

STEM@CookBook

## 문제 해결력을 키우는 유체역학

연습문제 정답

## Chapter 01

번호	답
1.1	라
1.2	가
1.3	가
1.4	라
1.5	라
1.6	라
1.7	다
1.8	가
1.9	다
1.10	나
1.11	라
1.12	나
1.13	가
1.14	다
1.15	라
1.16	나
1.17	가
1.18	가
1.19	다
1.20	다

1.21	변수	개념	차원	SI 단위
	(a) 동력	$power = \frac{Energy}{Time} = \frac{F \cdot L}{T}$	$\frac{(M \cdot L/T^2) L}{T} = M \cdot L^2 T^{-3}$	$\frac{kg \cdot m^2}{s^3}$ , W, Hp
	(b) 압력	$pressure = \frac{Force}{Area} = \frac{F}{L^2}$	$\frac{M \cdot L}{L^2 T^2} = M L^{-1} T^{-2}$	Pa, bar
	(c) 각속도	$Angular V. = \frac{Radians}{Time}$	$\frac{1}{T}$	$\frac{1}{s}$
	(d) 에너지	$Energy = Force \times distance$	$\frac{M \cdot L}{T^2} \cdot L = M L^2 T^{-2}$	J, N · m
	(e) 힘의 모멘트	$Moment = Force \times distance$	$\frac{M \cdot L}{T^2} \cdot L = M L^2 T^{-2}$	N·m
	(f) 운동량	$Momentum = Mass \times Velocity$	$M \cdot \frac{L}{T} = M L T^{-1}$	kg·m/s
	(g) 전단응력	$Shear Stress = \frac{Force}{Area}$	$\frac{M \cdot L}{T^2} \cdot \frac{1}{L^2} = M L^{-1} T^{-2}$	Pa
	(h) 변형률	$Strain = \frac{\leq ngth Change}{\leq ngth}$	$\frac{L}{L} = 1$	무차원
	(i) 각운동량	$Angular Momentum = Momentum \times Distance$	$\frac{M \cdot L}{T} \cdot L = M L^2 T^{-1}$	kg·m <sup>2</sup> /s

## Chapter 02

번호	답
2.1	㉡
2.2	㉢
2.3	㉡
2.4	$\rho = 7.8 \text{ [kg/m}^3\text{]}$
2.5	$W = 4.9 \text{ [N]}$
2.6	$\rho = 0.51 \text{ [kg/m}^3\text{]}$
2.7	$\nu = \frac{1}{3.2} \times 10^{-3} \text{ [m}^3\text{/kg]}$
2.8	유맥선
2.9	㉡
2.10	㉡
2.11	㉡
2.12	㉡
2.13	㉡
2.14	㉡
2.15	$\mu = 2.2752 \text{ [Pa}\cdot\text{s]}$
2.16	$\nu = 0.15' \text{ [cm}^2\text{/s]} = 0.15 \text{ [Stokes]}$
2.17	$S = 0.15$
2.18	$\tau = 3.6 \times 10^{-3} \text{ [N/m}^2\text{]}$
2.19	$\tau = 73.5 \text{ [Pa]}$
2.20	$F = 450 \text{ [N]}$

번호	답
2.21	$\tau = 5372 \text{ [Pa]}$
2.22	$\nu = 5.26 \times 10^{-1} \text{ [Stokes]}$
2.23	$y = 0.586 h$
2.24	$\frac{P}{\ell} = \frac{\mu \pi \omega^2 d^3}{2(D-d)}$
2.25	$\mu = 1 \text{ [N} \cdot \text{s/m}^2\text{]}$
2.26	$\left. \frac{du}{dy} \right _{y=0.2m} = 0.4 a \text{ [s}^{-1}\text{]} \quad \& \quad \left. \frac{du}{dy} \right _{y=0.4m} = 0.8 a \text{ [s}^{-1}\text{]}$
2.27	$\tau = \mu u_0 k$
2.28	$\tau = -\frac{a}{2} \cdot \frac{dp}{dx}$
2.29	$\tau = \frac{2\mu u_0}{h}$
2.30	$\tau = -4 \text{ [Pa]}$
2.31	$F = 74.517 \text{ [N]}$
2.32	$L = 0.66 \text{ [m]}$
2.33	$\mu = 8.08 \times 10^{-4} \text{ [Pa} \cdot \text{s]}$
2.34	$P = 24 \text{ [W]}$
2.35	㉠
2.36	㉡
2.37	$\Delta p = \frac{8\sigma}{d}$
2.38	$\Delta p = \frac{4\sigma}{R}$
2.39	$d = 0.05 \text{ [cm]}$
2.40	$p = 37.5 \text{ [Pa]}$

