4.1.6

Applying the energy equation; $h_A + \frac{P_A}{\gamma} + \frac{V_A^2}{2g} = h_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + h_L$; where $V_A = 0$, $V_1 = V$ (pipeline V),

$h_L = h_f + [\sum K](V)^2/2g$; $h_A = 10$ m, $h_1 = 7$ m, and $P_A/\gamma = P_0/\gamma = (9.79\ kN/m^2)/(9.79\ kN/m^3) = 1$ m. Thus,

$P_1/\gamma = h_A - h_1 + P_0/\gamma - [1 + f(L/D) + \sum K](V^2/2g) = 4\ m - [1 + f(L/D) + \sum K](V^2/2g)$

$V = Q/A = (0.0101\ m^3/s)/[(\pi/4)(0.102\ m)^2] = 1.24$ m/sec; $e/D = 0.045mm/102mm = 0.000441$

$N_R = DV/\nu = [(0.102m)(1.24\ m/s)]/(1.00 \times 10^{-6}\ m^2/s) = 1.26 \times 10^5$; From Moody; **f = 0.02**; Thus,

$P_1/\gamma = 4\ m - [1 + 0.02(10m/0.102m) + 0.5 + 12.0][(1.24\ m/s)^2/2 \cdot 9.81\ m/s^2] = 2.79$ m; **P_1 = 27.3 kPa**

For P_2, the energy equation yields: $P_2/\gamma = h_1 - h_2 + P_1/\gamma - h_L$, where $h_L = h_f = f(L/D)(V^2/2g)$. Thus,

$P_2/\gamma = 7\ m - 2\ m + 2.79\ m - [0.02(5m/0.102m)[(1.24\ m/s)^2/2 \cdot 9.81\ m/s^2] = 7.71$ m; **P_2 = 75.5 kPa**

For P_3, the energy equation yields: $P_3/\gamma = P_2/\gamma - h_L$, where $h_L = h_f = f(L/D)(V^2/2g)$. Thus,

$P_3/\gamma = 7.71\ m - [0.02(5m/0.102m)[(1.24\ m/s)^2/2 \cdot 9.81\ m/s^2] = 7.63$ m; **P_3 = 74.7 kPa**

4.1.11

a) Applying the energy equation; $h_A + \frac{P_A}{\gamma} + \frac{V_A^2}{2g} = h_B + \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + h_L$; where $V_A = V_B = P_A = P_B = 0$,

$h_L = h_f + [\sum K](V)^2/2g$; $K_e = 0.5$, $K_d = 1.0$, $h_A – h_B = 80$ m, & $V = Q/A = Q/[\pi\ D^2 4] = 0.255/D^2$. Substituting,

$80\ m = [f(25000/D) + 1.5] \cdot [(0.255/D^2)^2/2g]$. Let's assume that D = 0.5 m, thus V = 1.02 m/s, and

$e/D = 0.12/500 = 0.00024$; $N_R = DV/\nu = [(0.5)(1.02)]/(1.00 \times 10^{-6}) = 5.10 \times 10^5$; and thus **f = 0.016**

Solving energy e'qn for new D; $80\ m = [0.016(25000/D) + 1.5] \cdot [(0.255/D^2)^2/2g]$; D = 0.44 m,

With this new D; V = 1.32 m/s, e/D = 0.00027; and $N_R = [(0.44)(1.32)]/(1.00 \times 10^{-6}) = 5.81 \times 10^5$;

Now **f = 0.016**; ok and therefore, **D = 0.44 m**.

b) With new Q, $V = Q/A = 0.25/[(\pi/4) \cdot (0.44m)^2] = 1.64$ m/s, $N_R = DV/\nu = [(0.44)(1.64)]/(1.00 \times 10^{-6}) =$ 7.22×10^5; and **f = 0.0155** and therefore, **$h_A – h_B$** $= [0.0155(25000/0.44) + 1.5] \cdot [(1.64)^2/2g]$ **= 121 m**

4.2.6

Balancing energy between the upstream reservoir (A) and the downstream reservoir (B) yields

$H_A + H_p = H_B + h_L$; where $H_A - H_B = 30$ m; $h_L = h_f + [\sum K](V)^2/2g$; $K_e = 0.5$, $K_d = 1.0$ (exit coef). Thus,

30 m + H_P = [f(2000m/0.40m) + 1.5](V^2/2g); where V = Q/A = 0.388cms/[3.14(0.2m)^2] = 3.09 m/sec.

