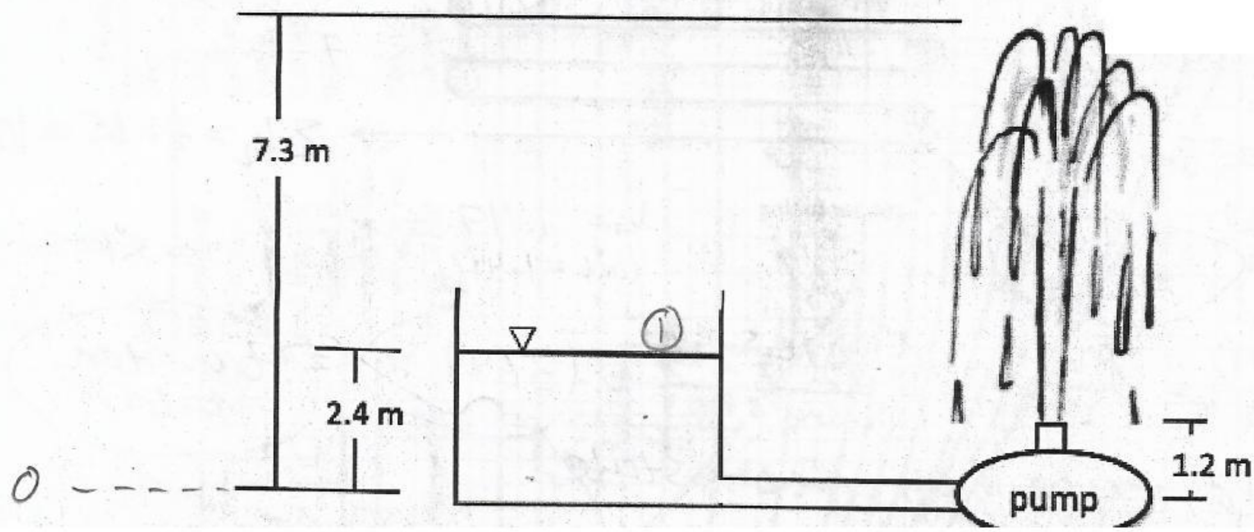
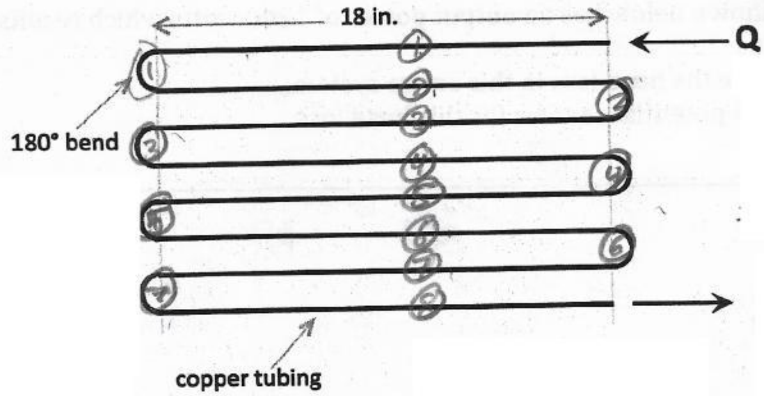
## Quiz 4 – November 7, 2022

