

# SOLUTIONS MANUAL

FIFTH EDITION

Basic Environmental Technology  
Water Supply, Waste Management, and Pollution Control

JERRY A. NATHANSON

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**Instructor's Manual**  
*to accompany*

# **BASIC ENVIRONMENTAL TECHNOLOGY**

*Water Supply, Waste Management, and Pollution Control*

**Fifth Edition**

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This manual provides instructors with (a) text page references and Internet URLs where answers to the end-of-chapter *Review Questions* can be found, (b) worked out solutions to each of the *Practice Problems*, and (c) supplemental problems and 100 multiple choice questions (and answers) that can be incorporated in tests or a final examination.

Generally, answers to end-of-chapter Practice Problems are rounded-off to reflect the precision of the data and/or the accuracy of the assumed factors in the problems. These answers are also listed in Appendix F of the text for students to use in checking their work. (The author has made every attempt to keep errors to a minimum. He can be notified of any mistakes that may be found in the text or in this manual at: nathanson1@comcast.net).

## CHAPTER 1 BASIC CONCEPTS

### Review Question Page References

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(4) 7	(18) 18	(32) <a href="http://www.usgs.gov/nawqa/">http://www.usgs.gov/nawqa/</a>
(5) 7	(19) 17-19	(33) <a href="http://www.envirosources.com">http://www.envirosources.com</a>
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Solutions to Practice Problems

- $P = 0.43 \times h$  (Equation 2-2b)  
 $P = 0.43 \times 50 \text{ ft} = 22 \text{ psi}$  at the bottom of the reservoir  
 $P = 0.43 \times (50 - 30) = 0.43 \times 20 \text{ ft} = 8.6 \text{ psi}$  above the bottom
- $h = 0.1 \times P = 0.1 \times 50 = 5 \text{ m}$  (Equation 2-3a)
- Depth of water above the valve:  $h = (78 \text{ m} - 50 \text{ m}) + 2 \text{ m} = 30 \text{ m}$   
 $P = 9.8 \times h = 9.8 \times 30 = 294 \text{ kPa} \approx 290 \text{ kPa}$  (Equation 2-2a)
- $h = 2.3 \times P = 2.3 \times 50 = 115 \text{ ft}$ , in the water main  
 $h = 115 - 40 = 75 \text{ ft}$   
 $P = 0.43 \times 75 = 32 \text{ psi}$ , 40 ft above the main (Equation 2-2b)
- Gage pressure  $P = 30 + 9.8 \times 1 = 39.8 \text{ kPa} \approx 40 \text{ kPa}$   
 Pressure head (in tube) =  $0.1 \times 40 \text{ kPa} = 4 \text{ m}$
- $Q = A \times V$  (Eq. 2-4), therefore  $V = Q/A$   
 $A = \pi D^2/4 = \pi (0.3)^2/4 = 0.0707 \text{ m}^2$   
 $100 \text{ L/s} \times 1 \text{ m}^3/1000\text{L} = 0.1 \text{ m}^3/\text{s}$   
 $V = 0.1 \text{ m}^3/\text{s} / 0.0707\text{m}^2 = 1.4 \text{ m/s}$
- $Q = (500 \text{ gal/min}) \times (1 \text{ min}/60 \text{ sec}) \times (1 \text{ ft}^3/7.5 \text{ gal}) = 1.11 \text{ cfs}$   
 $A = Q/V$  (from Eq. 2-4)  
 $A = 1.11 \text{ ft}^3/\text{sec} / 1.4 \text{ ft}/\text{sec} = 0.794 \text{ ft}^2$   
 $A = \pi D^2/4$ , therefore  $D = \sqrt{4A/\pi} = \sqrt{(4)(0.794)/\pi} = 1 \text{ ft} = 12 \text{ in.}$

8.  $Q = A_1 \times V_1 = A_2 \times V_2$  (Eq. 2-5)

Since  $A = \pi D^2/4$ , we can write

$$D_1^2 \times V_1 = D_2^2 \times V_2 \text{ and } V_2 = V_1 \times (D_1^2/D_2^2)$$

In the constriction,  $V_2 = (2 \text{ m/s}) \times (4) = 8 \text{ m/s}$

9. Area of pipe A =  $\pi(0.3)^2/4 = 0.0707 \text{ m}^2$

Area of pipe B =  $\pi(0.1)^2/4 = 0.00785 \text{ m}^2$

Area of pipe C =  $\pi(0.2)^2/4 = 0.03142 \text{ m}^2$

$$Q_A = Q_B + Q_C = 0.00785 \text{ m}^2 \times 2 \text{ m/s} + 0.03142 \text{ m}^2 \times 1 \text{ m/s}$$

