	ODU MET 330 Fluid MEC	HW 1.4

7.11 A submersible deep-well pump delivers 745 gal/h of water through a 1-in Schedule 40 pipe when operating in the system sketched in Fig. 7.18. An energy loss of 10.5 lb-ft/lb occurs in the piping system. (a) Calculate the power delivered by the pump to the water. (b) If the pump draws 1 hp, calculate its efficiency."

$P_1 = 0 \quad P_2 = 40 \frac{lb}{in^2}$

$V_1 = 0 \quad V_2 = 0$

$\gamma_w = 62.4 \frac{lb}{ft^3}$

Given:

Pump Rate: $745 \frac{gal}{hr}$

Pipe : 1in Sch 40

Energy loss: $-10.5 \frac{lb-ft}{lb}$

Find: a) Cal Power delivered by pump

b) Cal Eff of pump @ 1 Hp

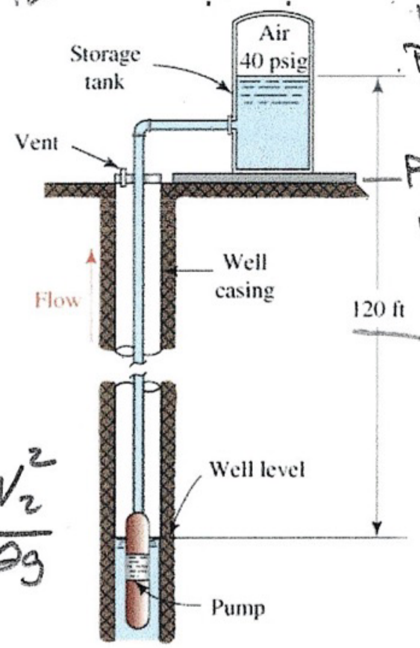


Figure 7.18

$V_2 = 0$, $P_2 = 40$

$P_1 = 0$, $V_1 = 0$

ⓐ Step 1 - Solve for h_A

$$\frac{P_1}{\gamma_w} + Z_1 \frac{V_1^2}{2g} + h_A - h_L = \frac{P_2}{\gamma_w} + Z_2 + \frac{V_2^2}{2g}$$

$$h_A = \frac{P_2}{\gamma_w} + (Z_2 + Z_1) + h_L$$

$$h_A = \frac{40 \frac{lb}{in^2} \cdot \frac{144 in^2}{1 ft^3}}{64.2 \frac{lb}{ft^3}} + (120 ft + 10.5 ft)$$

$$h_A = 89.72 ft + 130.5 ft$$

$$h_A = \underline{220.22 \frac{lb \cdot ft}{lb}}$$

Conversion

$1 \frac{gal}{min} = 0.002 \frac{ft^3}{sec}$

$449 \frac{gal}{min} = 1 \frac{ft^3}{sec}$

Solve for Q

$$Q = 745 \frac{gal}{hr} \left| \frac{1 hr}{60 min} \right|$$

$$12.42 \frac{gal}{min} \times \frac{1 \frac{gal}{min}}{0.002 \frac{ft^3}{sec}} = \underline{0.0273 \frac{ft^3}{sec}}$$

7.11 contined

ⓐ $P_A = h_A \gamma_w Q$

$= \left(220.22 \frac{lb \cdot ft}{lb}\right) \times \left(62.4 \frac{lb}{ft^3}\right) \times \left(0.0273 \frac{ft^3}{sec}\right)$

$= 375.15 \frac{lb \cdot ft}{lb \cdot s} \cdot \frac{1 \text{ HP}}{550 \text{ lb} \cdot \frac{ft}{sec}}$