번호	답
2.41	$\Delta p = 1.89 \text{ [kPa]}$
2.42	$\Delta p = 1.46 \text{ [kPa]}$
2.43	$h = \frac{\sigma}{\gamma t \cos \theta}$
2.44	$h_1 : h_2 : h_3 = 6 : 3 : 2$
2.45	㉔
2.46	㉒
2.47	㉒
2.48	$c = 1400 \text{ [m/s]}$
2.49	$K = 10^{10} \text{ [Pa]}$
2.50	$\Delta p = 2.086 \times 10^7 \text{ [Pa]}$
2.51	$20.4 \times 10^8 \text{ [Pa]}$
2.52	$\Delta V = 0.69404 \text{ [m}^3\text{]}$
2.53	$\Delta p = 2 \times 10^7 \text{ [N/m}^2\text{]}$
2.54	$K = kP = 1.4 \times 10^5 \text{ [Pa]}$

## Chapter 03

번호	답
3.1	㉔
3.2	㉒
3.3	$p_{abs} = 91.97 \text{ [kPa}_{abs}]$
3.4	$S_{oil} = 0.818$
3.5	$p = 1,009.4 \text{ [kPa]}$
3.6	$124.52 \text{ [kPa}_{abs}]$
3.7	$p_A = 213.64 \text{ [kPa]}$
3.8	$p_A = 213.64 \text{ [kPa]}$
3.9	$F = 15.4 \text{ [kN]}$
3.10	$119.168 \text{ [kPa]}$
3.11	$\rho_A / \rho_B = 1/3$
3.12	$p_x - p_y = -\gamma_1 \ell_1 + \gamma_3 h + \gamma_2 \ell_2$
3.13	$p_1 - p_2 = (\gamma_{Hg} - \gamma_{oil})(y_1 - y_2)$
3.14	$p_{air} = 3,136 \text{ [Pa]}$
3.15	$p_A = 76,048 \text{ [Pa]}$
3.16	$p_A - p_B = 41,454 \text{ [Pa]}$

## Chapter 04

번호	답
4.1	㉠
4.2	㉠
4.3	㉠
4.4	$h/2$
4.5	$y' = 0.463 [m]$
4.6	$F_h = 55,860 [N]$
4.7	$y' = \bar{y} + \frac{d^2}{16\bar{y}}$
4.8	$F_V = \gamma b \left( 1 + \frac{\pi}{4} \right)$
4.9	㉠
4.10	㉡
4.11	㉠
4.12	㉠
4.13	$S = 1.2$
4.14	$\nabla$ 떠있는 부분 = 9.84 [%]
4.15	㉠
4.16	$\theta = \tan^{-1} \left( \frac{a_x}{g} \right)$
4.17	$a_y = 2.5 [m/s^2]$
4.18	A점과 B점의 압력은 동일하다.
4.19	$\Delta p = 1075.4 [Pa]$



## Chapter 05

번호	답
5.1	$d_2 = 0.283 [m]$
5.2	$\frac{\partial \rho_{\text{tank}}}{\partial t} = -1.935 \left[ \frac{kg/m^3}{s} \right]$
5.3	$h = 0.919 [m]$
5.4	$Q_3 = 5 [m^3/s]$
5.5	$V_2 = 4 [m/s]$
5.6	$Q_{Inlet} = 150 [\ell/s]$
5.7	$Q_{CD} = U_o \frac{b}{2} \delta$
5.8	$p_2 - p_1 = 84,800 [Pa]$
5.9	(a) $U_1 = 10.0 [m/s]$ , (b) $u_{\max} = 15.0 [m/s]$ , (c) $\Delta p = 15,000 [Pa]$
5.10	$F_x = 20,370 [N]$ , $F_y = -8,660 [N]$ , $F = 22,134 [N]$
5.11	$F = R_x = 37.1 [kN]$
5.12	$F = 234.67 [N]$
5.13	$F = 4\rho V^2 A$ , 4배의 힘을 더 받는다.
5.14	$F = 5,339 [N]$
5.15	$\vec{R}_x = 938.23 [N]$ (설정방향과 반대)과 $\vec{R}_y = 251.4 [N]$
5.16	$P = 13.3 [kW]$
5.17	$F = 109 [N]$
5.18	$t = 1s \rightarrow V_{1s} = 5.13 [m/s] \rightarrow x_{1s} = 1.94 [m]$ $t = 2s \rightarrow V_{2s} = 3.18 [m/s] \rightarrow x_{2s} = 3.47 [m]$
5.19	$W_{Turbine} = 8.82 [MW]$
5.20	$H = 88.0 [m]$