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

$$V_A = Q_A/A_A = 0.04712/0.0707 \approx 0.67 \text{ m/s} \text{ (from Eq. 2-4)}$$

10.  $p_1/w + V_1^2/2g = p_2/w + V_2^2/2g$  (Eq. 2-8)

$$A_1 = \pi(1.33)^2/4 = 1.4 \text{ ft}^2 \quad A_2 = \pi(0.67)^2/4 = 0.349 \text{ ft}^2$$

$$V_1 = 6/1.4 = 4.29 \text{ ft/sec} \quad V_2 = 6/0.349 = 17.2 \text{ ft/sec}$$

$$w = 62.4 \text{ lb/ft}^3 \text{ and } g = 32.2 \text{ ft/sec}^2$$

From Eq. 2-8, and multiplying  $psi \times 144 \text{ in}^2/\text{ft}^2$  to get  $\text{lb/ft}^2$

$$50(144)/62.4 + 4.29^2/2(32.2) = p_2(144)/62.4 + 17.2^2/2(32.2)$$

$$115.38 + 0.28578 = 2.3076p_2 + 4.5937$$

$$p_2 = 111.07/2.307 \approx 48 \text{ psi}$$

11.  $p_1/w + v_1^2/2g = p_2/w + v_2^2/2g$  (Eq. 2-8)

$$A_1 = \pi(0.300)^2/4 = 0.0707 \text{ m}^2 \quad A_2 = \pi(0.100)^2/4 = 0.00785 \text{ m}^2$$

$$Q = 50 \text{ L/s} \times 1 \text{ m}^3/1000 \text{ L} = 0.05 \text{ m}^3/\text{s}$$

$$V_1 = 0.05/0.0707 = 0.70721 \text{ m/sec} \quad V_2 = 0.05/0.00785 = 6.369 \text{ m/sec}$$

$$w = 9.81 \text{ kN/m}^3 \text{ and } g = 9.81 \text{ m/s}^2; \text{ From Eq. 2-8,}$$

$$700/2(9.81) + 0.70721^2/2(9.81) = p_2/2(9.81) + 6.369^2/2(9.81)$$

$$35.67789 + 0.02549 = 0.05097p_2 + 2.06775 \text{ and } p_2 = 660 \text{ kPa}$$

12. From Figure 2.15, with  $Q = 200 \text{ L/s}$  and  $D = 600 \text{ mm}$ , read  $S = 0.0013$ .  
 Therefore  $h_L = S \times L = 0.0013 \times 1000 \text{ m} = 1.3 \text{ m}$   
 Pressure drop  $p = 9.8 \times 1.3 = 12.7 \approx 13 \text{ kPa per km}$
13.  $h_L = 2.3 \times 20 = 46 \text{ ft}$  and  $S = 46/5280 = 0.0087$  (where  $1 \text{ mi} = 5280 \text{ ft}$ )  
 From Figure 2.15, with  $Q = 1000 \text{ gpm}$  and  $S = 0.0087$ , read  $D = 10.3 \text{ in.}$   
 Use a  $12 \text{ in.}$  standard diameter pipe
14.  $S = 10/1000 = 0.01$   
 From the nomograph (Figure 2.15) read  $Q \approx 100 \text{ L/s} = 0.1 \text{ m}^3/\text{s}$   
 Check with Eq. 2-9:  $Q = 0.28 \times 100 \times 0.3^{2.63} \times 0.01^{0.54} \approx 0.1 \text{ m}^3/\text{s}$  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  $A_1 = \pi(6)^2/4 = 28.27 \text{ in}^2$  and  $A_2 = \pi(3)^2/4 = 7.07 \text{ in}^2$   
 $g = 32.2 \text{ ft/s}^2 = 386.4 \text{ in/s}^2$   
 $w = 62.4 \text{ lb/ft}^3 \times 1 \text{ ft}^3/12^3 \text{ in}^3 = 0.0361 \text{ lb/in}^3$   
 $Q = 0.98 \times 7.07 \times \{(2(386.4)(10)/0.0361)/(1 - (7.07/28.27)^2)\}^{1/2}$   
 $Q = 0.98 \times 7.07 \times \sqrt{228,354} = 3311 \text{ in}^3/\text{s} = 1.9 \text{ cfs} \approx 2 \text{ cfs}$
16. Use (Eq. 2-10):  $Q = C \times A_2 \times \{(2g(p_1 - p_2)/w)/(1 - (A_2/A_1)^2)\}^{1/2}$   
 $A_1 = \pi(0.15)^2/4 = 0.01767 \text{ m}^2$  and  $A_2 = \pi(0.075)^2/4 = 0.00442 \text{ m}^2$   
 $g = 9.81 \text{ m/s}^2$        $w = 9.81 \text{ kN/m}^3$   
 $1 - (A_2/A_1)^2 = 1 - (0.00442/0.01767)^2 = 0.93743$   
 $Q = 0.98 \times 0.00442 \times \{(2(9.81)(100)/9.81)/0.93743\}^{1/2} = 0.063 \text{ m}^3/\text{s}$   
 (or,  $Q = 0.063 \text{ m}^3/\text{s} \times 1000 \text{ Lm}^3 = 63 \text{ L/s}$ )
17. Use Manning's nomograph (Figure 2.21): With  $D = 800 \text{ mm} = 80 \text{ cm}$ , and  
 $S = 0.2\% = 0.002$ , read  $Q = 0.56 \text{ m}^3/\text{s} = 560 \text{ L/s}$  and  $V = 1.17 \text{ m/s}$
18.  $S = 1.5/1000 = 0.015$ ; from Fig. 2.21,  $Q \approx 1800 \text{ gpm}$  and  $V \approx 2.3 \text{ ft/s}$
19.  $Q = 200 \text{ L/s} = 0.2 \text{ m}^3/\text{s}$ ; from Fig. 2.21,  $D \approx 42 \text{ cm}$ ; use  $450 \text{ mm}$  pipe