$P_A = \underline{\underline{0.682 \text{ HP}}}$

ⓑ $Eff_m = \frac{P_A}{P_I} = \frac{0.682 \text{ HP}}{1 \text{ HP}}$

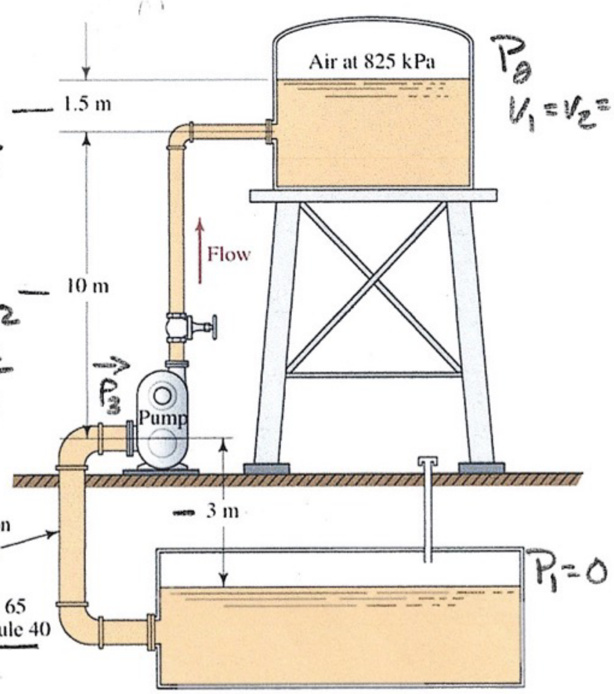
$Eff = 0.68$

$Eff = \underline{\underline{68\%}}$

	ODU MET 330 Fluid Mechanics	HW 1.3

7.16 Figure P7.16 shows a pump delivering 840L/MIN. of crude oil (sg = 0.85) from an underground storage drum to the first stage of a processing system. (a) If the total energy loss in the system is 4.2 N *m/N of oil flowing, calculate the power delivered by the pump. (b) If the energy loss in the suction pipe is 1.4N * m/N of oil flowing, calculate the pressure at the pump inlet.

Figure P7.16



Oil pump and tanks for Problem 7.16.

Given:

Pump $840 \frac{L}{min}$ $P_2 = 825\ kPa$

Oil $sg = 0.85 \cdot 1000 \rightarrow 850 \frac{kg}{m^3}$

$\rho = 850 \frac{kg}{m^3}$

$$\frac{P_1}{\gamma_o} + z_1 + \frac{V_1^2}{2g} + h_A - h_L = \frac{P_2}{\gamma_o} + z_2 + \frac{V_2^2}{2g}$$

$$h_A = \frac{P_2}{\gamma_o} + (z_2 - z_1) + h_L$$

$$h_A = \frac{825\ kN\, m^3}{(0.85)(9.81\ kN)} + 14.5_m + 4.2_m$$

$h_A = 98.94 + 18.7$

$h_A = \underline{117.64\ m}$

$1 \frac{m^3}{sec} = 60000 \frac{L}{min}$

$$Q = \frac{840 \frac{L}{min}}{1} \left| \frac{1 \frac{m^3}{sec}}{60000 \frac{L}{min}} \right.$$

$Q = 0.014 \frac{m^3}{sec}$

$P_A = h_A \gamma_o Q$

$= (117.64 m)(0.85)\left(\frac{9.81 kN}{m^3}\right)$

$= 980.94 \frac{kN}{m^2} \left(0.014 \frac{m^3}{sec}\right)$

(a) $P_A = 13.73 \frac{kN \cdot m}{sec}$ — watt $\rightarrow \underline{13.73\ kW}$

7.16 Continued...

(b)

$$\frac{P_1}{\gamma_o} + z_1 + \frac{V_1^2}{2g} - h_{Ls} = \frac{P_3}{\gamma_o} + z_3 + \frac{V_3^2}{2g}$$

$$V_3 = \frac{Q}{A_3} = \frac{0.014 \frac{m^3}{sec}}{0.003091 m^2} = 4.63 \frac{m}{sec}$$

→ DN Sch 40 pipe
Table F.1
Flow Rate
→ $3.090 \times 10^{-3} m^2$

$$P_3 = \gamma_o \left[(z_1 - z_3) - \frac{V_3^2}{2g} - h_{Ls} \right]$$

$$P_3 = (0.85)(9.81 \frac{kN}{m^3}) \left[-3m - \frac{(4.63 \frac{m}{sec})^2}{2(9.81 \frac{m}{sec^2})} - 1.4 \frac{N \cdot m}{N} \right.$$

$$P_3 = (8.338 \frac{kN}{m})(-3m - 1.093m - 1.4 \frac{N \cdot M}{N})$$

$$-5.493$$

$$P_3 = -45.80 k \frac{N}{m^2} \rightarrow -45.80 kPa$$

	ODU MET 330 Fluid Mechanics	HW 1.3

7.22 Figure P7.22 shows the arrangement of a circuit for a hydraulic system. The pump oil with a specific gravity of 0.90 from a reservoir and delivers it to the hydraulic cylinder. The cylinder has an inside diameter of 5.0 in, and 15 sec the piston must travel 20 inches while exerting a force of 11000 lb. It is established that there are energy losses of 11.5lb-ft/lb in the section pipe and 35.0 lb-ft/lb in the discharge pipe. Both pipes are 3/8 inches Schedule 80 steel pipe. Calculate:

- ✓ a. The volume flow rate through the pump
- ✓ b. The pressure at the cylinder
- ✓ c. The pressure at the outlet of the pump
- ✓ d. The pressure at the inlet to the pump
- ✓ e. The power delivered to the oil by the pump

Given:

Oil $sg = 0.90$

$\gamma_o(sw) = sg\,\gamma_{H_2O} = 0.90(62.4\ \frac{lb}{ft^3})$

→ Cylinder

Inside Dia $= \frac{5.0\ in}{} \left| \frac{1\ ft}{12\ in} \right. = 0.416\ ft$

→ Energy loss

Suction side $= 11.5\ \frac{lb-ft}{lb}$

discharge side $= 35\ \frac{lb-ft}{lb}$

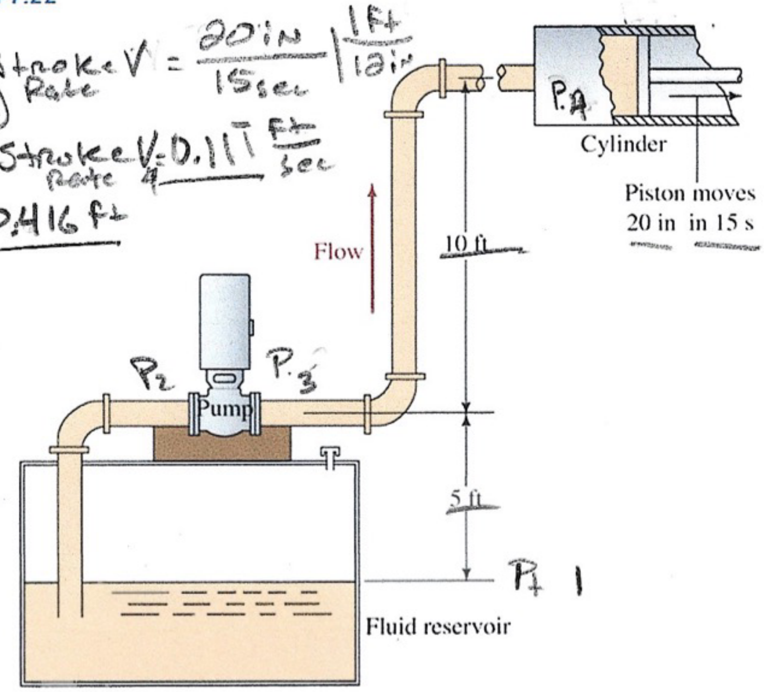
Pipe $\frac{3}{8}$ in Sch 80

$A = \frac{1}{4}\pi($

Stroke Rate $V = \frac{20\ in}{15\ sec} \left| \frac{1\ ft}{12\ in} \right.$

Stroke Rate $V = 0.11\overline{1}\ \frac{ft}{sec}$

Figure P7.22



Hydraulic system for Problem 7.22.

ⓐ $Q = A_{cy} \cdot \text{Stroke Rate}\,(v)$

$= \frac{\pi (0.416)^2 ft^2}{4} \cdot 0.1\overline{1}\ \frac{ft}{sec}$

$Q = 0.0152\ \frac{ft^3}{sec}$

ⓑ $P_{cy_3} = \frac{F}{A_{cy}}$

$P_{cy_3} = \frac{11000\ lb}{\left[\frac{\pi (0.416\ ft^2)}{4}\right]}$

$P_{cy_3} = 80659.55\ \frac{lb}{ft^2}$

7.22 Continued....

c) Pressure @ outlet of pump

$$\frac{P_2}{\gamma_0} + Z_2 + \frac{V_2^2}{2g} + h_L = \frac{P_3}{\gamma_0} + Z_3 + \frac{V_3^2}{2g}$$

$$P_2 = P_3 + \gamma_0 (Z_3 - Z_2) + \frac{V_3^2 - V_2^2}{2g} + h_L$$

Find!