번호	답
5.21	$P \doteq 190 [kW]$
5.22	$P = 65.2 [kW]$
5.23	㉠
5.24	㉠
5.25	$V = 9.4 [m/s]$
5.26	$Q = 0.0132 [m^3/s]$
5.27	$V_2 = \sqrt{\frac{2p_1}{\rho}}$
5.28	$V_2 = \sqrt{2g(z_z - z_1)}$
5.29	$V_2 = 9.74 [m/s]$

## Chapter 06

번호	답
6.1	㉔
6.2	㉔
6.3	(a) $x-z$ 단면의 2차원 유동, (b) 비압축성유동
6.4	$Q = 30 [m^3/s], M_{flux} = 80 \vec{i} + 75 \vec{j}$
6.5	(a) $\vec{V}_{x=2, y=4, z=0} = 48 \vec{i} + 10 \vec{j} + 0 \vec{k}$ , (b) $\vec{a}_{p_t} = \frac{\partial \vec{V}}{\partial t} = 0$ (c) $\vec{a}_{p_c} = 30xy \vec{i} + 15y^2 \vec{j} + 0 \vec{k}$
6.6	$\vec{a}_{p(2,3,4)} = 729 \vec{i} + \frac{2,187}{4} \vec{j} + \frac{243}{2} \vec{k}$
6.7	$\vec{a}_p = \left(1 - \frac{x}{2L}\right) \frac{U^2}{2L} = \frac{25}{6} \left(1 - \frac{x}{6}\right)$
6.8	$xy = C$
6.9	$\frac{dy}{dx} = \frac{1}{5}$
6.10	(a) $y^3 = 4.5x + 475.99$ , (b) $t = 2s$ 을 지난 좌표 (145, 12) (c) $t = 4s$ 을 지난 좌표 (-4, 6)
6.11	압축성유동, 회전유동
6.12	$\omega_x = 3y$
6.13	$\psi = -2x^2 + y^2$
6.14	비압축성유동이며 회전유동이 발생한다
6.15	(a) $u = -\frac{3}{4} V_o \left( \frac{y^2}{h^2} - 1 \right) + \frac{V_o}{2} \left( \frac{y}{h} + 1 \right)$ , (b) $\frac{\partial p}{\partial x} = -\frac{3\mu}{2h^2} V_o$
6.16	$\frac{\partial p}{\partial y} = const.$
6.17	㉔
6.18	$V = 1.4 [m/s]$
6.19	$Q = 0.64 [m^3/min]$
6.20	$\Delta h = 0.33 [m]$

## Chapter 07

번호	답
7.1	㉠
7.2	$\Pi = \frac{gL}{V_o^2}$
7.3	$\Pi_1 = \frac{\delta}{x}, \Pi_2 = \frac{1}{Re}, \Pi_2 = f(\Pi_1)$
7.4	$\frac{\Pi_1}{\Pi_2} = \frac{T}{\mu \omega e^3}$
7.5	$\Pi_1 = \frac{d}{D}, \Pi_2 = \frac{\mu}{\rho VD}, \Pi_3 = \frac{\sigma}{\rho V^2 D}$
7.6	$\Pi_1 = \frac{d}{D}, \Pi_2 = \frac{\mu}{\rho VD}, \Pi_3 = \frac{\sigma}{\rho V^2 D}$

