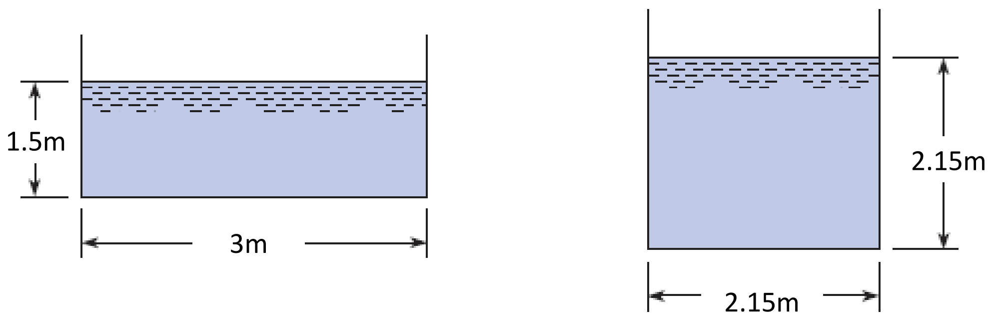
15.3 PQ◀ Two channels have the same cross-sectional area, but different geometry, as shown.

a. Which channel has the largest wetted perimeter?

b. Which channel has more contact between water and channelwall?

c. Which channel will have more energy loss to friction?



15.3: PROBLEM DEFINITION

Situation:

Two channels have the same cross-sectional area, but different geometry, as shown for Problem 15.4.

Find:

a. Which channel has the largest wetted perimeter?

b. Which channel has more contact between water and channel-wall?

c. Which channel will have more energy loss to friction?

SOLUTION

a. Compare wetted perimeters

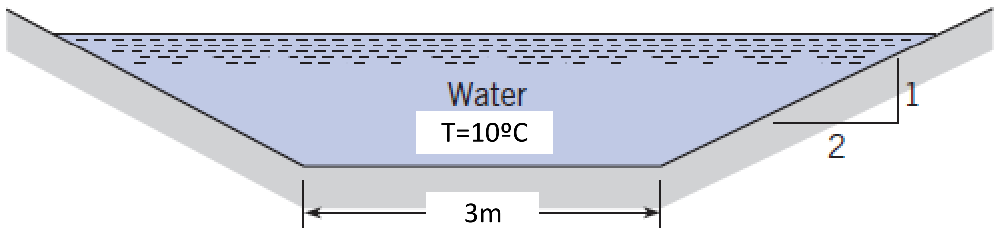
$P_A = 1.5 \cdot 2 + 3 = 6m$; $P_B = 2.15 \cdot 3 = 6.45\ m$;

Conclusion: **Channel B has largest wetted perimeter**

b. **Channel B has the most contact between water and channel-wall.** This corresponds to its having the largest wetted perimeter.

c. **Channel B will have the most energy loss to friction**, because it has the largest wetted perimeter. This assumes that the two channels are of the same roughness.

15.12 Water flows at a depth of 2m in the trapezoidal, concrete-lined channel shown. If the channel slope is 30 cm in 600m, what is the average velocity and what is the discharge?



PROBLEM 15.12

15.12: PROBLEM DEFINITION

Situation:

Trapezoidal, concrete-lined channel - figure in the problem statement
Depth = 2 m
S = 0.3 m in 600 m

Find:

Average velocity (m / s).
Discharge (m^3 / s).

Assumptions:

$k_s = 9 \times 10^{-4}$ m or $n = 0.015$
$\nu = 1.31 \times 10^{-6}\ m^2/s$

PLAN

1. Use Darcy-Weisbach equation to solve for Q.
2. Alternate Solution: use Manning equation.

SOLUTION

1. Darcy-Weisbach equation

$$R_h = \frac{A}{P} = \frac{14 \text{ m2}}{11.94 \text{ m}} = 1.174 \text{ m}$$

2. Manning equation

$$\begin{aligned} V &= \frac{1.00}{n} R^{2/3} S^{1/2} \\ &= \frac{1.0}{0.015} (1.174)^{2/3} \left(\frac{0.3}{600}\right)^{1/2} \\ &\boxed{V = 1.66 \text{ m/s}} \\ Q &= 1.66(14) \\ &\boxed{Q = 23.2 \text{ m}^3/\text{s}} \end{aligned}$$

15.13 What will be the depth of flow in a trapezoidal concrete-lined channel that has a water discharge of 30 m^3/s ? The channel has a slope of 30 cm in 150m The bottom width of the channel is 3 m and the side slopes are 1 vertical to 1 horizontal.

15.13: PROBLEM DEFINITION

Situation:

Trapezoidal, concrete-lined channel

$Q = 30\,\mathrm{m}^3/\mathrm{s}$

Slope is 0.3 m in 150 m

Bottom width = 3 m, and side slopes are 1:1

Find:

Depth of flow (m).

Assumptions:

$n = 0.012$

PLAN

Use Manning's equation (SI units).