Velocity

@ $V_3 = 0.111 \frac{ft}{sec}$

@ V_2

$\gamma_0 = (0.90) 62.4 \frac{lb}{ft^3}$

$\gamma_0 = 56.16 \frac{lb}{ft^3}$

$V_2 = \frac{Q}{A_c}$

$V_2 = \frac{0.0152 \frac{ft^3}{sec}}{0.000976 ft^2}$

$V_2 = 15.57 \frac{ft}{sec}$

→ Table F.2

Flow Rate

$\frac{3}{8}$ sch 80

$0.000976 ft^2$

$P_3 = \frac{11000 lb f}{19.63 in^2 A_c}$

$P_3 = 560 \frac{lb}{in^2}$

$$P_2 = 560 \frac{lb}{in^2} + 56.16 \frac{lb}{ft^2}\left(10 ft + \frac{(0.111 ft^2 - 15.57 ft^2)}{(2 \cdot (32.2 \frac{ft}{sec^2}))} + 35 ft\right)$$

$$= 560 \frac{lb}{in^2} + 56.16 \frac{lb}{ft}\left(10 ft + \left(\frac{-248.051}{64.4}\right) + 35 ft\right)$$

$$= 560 \frac{lb}{in} + \left[56.16 \frac{lb}{ft}\right.$$

$$2315.80 \frac{lb}{ft^2} \cdot \frac{ft^2}{144 in}$$

$$= 560 \frac{lb}{in^2} + 16.08 \frac{lb}{in^2}$$

$$P_2 = 576.08 \frac{lb}{in^2}$$

7.22

d. Find Pressure @ inlet pump.

$$\frac{P_1}{\gamma_o} + z_1 + \frac{V_1^2}{2g} - h_{L_4} = \frac{P_4}{\gamma_o} + z_4 + \frac{V_4^2}{2g}$$

$$P_4 = \gamma_o \left(\overset{5^{ft}}{z_1} - \overset{10^{ft}}{z_4} - \frac{V_4^2}{2g} - h_{L_4} \right)$$

$$P_4 = 56.16 \frac{lb}{ft^3} \left(-5_{ft} - \frac{\left(15.57 \frac{ft}{sec}\right)^2}{2\left(32.2 \frac{ft}{sec^2}\right)} - 11.5 \, ft \right)$$

$$= 56.16 \frac{lb}{ft^3} \left(-5 - 3.76 - 11.5 \right)$$

$$= \left(56.16 \frac{lb}{ft^3}\right) \cdot \left(-12.74 \, ft\right)$$

$$= -715.23 \frac{lb}{ft^2} \left| \frac{1 \, ft^2}{144 \, in^2} \right.$$

$$= \underline{\underline{-4.97 \frac{lb}{in^2}}} \quad \text{OR} \quad \underline{\underline{-4.97 \, PSI}}$$

7.22 e) Power to Oil by Pump

$$\frac{P_1}{\gamma_o} + Z_1 + \frac{V_1^2}{2g} + h_1 - h_{s_4} - h_{L_4} = \frac{P_3}{\gamma_o} + Z_3 + \frac{V_3^2}{2g}$$

$$h_1 = \frac{P_3}{\gamma_o} + (Z_3 - Z_1) + \frac{V_4^2}{2g} + h_{s_4} + h_{L_4}$$

$$= \frac{80659.55 \frac{lb}{ft^2}}{56.16 \frac{lb}{ft^3}} + \frac{\left(0.117 \frac{ft}{sec}\right)^2}{\left(2\left(32.2 \frac{ft}{sec^2}\right)\right)} + 11.5\,ft + 35\,ft$$

$\gamma_o = 56.16 \frac{lb}{ft^3}$

$$= 1436.25\,ft + \left[0.000192\,ft + 11.5\,ft + 35\,ft\right]$$

$P_3 = 80659.5 \frac{lb}{ft^2}$

$$h_1 = 1482.75\,ft$$

$V_4 = 0.117 \frac{ft}{sec}$

$$P_1 = h_1 \gamma_o Q$$

$$P_1 = (1482.75\,ft)\left(56.16 \frac{lb}{ft^3}\right)\left(0.0152 \frac{ft^3}{sec}\right)$$

$$P_1 = 1265.72 \frac{ft \cdot lb}{sec} \left| \frac{1\,HP}{550 \frac{ft \cdot lb}{sec}} \right|$$

