CHAPTER 2 - HYDRAULICS

Review Question Page References

(1) 24	(8) 30	(15) 42
(2) 24	(9) 31	(16) 44
(3) 25	(10) 32	(17) 44
(4) 25	(11) 33	(18) 44
(5) 27	(12) 35	(19) 45
(6) 28	(13) 36	(20) 45
(7) 30	(14) 40-42	(21) 46
		(22) www.iihr.uiowa.edu/research

Solutions to Practice Problems

1. P = 0.43 x h (Equation 2-2b)
   P = 0.43 x 50 ft = 22 psi at the bottom of the reservoir
   P = 0.43 x (50 -30) = 0.43 x 20 ft = 8.6 psi above the bottom

2. h = 0.1 x P = 0.1 x 50 = 5 m (Equation 2-3a)

3. Depth of water above the valve: h = (78 m -50 m) + 2 m = 30 m
   P = 9.8 x h = 9.8 x 30 = 294 kPa ≈ 290 kPa (Equation 2-2a)

4. h = 2.3 x P = 2.3 x 50 = 115 ft, in the water main
   h = 115 - 40 = 75 ft
   P = 0.43 x 75 = 32 psi, 40 ft above the main (Equation 2-2b)

5. Gage pressure P = 30 + 9.8 x 1 = 39.8 kPa ≈ 40 kPa
   Pressure head (in tube) = 0.1 x 40 kPa = 4 m

6. Q= A x V (Eq. 2-4), therefore V = Q/A
   $A = \pi D^2/4 = \pi (0.3)^2/4 = 0.0707 m^2$
   $100 L/s \times 1 m^3/1000 L = 0.1 m^3/s$
   $V = 0.1 m^3/s$ $0.707 m^2$ = 1.4 m/s

7. Q = (500 gal/min) x (1 min/60 sec) x ($1 ft^3$/7.5 gal) = 1.11 cfs
   A = Q/V (from Eq. 2-4)
   $A = 1.11 ft^3/sec / 1.4 ft/sec = 0.794 ft^2$
   $A = \pi D^2/4$, therefore $D = \sqrt{4A/\pi} = \sqrt{(4)(0.794)/\pi}$ = 1 ft = 12 in.

8. Q=A1 x V1 = A2 x V2 (Eq.2-5)
   Since $A = \pi D^2/4$, we can write
   $D_1^2 x V_1 = D_2^2 x V_2$ and $V_2 = V_1 \times (D_1^2 / D_2^2)$
   In the constriction, V_2 = (2 m/s) x (4) = 8 m/s

9. Area of pipe A = $\pi(0.3)^2/4 = 0.0707\ m^2$
Area of pipe B = $\pi(0.1)^2/4 = 0.00785\ m^2$
Area of pipe C= $\pi(0.2)^2/4 = 0.03142\ m^2$
$Q_A = Q_B + Q_C = 0.00785\ m^2 \times 2\ m/s + 0.03142\ m^2 \times 1\ m/s$

$= 0.04712\ m^3/s$ (from continuity of flow: $Q_{IN} = Q_{OUT}$)

$V_A = Q_A/A_A = 0.4712/0.0707 \approx 0.67\ m/s$ (from Eq. 2-4)

10. $p_1/w + V_1^2/2g = p_2/W + V_2^2/2g$ (Eq.2-8)
$A_1 = \pi(1.33)^2/4 = 1.4\ ft^2$ $A_2 = \pi(0.67)^2/4 = 0.349\ ft^2$
$V_1 = 6/1.4 = 4.29$ ft/sec $V_2 = 6/0.349 = 17.2$ ft/sec
$w = 62.4\ lb/ft^3$ and $g = 32.2\ ft/sec^2$
From Eq. 2-8, and multiplying *psi* x 144 in^2/ft^2 to get lb/ft^2
$50(144)/62.4 + 4.29^2/2(32.2) = p_2(144)/62.4 + 17.2^2/2(32.2)$
$115.38 + 0.28578 = 2.3076p_2 + 4.5937$
$p_2 = 111.07 /2.307 \approx 48$ psi

11. $p_1/w + v_1^2/2g = p_2/w + v_2^2/2g$ (Eq.2-8)
$A_1 = \pi(0.300)^2 / 4 = 0.0707\ m^2$ $A_2 = \pi(0.1\ 00)^2/4 = 0.00785\ m^2$

Q= 50 L/s x 1 m^3/1000 L = 0.05 m^3/s
$V_1 = 0.05/0.0707 = 0.70721$ m/sec $V_2 = 0.05/0.00785 = 6.369$ m/sec

$w = 9.81\ kN/m^3$ and $g = 9.81\ m/s^2$; From Eq. 2-8,
$700/2(9.81) + 0.70721^2/2(9.81) = p_2/2(9.81) + 6.369^2/2(9.81)$
$35.67789 + 0.02549 = 0.05097p_2 + 2.06775$ and $p_2 = 660$ kPa

12. From Figure 2.15, with Q = 200 L/s and D = 600 mm, read S = 0.0013. Therefore $h_L = S \times L$ = 0.0013 x 1000 m = 1.3 m
Pressure drop p = 9.8 x 1.3 ≈ 12.7 ≈ 13 kPa per km

13. h_L= 2.3 x 20 = 46 ft and S = 46/5280 = 0.0087 (where 1 mi = 5280 ft)