## Chapter 08

번호	답
8.1	$V_p = 5 [m/s]$
8.2	$V_m = 1.41 [m/s]$
8.3	$V_m = 8.94 [km/h]$
8.4	$V_m = 18 [km/h]$
8.5	$V_m = 4.02 [m/s]$
8.6	$V_m = 16.78 [km/h]$
8.7	$F_{D_p} = 867 \times 10^3 [N] = 867 [kN]$
8.8	$\nu_m = 4.11 \times 10^8 [m^2/s]$
8.9	$V_m = 3.81 [m/s]$
8.10	$V_m = 15 [km/h]$
8.11	$Q = 78.54 [\ell/s]$
8.12	$V_m = 83.3 [m/s]$
8.13	$V_m = 15.72 [m/s]$
8.14	$V_m = 125 [m/s]$
8.15	$V_m = 2.7 [m/s]$
8.16	$V_m = 16 [m/s]$
8.17	$F_{d_p} = 3.33 [N]$
8.18	(a) $p_m = 2.026 [MPa]$ , (b) $F_{D_p} = 375 [N]$
8.19	(a) $V_m/V_p = 0.331$ , (b) $F_p = 213 [N]$
8.20	(a) $C_{D_m} = 0.097$ , (b) $F_{D_p} = 331.2 [N]$

번호	답
8.21	$N_m = 25 [rpm]$
8.22	(a) $P_m/P_p = 0.225$ ,      (b) $h_m = 3.04 [m]$ ,      (c) $Q_m = 0.0171 [m^3/s]$
8.23	$\nu_m = 1.15 \times 10^{-6} [m^2/s]$

## Chapter 09

번호	답
9.1	(a) $L_{e_{lam}} = 17.25 [m]$ , (b) $L_{e_{turb}} = 3.125 \sim 5.0 [m]$
9.2	(a) $Re = 0.682$ , (b) $\tau = 1,445.8 [Pa]$ , (c) $P = 0.28 [W]$
9.3	(a) $\tau_{yx} = -3.0 [Pa]$ , (b) $Q = 5.714 \times 10^{-6} [m^3/s]$
9.4	$\tau_{yx} = 86.25 [Pa]$
9.5	$Q = 2.17 \times 10^{-8} [m^3/s] = 1.302 \times 10^{-3} [\ell pm]$
9.6	$Q_1 : Q_2 = 1 : 625$
9.7	(a) 수평관의 배관의 수두 손실 : $h_\ell = 28.06 [m]$ (b) 배관 출구가 입구보다 15 [m]보다 높을 때의 수두 손실 : $h_\ell = 43.06 [m]$ (c) 배관 출구가 입구보다 15 [m]보다 낮을 때의 수두 손실 : $h_\ell = 13.06 [m]$ (d) 배관의 입, 출구가 모두 대기압일 때 15 [m]보다 낮을 때의 수두 손실 $h_\ell = z_2 - z_1 = 28.06 [m]$
9.8	$Q = 1.162 \times 10^{-3} [m^3/s]$
9.9	$D_h = 0.3 [m]$
9.10	$R_h = 0.5 [m]$
9.11	$R_h = h/6$
9.12	$h_L = 0.0735L$
9.13	$p_2 = 10.05 [MPa]$
9.14	$\Delta p = 296.23 [kPa]$
9.15	$\Delta p = 286.39 [kPa]$
9.16	$\gamma h_{\ell_{30^\circ}} = 7,400 [Pa]$
9.17	$\Delta p = 60 [kPa]$
9.18	$Q = 0.0044 [m^3/s] = 4.4 [\ell/s]$

번호	답
9.19	$f = 0.064$
9.20	$f = 0.063$
9.21	$f = 0.0512$
9.22	$h = 2.244 [m]$
9.23	$\ell = 3.33 [m]$
9.24	$d = 38 [cm]$
9.25	$P = 94.25 [kW]$
9.26	$h = 0.1 [m]$
9.27	$L_e = 4 [m]$
9.28	$h = 24.96 [m]$
9.29	$H = \left( f \frac{\ell}{D} + 0.5 + 1 \right) \frac{V^2}{2g}$
9.30	$V_2 = 25.5 [m/s]$
9.31	$L_w = 2.27 [kW]$
9.32	$L_w = 88.36 [kW]$
9.33	$h_l = 13 [m]$
9.34	$p = -31,548 [Pa]$
9.35	$p_1 = 1.524 [MPa]$
9.36	$V = 4.21 [m/s]$
9.37	$\ell_2 = 160 [m]$
9.38	$V_1 = 0.2556 [m/s], \quad Q = 0.0045 [m^3/s]$
9.39	$V_1 = \sqrt{\frac{2g \cdot \Delta h}{3}}$

