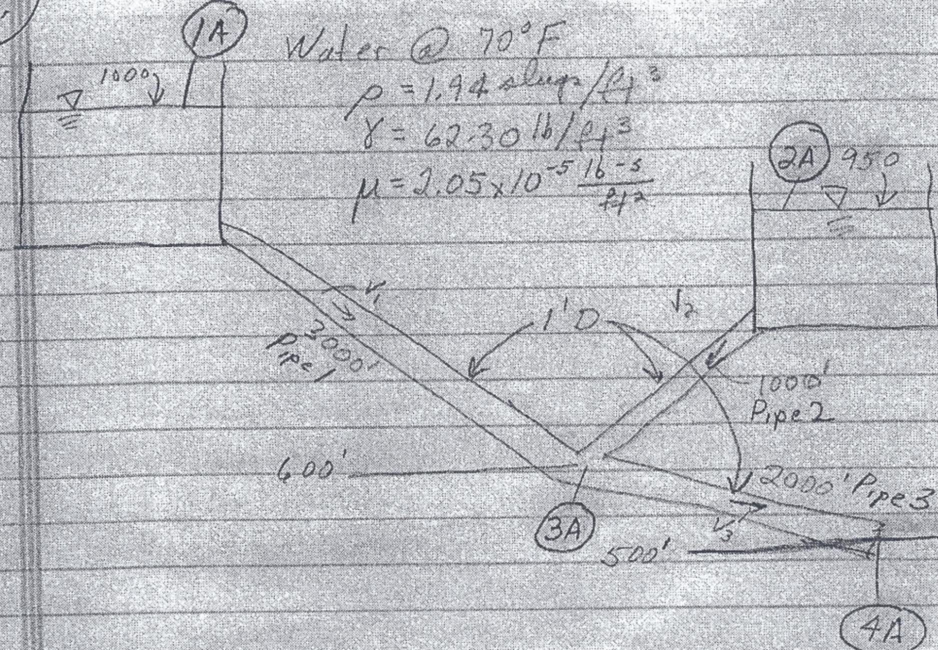
$R_n = 9.884 \times 10^3$ (Laminar Flow)

$f = \frac{64}{R_n} = \frac{64}{9884.78} = 0.006475$

$\boxed{h_{f@110°F} = 0.83\ Ft}$

4. Below is the two reservoir problem from class. Choose a pipe material that will work. Show all calculations.

4.)



$$E_{1A} = \frac{p_{1A}}{\gamma} + z_{1A} + \frac{V_{1A}^2}{2g} = 0 + 1000 + 0 = 1000'$$

$$E_{2A} = \frac{p_{2A}}{\gamma} + z_{2A} + \frac{V_{2A}^2}{2g} = 0 + 950 + 0 = 950'$$

$$E_{4A} = \frac{p_{4A}}{\gamma} + z_{4A} + \frac{V_{4A}^2}{2g} = 0 + 500 + 0 = 500'$$

Assume $f = 0.02$ for all pipes

$$E_{3A} = 1000 - .02 \frac{3000}{1} \frac{V_1^2}{2g}$$ {E3-1 means E_{3A} from 1A

$$E_{3A} = 950 - .02 \frac{1000}{1} \frac{V_2^2}{2g}$$ {E3A from 2A (Use to get V_2)

$$A_1V_1 + A_2V_2 = A_3V_3 \Rightarrow V_3 = \frac{A_1V_1 + A_2V_2}{A_3}$$ but $A_1 = A_2 = A_3$

$= V_1 + V_2$

$$V_3 = V_1 + V_2$$

$$E_{3A} = 500 + .02 \frac{2000}{1} \frac{V_3^2}{2g}$$ {E_{3A} from 4A (E3-4)

Assumed V_1	E3-1	V_2	V_3	E3-4
10	906.8	11.8	21.8	794.9
20	627.3	32.2	52.2	2194.6
10.94	888.5	14.1	25.01	888.6

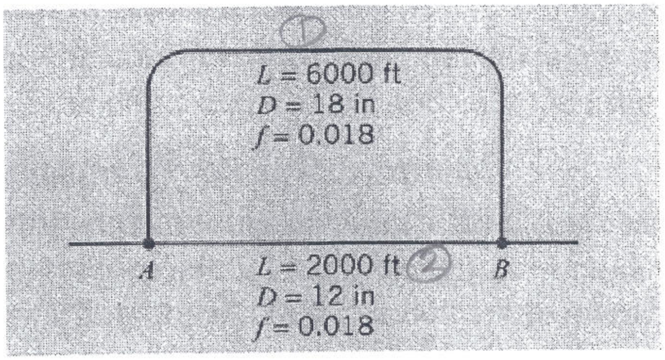
Must be equal

Using the same assumption above $f = 0.02$ for all pipes
if all pipe = 12 in Ø

$\frac{k_s}{d} = 0.001 \therefore k_s = 0.001 \times 12\text{ in} = 0.012\text{ in}$

From table 10.2 <u>Concrete</u> has ks 0.012 – 0.12

5. With a total flow of 14 cfs, determine the division of flow and the head loss from A to B.



head loss either direction is the same

$Q_t = Q_1 + Q_2 = 14\ ft^3/s$

$f_1 = f_2 = 0.018$

$d_1 = 18'' = 1.5 ft$

$d_2 = 12'' = 1.0 ft$

$L_1 = 6{,}000\ ft$

$L_2 = 2{,}000\ ft$

$A_1 = 1.767\ ft^2$

$A_2 = 0.785\ ft^2$

$$h_f = f_1 \frac{L_1}{d_1}\frac{V_1^2}{2g} = f_2 \frac{L_2}{d_2}\frac{V_2^2}{2g}$$

$$(0.018)\left(\frac{6{,}000 ft}{1.5 ft}\right)\frac{V_1^2}{2(32.2 ft/s^2)} = (0.018)\left(\frac{2{,}000 ft}{1.0 ft}\right)\left(\frac{V_2^2}{(2)32.2 ft/s^2}\right)$$

$$72 V_1^2 = 36 V_2^2$$

$$8.4853 V_1 = 6.0 V_2 \Rightarrow V_1 = 0.707 V_2$$

$$Q = A_1 V_1 + A_2 V_2$$

$$14 ft^3/s = (1.767 ft^2)(0.707 V_2) + (0.785 ft^2)(V_2)$$

$$14 ft^3/s = 1.249 ft^2 V_2 + 0.785 ft^2 V_2$$

$$14 ft^3/s = 2.0343 ft^2 V_2$$

$$V_2 = \boxed{6.882 ft/s} \Rightarrow V_1 = 0.707(6.882 ft/s) = \boxed{4.866 ft/s}$$

$$h_{L_1} = f\left(\frac{L_1}{d}\right)\left(\frac{V_1^2}{2g}\right) = (0.018)\left(\frac{6{,}000 ft}{1.5 ft}\right)\left(\frac{(4.866 ft/s)^2}{2(32.2 ft/s^2)}\right) = \boxed{26.47 ft}$$

$$h_{L_2} = f\left(\frac{L_2}{d}\right)\left(\frac{V_2^2}{2g}\right) = (0.018)\left(\frac{2{,}000 ft}{1 ft}\right)\left(\frac{(6.882 ft/s)^2}{2(32.2 ft/s^2)}\right) = \boxed{26.48 ft}$$

$$\boxed{h_{L_{A \to B}} = 26.475 ft}$$