20.  $Q = 7 \text{ mgd} = 7,000,000 \text{ gal/day} \times 1 \text{ day}/1440 \text{ min} \approx 4900 \text{ gpm}$   
 From Fig. 2.21, with 36 in and 4900 gpm:  $S = 0.00027$ ,  $V = 1.54 \text{ ft/s}$   
 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:  $S = 0.00047 = 0.047\% \approx 0.05\%$

21. For full-flow conditions, with  $D = 300 \text{ mm}$  and  $S = 0.02$ , read from  
 Fig. 2.21:  $Q = 0.135 \text{ m}^3/\text{s} = 135 \text{ L/s}$  and  $V = 2 \text{ m/s}$  "  
 $q/Q = 50/135 = 0.37$  From Fig. 2.22,  $d/D = 0.42$  and  $v/V = 0.92$   
 Depth at partial flow  $d = 0.42 \times 300 = 126 \text{ mm} \approx 130 \text{ mm}$   
 Velocity at partial flow  $v = 0.92 \times 2 \approx 1.8 \text{ m/s}$

22. For full-flow conditions, from Fig. 2.21 read  $Q = 1800 \text{ gpm}$ . 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,  $q_{\text{max}} = 1800 \times 1.08 \approx 1900 \text{ gpm}$ , would occur at a depth of  $d = 18 \times 0.93 \approx 17 \text{ in}$ .

23. For full-flow conditions, from Fig. 2.21 read  $Q = 0.55 \text{ m}^3/\text{s} = 550 \text{ L/s}$ . 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,  $v_{\text{max}} = 0.9 \times 1.15 \approx 1 \text{ m/s}$ , would occur at a depth of  $d = 900 \times 0.82 \approx 740 \text{ mm}$   
 When the flow occurs at that depth,  $q/Q = 1.05$  and the discharge  $q = 580 \text{ L/s}$

24.  $S = 0.5/100 = 0.005$   
 For full-flow conditions,  $Q = 0.44 \text{ m}^3/\text{s} = 440 \text{ L/s}$  and  $V = 1.6 \text{ m/s}$   
 Since  $d/D = 200/600 = 0.33$ , from Fig. 2.22  $q/Q = 0.23$  and  $v/V = 0.8$   
 Therefore,  $q = 440 \times 0.23 \approx 100 \text{ L/s}$  and  $v = 1.6 \times 0.8 \approx 1.3 \text{ m/s}$

25.  $Q = A \times V = 2 \times 0.75 \times 25/75 = 0.5 \text{ m}^3/\text{s} = 500 \text{ L/s}$

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

27.  $150 \text{ mm} \times 1 \text{ in}/25.4 \text{ mm} \times 1 \text{ ft}/12 \text{ in} = 0.492 \text{ ft}$

From Eq. 2-12,  $Q = 2.5 \times (0.492)^{2.5} = 0.425 \text{ cfs} \times 28.32 \text{ L/ft}^3 \approx 12 \text{ L/s}$

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