From Figure 2.15, with Q = 1000 gpm and S = 0.0087, read D = 10.3 in.
Use a 12 in. standard diameter pipe

14. S = 10/1000 = 0.01
From the nomograph (Figure 2.15) read Q ≈ 100 L/s = 0.1 m^3/s
Check with Eq. 2-9: $Q = 0.28 \times 100 \times 0.3^{2.63} \times 0.01^{0.54} \approx 0.1\ m^3/s$ OK

15. Use (Eq. 2-10): $Q = C \times A_2 \times \{(2g(p_1 - p_2)/w)/(1 - (A_2/A_1)^2\}^{1/2}$
where $A_1 = \pi(6)^2/4 = 28.27\ in^2$ and $A_2 = \pi(3)^2/4 = 7.07\ in^2$

$g = 32.2\ ft/s^2 = 386.4\ in/s^2$
$w = 62.4\ lb/ft^3 \times 1\ ft^3/12^3\ in^3 = 0.0361\ lb/in^3$

$Q = 0.98 \times 7.07 \times \{(2(386.4)(10)/0.0361)1(1 - (7.07/28.27)^2)\}^{1/2}$

$Q = 0.98 \times 7.07 \times \sqrt{228{,}354} = 3311\ in^3/s = 1.9\ cfs \approx 2\ cfs$

16. Use (Eq. 2-10): $Q = C \times A_2 \times \{(2g(p_1 - p_2)/w)/(1 - (A_2/A_1)^2)\}^{1/2}$

$A_1 = \pi(0.15)^2/4 = 0.01767\ m^2$ and $A_2 = \pi(0.075)^2/4 = 0.00442\ m^2$

$g = 9.81\ m/s^2$ $w = 9.81\ kN/m^3$

$1 - (A_2/A_1)^2 = 1 - (0.00442/0.01767)^2 = 0.93743$

$Q = 0.98 \times 0.00442 \times \{(2(9.81)(100)/9.81)/0.93743)\}^{1/2} = 0.063\ m^3/s$

(or, $Q = 0.063\ m^3/s \times 1000\ L/m^3 = 63\ L/s$)

17. Use Manning's nomograph (Figure 2.21): With D = 800 mm = 80 cm, n=0.013 and S = 0.2% = 0.002, read Q= 0.56 m^3/s = 560 L/s and V = 1.17 m/s

18. S = 1.5/1000 = 0.015; from Fig. 2.21, Q ≈ 1800 gpm and V ≈ 2.3 ft/s

19. Q= 200 L/s = 0.2 m^3/s; from Fig. 2.21, D ≈ 42 cm; Use 450 mm pipe

20. Q = 7 mgd = 7,000,000 gal/day x 1 day/1440 min ≈ 4900 gpm

From Fig. 2.21, with n=0.013, D=36 in and Q=4900 gpm: S = 0.00027, V = 1.54 ft/s Since 1.54 ft/s is less than the minimum self-cleansing velocity of 2 ft/s, it is necessary to increase the slope of the 36 in pipe.

From Fig. 2.21, with 36 in and 2 ft/s: S = 0.00047 = 0.047% = 0.05%

21. For full-flow conditions, with D = 300 mm and S = 0.02, read from

Fig. 2.21: Q = 0.135 m^3/s = 135 L/s and V = 2m/s

q/Q = 50/135 = 0.37 From Fig. 2.22, d/D = 0.42 and v/V = 0.92

Depth at partial flow d = 0.42 x 300 = 126 mm ≈ 130 mm

Velocity at partial flow v = 0.92 x 2 ≈ 1.8 m/s

22. For full-flow conditions, from Fig. 2.21 read Q = 1800 gpm. From Fig. 2.22, the maximum value of q/Q = 1.08 when d/D = 0.93. Therefore, the highest discharge capacity for the 18" in pipe, q_{max} = 1800 x 1.08 ≈ 1900 gpm,

would occur at a depth of d = 18 x 0.93 ≈ 17 in.

23. For full-flow conditions, from Fig. 2.21 read Q = 0.55 m^3/s = 550 L/s*.* From Fig.2.22, the maximum value of v/V = 1.15 when d/D = 0.82. Therefore, the highest flow velocity for the 900 mm pipe, v_{max} = 0.9 x 1.15 ≈ 1 m/s, would occur at a depth of d = 900 x 0.82 ≈ 740 mm. When the flow occurs at that depth, q/Q = 1.05 and the discharge q = 580 L/s

24. S = 0.5/100 = 0.005

For full-flow conditions, Q = 0.44 m^3/s = 440 L/s and V = 1.6 m/s

Since d/D = 200/600 = 0.33, from Fig. 2.22 q/Q = 0.23 and v/V = 0.8 Therefore, q = 440 x 0.23 ≈ 100 L/s and v = 1.6 x 0.8 ≈ 1.3 m/s

25. Q = A x V = 2 x 0.75 x 25/75 = 0.5 m^3/s = 500 L/s

26. From Eq. 2-12, Q = 2.5 x $(4/12)^{2.5}$ = 0.16 cfs

27. 150 mm x 1 in/25.4 mm x 1 ft/12 in = 0.492 ft
    From Eq. 2-12, Q = 2.5 x $(0.492)^{2.5}$ = 0.425 cfs x 28.32 L/ft^3 ≈ 12 L/s

28. From Eq. 2-13, Q = 3.4 x (20/12) x $(10/12)^{1.5}$ = 4.3 cfs ≈ 120 L/s