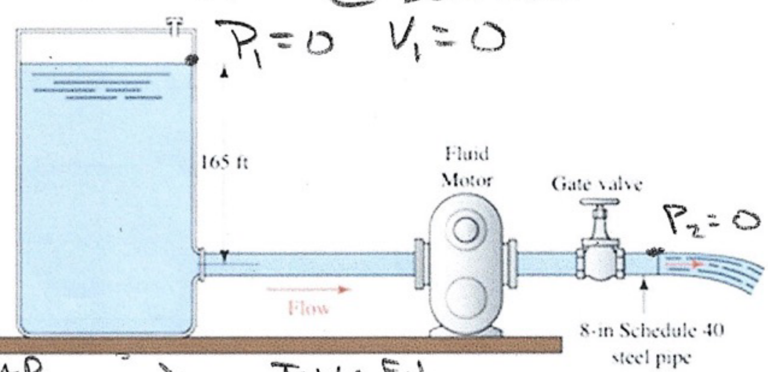
$$P_1 = \underline{2.30\,HP}$$

	ODU MET 330 Fluid Mechanics	HW 1.3

7.30 Water at 60 0F flows from a large reservoir through a fluid motor at a rate of 1000 gal/min in the system shown in Fig. 7.33. If the motor removes 37 hp from the fluid, calculate the energy losses in the system.

Given:
- Water
  Temp = 60 °F
- motor
  Flow Rate = 1000 $\frac{gal}{min}$
  $1\frac{ft^3}{sec} = 449 \frac{gal}{min}$
- Energy Loss

open @ surface
$P_1 = 0 \quad V_1 = 0$



$P_2 = 0$

Figure 7.33
Problem 7.30

Power = 37 HP $\left(550 \frac{1\,HP}{ft \cdot lb/sec}\right)$
Conversion
Power = 20350 $\frac{ft \cdot lb}{sec}$

Table F.1
8 in sch 40
steel pipe
→ Flow Area
$0.3422\ ft^2$

$$\frac{P_1}{\gamma_w} + z_1 \frac{V_1^2}{2g} - h_R - h_L = \frac{P_2}{\gamma_w} + z_2 + \frac{V_2^2}{2g}$$

$$h_L = (z_1 - z_2) - \frac{V_2^2}{2g} - h_R \qquad (z_1 - z_2 = 165\,ft - 0)$$

$$h_R = \frac{Power}{\gamma_w Q} = \frac{20350 \frac{ft \cdot lb}{sec}}{\left(62.4 \frac{lb}{ft^3}\right) 2.227}$$

$h_R = 146.43\ ft$

$Q = \frac{1000}{449} = 2.227 \frac{ft^3}{sec}$

$Q = V_2 A$

$$V_2 = \frac{Q}{A} = \frac{1000 \frac{gal}{min}}{0.3422\,ft^2} \left| \frac{1 \frac{ft^3}{sec}}{449 \frac{gal}{min}} \right. = 6.42 \frac{ft}{sec}$$

$$h_L = 165\,ft - \frac{\left(6.42 \frac{ft}{sec}\right)^2}{\left(2 \cdot 32.2 \frac{ft}{sec^2}\right)} - 146.43\,ft$$

$$h_L = 165\,ft - 0.640\,ft - 146.43\,ft$$

$$h_L = 17.94\ ft = 17.94 \frac{ft \cdot lb}{lb}$$

(1)

	ODU MET 330 Fluid MEC	HW 1.4

7.35 Shows a diagram of a fluid power system for a hydraulic press used to extrude rubber parts. The following data are known:

$\gamma_o = (0.90)(62.4 \frac{lb}{ft^3}) = 58.03 \frac{lb}{ft^3}$

Table F.1
3 in Sch 40
Flow Rate
→ $0.05132\ ft^2$

2½ in Sch 40
Flow Rate
→ $0.03326\ ft^2$

a. The fluid is oil (sg = 0.90)
$\gamma_o = 58.03 \frac{lb}{ft^3}$

b. Volume flow rate is 175 gal/min.
$Q = 0.390 \frac{ft^3}{sec}$

c. Power input to the pump is 28.4 hp.
$28.4\,HP \cdot 550 = 12496 \frac{ft \cdot lb}{sec}$