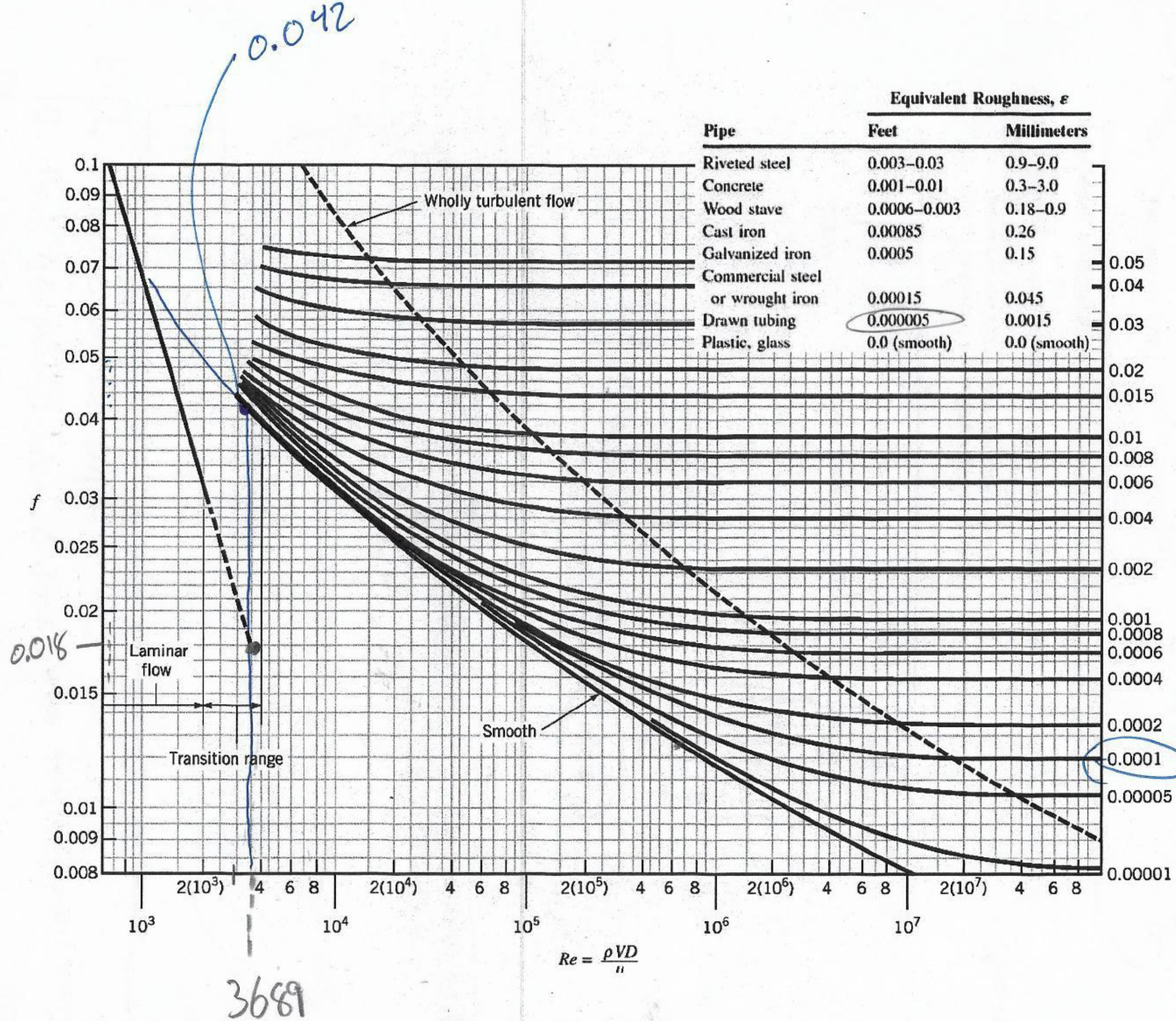
*Please label units in all calculations and write all relevant equations explicitly. Make sure the units make sense!! BE CAREFUL!!!! You all are masters at making arithmetic errors!!!*

1. The pump shown below has an output power of 1200 watts which results in a flowrate of $0.017 m^3/s$.
   a. Determine the head loss in this entire system.
   b. List three potential sources for this head loss.



2. Heated water ($\nu = 1.66 \times 10^{-5}$ ft$^2$/s) flow through coils of a heat exchanger lying on a flat surface, at a rate of 0.9 gal/min. The coils are made of 18 inch copper drawn tubing with a diameter 0.5 inch, connected to each other with 180° threaded return bends (each $K_L = 1.5$) as shown below. What is the pressure drop between the inlet and the outlet of this horizontal device?
1 ft$^3$ = 7.48 gal






| Pipe | Equivalent Roughness, $\varepsilon$ Feet | Millimeters |
|---|---|---|
| Riveted steel | 0.003–0.03 | 0.9–9.0 |
| Concrete | 0.001–0.01 | 0.3–3.0 |
| Wood stave | 0.0006–0.003 | 0.18–0.9 |
| Cast iron | 0.00085 | 0.26 |
| Galvanized iron | 0.0005 | 0.15 |
| Commercial steel or wrought iron | 0.00015 | 0.045 |
| Drawn tubing | 0.000005 | 0.0015 |
| Plastic, glass | 0.0 (smooth) | 0.0 (smooth) |