If the flow is to be doubled; V = 2(3.09 m/s) = 6.18 m/sec. Now

$N_R = DV/\nu$ = [(0.40)(6.18)]/(1.31x10^{-6}) = 1.89 x 10^6. From Moody; **f = 0.0105** Solving the energy eq'n

30 m + H_P = [0.0105(2000m/0.40m) + 1.5]·[(6.18)^2/2g); Solving yields, **H_P = 75.1 m**

4.2.11

Balancing energy between the upstream side of the pump (2) and the receiving tank (3) yields

$h_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} = h_3 + \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + h_L$; where V_3= 0; P_3/γ = [(32.3 lb/in^2)(144 in^2/ft^2)]/(62.3lb/ft^2) = 74.7 ft;

h_3 = 20 ft; h_2 = 10 ft; V_2 = Q/A = (8 ft^3/s)/[(π/4)(1.0ft)^2] = 10.2 ft/sec; and head losses are

$h_L = h_f + [\sum K](V)^2/2g$; where K_d = 1.0 (exit coef.). Thus, h_L = [f(130/1.0) + 1.0](V^2/2g); & V is pipe V.

For ductile iron: e/D = 0.0004ft/1.0ft = 0.0004; $N_R = DV/\nu$ = [(1.0)(10.2)]/(1.08x10^{-5}) = 9.44 x 10^5;

From Moody; **f = 0.017**; and h_L = [0.017(130/1.0) + 1.0]·[(10.2)^2/2g) = 5.19 ft; now from the energy eq'n;

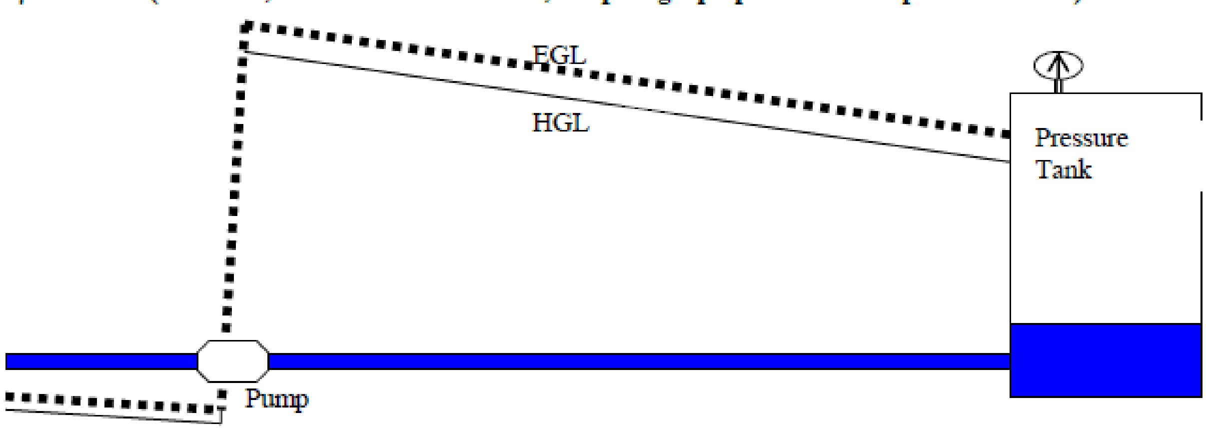
10 ft + P_2/γ + (10.2)^2/2g = 20 ft + 74.7 ft + 5.19 ft; therefore, **P_2/γ = 88.3 ft and P_2 = 38.2 psi**

Now balancing energy from the suction side of the pump (S) to the discharge side (2) yields;

$h_S + \frac{P_S}{\gamma} + \frac{V_S^2}{2g} + H_P = h_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g}$; where V_2 = 10.2 ft/s; V_S = Q/A = (8)/[(π/4)(1.33)^2] = 5.76 ft/sec;

P_2/γ = 88.3 ft; $h_S = h_2$; H_P = 111 ft; and thus: P_S/γ + (5.76)^2/2g + 111 ft = 88.3 ft + (10.2)^2/2g; yielding

P_S/γ = -21.6 ft (> -23.0 ft; no cavitation concerns; see paragraph prior to Example 4.4 in book)



Sketch the EGL and HGL such that a) the EGL and HGL start below the pump, b) they are separated by the velocity head, c) the pump adds a significant boost (abrupt rise) to the EGL, d) the EGL slopes toward the tank based on the friction loss, e) the HGL runs parallel to and below the EGL separated by the velocity head, and f) the HGL ends at the tank a distance above the water surface due to the pressure head.