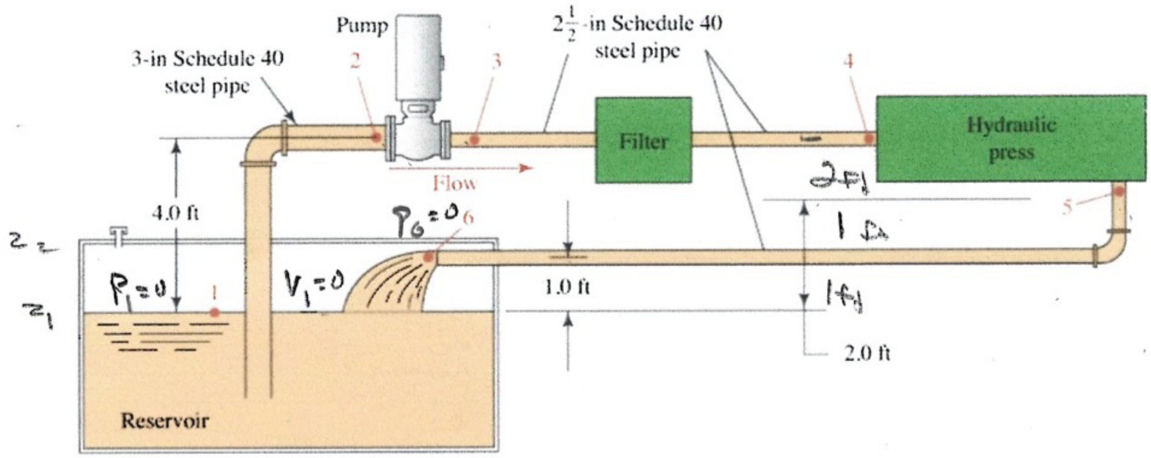
d. Pump efficiency is 80 percent.

$h_{L_{1-6}}$ {
e. Energy loss from point 1 to 2 is 2.80 lb-ft/lb.

f. Energy loss from point 3 to 4 is 28.50 lb-ft/lb.

g. Energy loss from point 5 to 6 is 3.50 lb-ft/lb."
}

$Q = 175 \frac{gal}{min} \left| \frac{1 \frac{ft^3}{s}}{449\frac{gal}{min}} \right| = 0.390 \frac{ft^3}{sec}$



$$\frac{P_1}{\gamma} + z_1 + \frac{V_1^2}{2g} - h_{L_{1-6}} + h_A - h_R = \frac{P_6}{\gamma} + z_6 + \frac{V_6^2}{2g}$$

$$h_R = \overset{0-1}{(z_1 - z_6)} - \frac{V_6^2}{2g} - h_{L_{1-6}} + h_A$$

$$\underset{(5,4,3)}{V_6} = \frac{Q}{A_6} = \frac{0.390 \frac{ft^3}{sec}}{0.03326\ ft^2} = \underline{11.73 \frac{ft}{sec}}$$

7.35.

$$V_6 = \frac{Q}{A_6} = \frac{0.390 \frac{ft^3}{sec}}{0.03326\, ft^2} = 11.73 \frac{ft}{sec}$$

$$h_R = \overset{0-1}{(z_1 - z_6)} - \frac{V_6^2}{2g} - h_{L_{1-6}} + h_A$$

$$h_R = -1\, ft - \frac{\left(11.73 \frac{ft}{sec}\right)^2}{2\left(32.2 \frac{ft}{sec^2}\right)} - \left[\overbrace{2.80 + 28.5 + 3.50}^{34.80\, ft}\right]$$

$$h_R = -1\, ft - 2.14\, ft - \underset{h_{L\,1-6}}{34.80\, ft} + \underset{h_A}{552.43\, ft}$$