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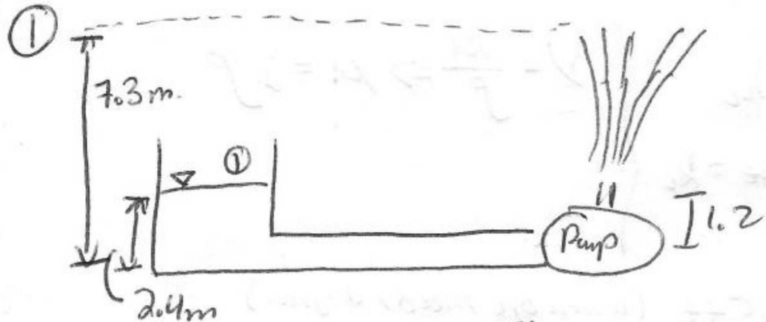
1




Power $= h_p \dot{m} g$ ($\dot{m} = \rho Q$)

$$h_p = \frac{(1200\ \frac{J}{s})}{(1000\frac{kg}{m^3})(0.017\frac{m^3}{s})(9.8\frac{m}{s^2})} = 7.203m$$

a) $\cancel{\frac{V_1^2}{2g}} + \cancel{\frac{P_1}{\gamma}} + z_1 + h_p = \cancel{\frac{V_2^2}{2g}} + \cancel{\frac{P_2}{\gamma}} + z_2 + h_L + \cancel{h_T}$

$h_L = z_1 + h_p - z_2$

$= 2.4m + 7.203 - 7.3m$

$\boxed{h_L = 2.3\ m.}$

b) 1. friction in pipe

2. Bend at pump when direct water from horizontal to vertical flow.

3. Water is not a uniform column as it exits pipe, it becomes spreadout as it gets higher (interaction with air)

(2)

Pipe $h_L$ and $k_L$

major headloss $8 \times \frac{18in}{12in} = 12ft = h_L$

minor headloss $\Sigma k_L = 7 \times 1.5 = 10.5ft = k_L$

$\nu = \frac{\mu}{\rho} \Rightarrow \mu = \nu\rho$

$V_{in} = 1.47 \frac{ft}{sec} = V_{out}$

$Q = \frac{0.9gal}{min} = 0.002 \frac{ft^3}{sec}$ $\quad \varepsilon = 0.000005ft$ (given on moody digram)

$\frac{\varepsilon}{D} = \frac{0.000005ft}{(\frac{0.5in}{12in})ft} = 1.2 \times 10^{-4}$

$Re = \frac{\rho VD}{\mu} = \frac{\cancel{\rho} VD}{\nu \cancel{\rho}} = \frac{(1.47\frac{ft}{s})(\frac{0.5}{12}ft)}{1.66 \times 10^{-5} ft^2/s} = 3689.8 \Rightarrow$ transition state.

$f = 0.042 \Rightarrow$ moody chart.

$$\cancel{\frac{V_1^2}{2g}}^{0} + \frac{P_1}{\gamma} + \cancel{z_1}^{0} = \cancel{\frac{V_2^2}{2g}}^{0} + \frac{P_2}{\gamma} + \cancel{z_2}^{0} + h_L + \Sigma k_L$$

$$\frac{P_1 - P_2}{\gamma} = h_L = \underbrace{f\left(\frac{L}{D}\right)\frac{\bar{V}^2}{2g}}_{major} + \underbrace{\Sigma k_L \frac{\bar{V}^2}{2g}}_{minor}$$

$$\Delta P = \rho g \left(f\left(\frac{L}{D}\right) + \Sigma k_L\right)\frac{\bar{V}^2}{2g}$$

$$= \rho\left[f\left(\frac{L}{D}\right) + \Sigma k_L\right]\frac{\bar{V}^2}{2}$$

$$= \left(1.94 \frac{slug}{ft^3}\right)\left[(0.042)\left(\frac{144in}{0.5in}\right) + (7 \times 1.5)\right]\frac{(1.47\frac{ft}{s})^2}{2}$$

$$\boxed{\Delta P = 47.36 \frac{lb}{ft^2}}$$