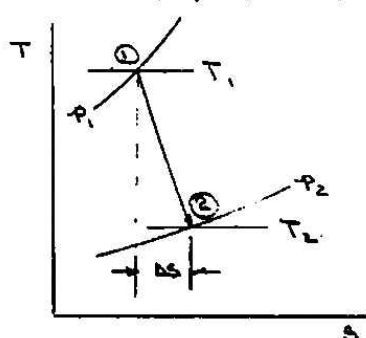


## Chapter 10

번호	답
10.1	$V = 2U$
10.2	$\theta = 30^\circ$
10.3	$F_D = 0.192 [N]$
10.4	$V = 53.45 [m/s]$
10.5	$F_D = 0.16 [N]$
10.6	(a) $x_p = 0.21 [m]$ , (b) $x_{p_{10,000m}} = 0.149 [m]$
10.7	$Re = 20,468$
10.8	$\delta = 6.32 [mm]$
10.9	$\delta = 0.989 [mm]$
10.10	$x = 40 cm$
10.11	(a) $U_1 = 2.5 [m/s]$ , (b) $p_1 - p_2 = 0.94 [Pa]$
10.12	$p_1 - p_2 = 27.26 [Pa]$
10.13	(a) $\left. \frac{\delta}{x} \right _{Laminar} = 6.711 [mm]$ , $\tau_{w_{Laminar}} = 0.055 [Pa]$ (b) $\left. \frac{\delta}{x} \right _{Turbulent} = 26.13 [mm]$ , $\tau_{w_{Turbulent}} = 0.25 [Pa]$
10.14	(a) $\delta_{turb_1}^* = 1.525 [mm]$ , $\delta_{turb_2}^* = 2.075 [mm]$ (b) $p_1 - p_2 = 3.21 [Pa]$ (c) $\Delta x = 0.231 [m]$
10.15	$F_{D_{total}} = 8.52 \times 10^{-3} [N]$
10.16	$F_D = 1.353 [N]$ 과 $P = 13.5 [kW]$
10.17	$P = 120 [W]$
10.18	$V = 35.86 [m/s]$

번호	답
10.19	$M = 21.6 \text{ [N}\cdot\text{m]}$
10.20	$F_D = 2.69 \text{ [kN]}$
10.21	$V = 7.253 \text{ [m/s]}$
10.22	$P = 23 \text{ [kW]}$
10.23	$F_L = 44.165 \text{ [kN]}$
10.24	$P = 1171.52 \text{ [kW]}$
10.25	$F_D = 12.57 \text{ [N]}$
10.26	$F_D = 4.26 \times 10^{-2} \text{ [N]}$
10.27	$F_D = 10 \text{ [kN]}$
10.28	$F_D = 0.377 \text{ [N]}$
10.29	탑승자가 $10 \text{ [km/h]}$ 의 맞바람이 불 때 $24 \text{ [km/h]}$ 의 속도를 유지한다면 동력이 제일 적게 든다.
10.30	(a) $F_D = 2,595 \text{ [N]}$ ,      (b) $h = 6.82 \text{ [m]}$
10.31	$P = 78.375 \text{ [kW]}$

## Chapter 11

번호	답
11.1	 $ds = 143.62 [J/kg \cdot K], \quad dh = -803.2 [kJ/kg]$
11.2	㉔
11.3	$M = 3$
11.4	㉔
11.5	$V = 1,958 [m/s]$
11.6	(a) $V = 492.52 [m/s]$ , (b) $\Delta t = 0.398 [s]$
11.7	$M = 0.64$
11.8	$V = 244.44 [m/s]$ , $c = 301.34 [m/s]$ , $V/c = 0.81$
11.9	$c_2 = 1.5c_1$
11.10	$M_1 = 0.457$ , $M_2 = 1.13$
11.11	$\Delta T = 124.44 [^{\circ}C]$
11.12	$T_2 - T_1 = -1.38 [^{\circ}C]$
11.13	$V_2 = 247 [m/s]$
11.14	$T^* = 0.833 T_o$
11.15	$V^* = 251.7 [m/s]$ , $T^* = 260 [K]$ , $p^* = 24.64 [MPa_{abs}]$
11.16	$\frac{T}{T_o} = 0.6 \sim 0.7$