$$h_R = \underline{512.49}\, ft$$

$Q = 0.390 \frac{ft^3}{sec}$

$\gamma_o = 58.03 \frac{lb}{ft^3}$

$P_A = 12496 \frac{ft \cdot lb}{sec}$

$$P_A = h_A \gamma_o Q$$

$$h_A = \frac{P_A}{\gamma_o Q}$$

$$h_A = \frac{12496 \frac{ft \cdot lb}{sec}}{\left(58 \frac{lb}{ft^3}\right)\left(0.390 \frac{ft^3}{sec}\right)}$$

$$h_A = \underline{552.43}\, ft$$

$$P_R = h_R \gamma_o Q$$

$$P_R = (512.49\, ft)\left(58 \frac{lb}{ft^3}\right)\left(0.390 \frac{ft^3}{sec}\right)$$

$$P_R = 11592.5 \frac{ft \cdot lb}{sec} \cdot \frac{1\, HP}{550 \frac{ft \cdot lb}{sec}}$$

$$P_R = \underline{21.08\, HP}$$

	ODU MET 330 Fluid Mechanics	HW 1.3

7.42 Professor Crocker is building a cabin on a hillside and has proposed the water system shown Fig 7.38. The distribution tank in the cabin maintains a pressure of 30.0 psig above the water. There is an energy loss of 15.5 lb-ft/lb in the piping. When the pump is delivering 40 gal/min of water, compute the horsepower delivered by the pump to the water.

Givens!

(Cabin TANK) $P_2 = 30 \frac{lb}{in^2} \left| \frac{144 in^2}{ft^2} \right. = 4320 \frac{lb}{ft^2}$

(h_L) Energy Loss $= 15.5 \frac{lb-ft}{lb}$

(Q) Pump Flow Rate $= 40 \frac{gal}{min} \left| \frac{1 ft^3/sec}{449 \, gal/min} \right.$

$Q = 0.0891 \frac{ft^3}{sec}$

$\gamma_{w} = 62.4 \frac{lb}{ft^3}$

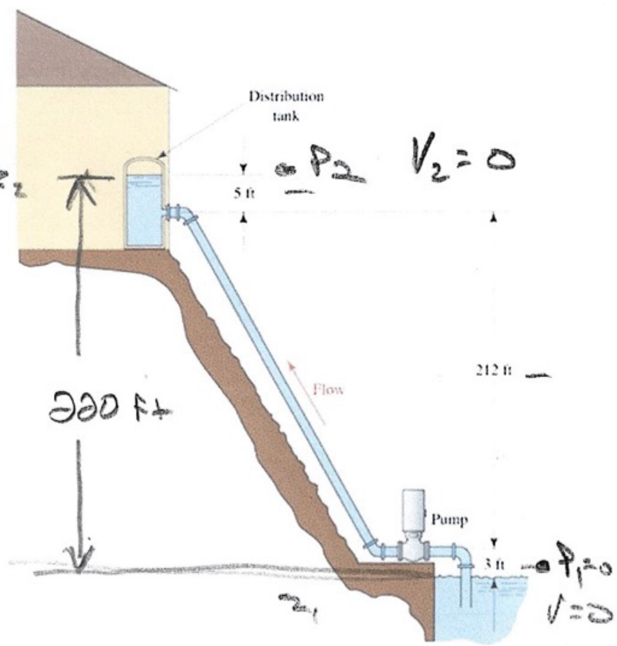


Figure 7.38
Problems 7.42 and 7.43

$$\frac{P_1}{\gamma} + z_1 + \frac{V_1^2}{2g} - h_L + h_A = \frac{P_2}{\gamma} + z_1 + \frac{V_2^2}{2g}$$

$$h_A = \frac{P_2}{\gamma} + (z_2 - z_1) + h_L \quad (220.)$$

$$= \frac{4320 \frac{lb}{ft^2}}{62.4 \frac{lb}{ft^3}} + 220 ft + 15.5 ft$$

$$= 69.23 ft + 220 ft + 15.5 ft$$

$$\Rightarrow h_A = 304.73 ft$$

$$P_A = h_A \gamma Q = (304.73 ft)\left(62.4 \frac{lb}{ft^3}\right)\left(0.0891 \frac{ft^3}{sec}\right)$$

$$P_A = 1694.25 \frac{ft \cdot lb}{sec} \left| \frac{1 HP}{550 \frac{ft \cdot lb}{sec}} \right. = 3.08 HP$$