번호	답
11.17	(a) $V_{compressible} = 194.74 \text{ [m/s]}$ (b) $V_{Incompressible} = 205.5 \text{ [m/s]}$ (c) $\Delta V = 10.76 \text{ [m/s]}$
11.18	㉔
11.19	㉔
11.20	㉔
11.21	㉔
11.22	㉔
11.23	$\dot{m}_{choked} = 0.325 \text{ [kg/s]}$
11.24	(a) $A = 38.6 \text{ [cm}^2\text{]},$ (b) $\dot{m}_{choked} = 17.646 \text{ [kg/s]}$
11.25	㉔
11.26	㉔
11.27	㉔
11.28	㉔
11.29	㉔
11.30	㉔
11.31	$p_2 = 842 \text{ [kPa]},$ $T_2 = 138.3 \text{ [}^\circ\text{C]},$ $c_2 = 406.5 \text{ [m/s]},$ $V_2 = 241.9 \text{ [m/s]}$

## Chapter 12

번호	답
12.1	㉔
12.2	$Fr < 1$
12.3	$Fr > 1$
12.4	$y = 1.975 [m]$
12.5	(a) $Fr_{V=1m/s} = 0.369$ , (b) $Fr_{V=4m/s} = 1.475$
12.6	㉔
12.7	㉔
12.8	$E = 1.46 [m]$
12.9	$y < y_c$
12.10	$y_c = \left( \frac{Q^2}{g} \right)^{\frac{1}{3}}$ , $V_c = \sqrt{gy_c}$
12.11	$E = 2.2 [m]$
12.12	$y_c = 6 [m]$
12.13	$V_c = 7.67 [m/s]$
12.14	(a) $V_c = 7.67 [m/s]$ , (b) $y = 0.445 [m]$ , (c) $V = 2.09 [m/s]$
12.15	$Q = 0.089 [m^3/s]$
12.16	$y_2 = 0.37 [m]$
12.17	$y_2 = 0.395 [m]$
12.18	㉔
12.19	$y_2 = 4.45 [m]$ 과 $H_t = 9.33 [m]$
12.20	$y_2 = 1.587 [m]$

번호	답
12.21	$y_2 = 1.587[m]$
12.22	$y = 0.815[m]$
12.23	$\oplus$
12.24	$y = \frac{b}{2}$
12.25	$P = 2.481[m]$

## Chapter 13

번호	답
13.1	$H_{th} = 135.3 [m], P = 994.5 [kW]$
13.2	$H_o = 117.4 [m], w_2 = 45.77 [m/s], v_2 = 49.4 [m/s],$ $H_{th} = 76.45 [m], P = 374.6 [kW]$
13.3	$Q = 5.69 [m^3/s], \dot{W} = 17.576 [kW], \alpha_2 = 68.84^\circ$
13.4	$Q_p = 4.03 [m^3/s]$
13.5	(a) $h_{l_{Total}} = 10.785 [m]$ (b) $H = 90.785 [m], Q = 0.8 [m^3/min], N = 3,600 [rpm]$ $N_s = 110 [rpm \cdot m^3/min \cdot m]$ 인 $L_s = 15.8 [kW]$ 의 원심펌프 (c) $NPSH_{av} = 7.82 [m]$
13.6	(a) $Q = 0.028 [m^3/s]$ (b) $V_{nozzle} = 37.68 [m/s]$ (c) $L_s = 38.4 [kW]$ (d) $H = 105.12 [m], Q = 0.028 [m^3/s], N = 3,600 [rpm]$ $N_s = 142 [rpm \cdot m^3/min \cdot m]$ 인 $L_s = 38.4 [kW]$ 의 원심펌프
13.7	(a) NPSH <sub>re</sub> 과 NPSH <sub>av</sub> 의 비가 3.84로 1.3배보다 크므로 캐비테이션은 발생하지 않는다. (b) 실양정 3[m]는 적정하고 조금 더 실양정을 높일 수 있다.
13.8	(a) $Q = 90.38 [m^3/s],$ (b) $N_s = 134.7 [rpm, kW, m],$ (c) $D = 3.88 [m]$
13.9	(a) $N_m = 665.8 [rpm], D_m/D_p = 0.0824$ (b) $Q_m = 0.83 [m^3/s]$