SOLUTION

Flow area

$$\begin{aligned} A_c &= \left(\frac{3\,\mathrm{m} + (3\,\mathrm{m} + 2d)}{2}\right) d \\ &= 3d + d^2 \end{aligned}$$

Wetted perimeter

$$\begin{aligned} P_{\text{wet}} &= 3\,\mathrm{m} + 2 \times \sqrt{2d^2} \\ &= 3 + 2\sqrt{2}d \end{aligned}$$

Hydraulic radius

$$\begin{aligned} R_h &= \frac{A_c}{P_{\text{wet}}} \\ &= \frac{3d + d^2}{3 + 2\sqrt{2}d} \end{aligned}$$

Manning's equation (traditional units)

$$\begin{aligned} Q &= \frac{1.00}{n} A_c R_h^{2/3} \sqrt{S_o} \\ 30 &= \frac{1.00}{0.012} \times (3d + d^2) \times \left(\frac{3d + d^2}{3 + 2\sqrt{2}d}\right)^{2/3} \sqrt{\frac{0.3\,\mathrm{m}}{150\,\mathrm{m}}} \end{aligned}$$

Solve this equation (use a computer program such as MathCAD) to give $d = 1.692\,\mathrm{m}$.

$$\boxed{d = 1.69\,\mathrm{m}}$$

15.21 Water flows at a depth of 10cm with a velocity of 10 m/s in a rectangular channel. Is the flow subcritical or supercritical? What is the alternate depth?

15.21: PROBLEM DEFINITION

Situation:

Water flows through a rectangular channel.

$V = 10\,\mathrm{m/s}$, $y = 10\,\mathrm{cm}$.

Find:

(a) Determine if the flow is subcritical or supercritical.

(b) Calculate the alternate depth (m).

PLAN

Check the Froude number, then apply the specific energy equation to calculate the alternative depth.

SOLUTION

Froude number

$$\begin{aligned} Fr &= V/\sqrt{gy} \\ &= 10\sqrt{9.81 \times 0.1} \\ Fr &= 10.09 \end{aligned}$$

The Froude number is greater than 1 so the flow is $\boxed{\text{supercritical}}$.

Specific Energy Equation

$$\begin{aligned} E &= y + V^2/2g \\ E &= 0.1 + 10^2/(2 \times 9.81) \\ E &= 5.2 \text{ m} \end{aligned}$$

Let the alternate depth $= y_2$, then

$$\begin{aligned} E &= y_2 + \frac{V_2^2}{2g} \\ &= y_2 + \frac{Q^2}{2g\left(y_2 \times B\right)^2} \end{aligned}$$

B – arbitrary width

$$= y_2 + \frac{V_1^2 B^2 y_1^2}{2g\, y_2^2\, B^2} = y_2 + \frac{V_1^2\, y_1^2}{2g\, y_2^2} = y_2 + \frac{1}{2g\, y_2^2}$$

$$\boxed{5.2 = y_2 + \frac{1}{2g\, y_2^2}}$$

You just have to solve this third order polynomial equation

$$y_2 = 5.2m$$

15.30 A rectangular channel is 6 m wide, and the discharge of water in it is 18 m^3/s. Plot depth versus specific energy for these conditions. Let specific energy range from E_{min} to $E = 7$ m. What are the alternate and sequent depths to the 30 cm depth?

15.30: PROBLEM DEFINITION

Situation:

Water flows in a rectangular channel–additional details are provided in the problem statement.

Find:

(a) Plot depth versus specific energy.
(b) Calculate the alternate depth (m).
(c) Calculate the sequent depth (m).

PLAN

Apply the specific energy equation.

SOLUTION

Specific Energy Equation for a rectangular channel.

$$E = y + q^2/(2gy^2)$$

For this problem

$$q = Q/B = 18/6 = 3 \text{ m}^2/\text{s}$$

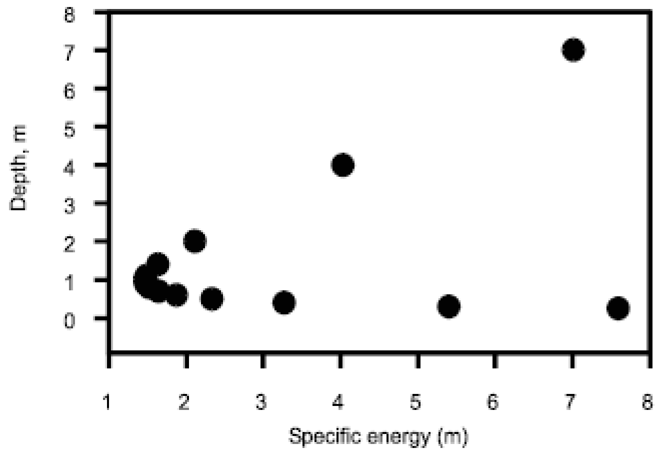
so

$$\begin{aligned} E &= y + 3^2/(2gy^2) \\ &= y + 0.4587/y^2 \end{aligned}$$

The calculated E versus y is shown below

y (m)	0.25	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.4	2.0	4.0	7.0
E (m)	7.59	5.4	3.27	2.33	1.87	1.64	1.52	1.47	1.46	1.48	1.63	2.11	4.03	7.01

(a) The corresponding plot is



(b) The alternate depth to $y = 0.30$ is $\boxed{y = 5.38 \text{ m}}$

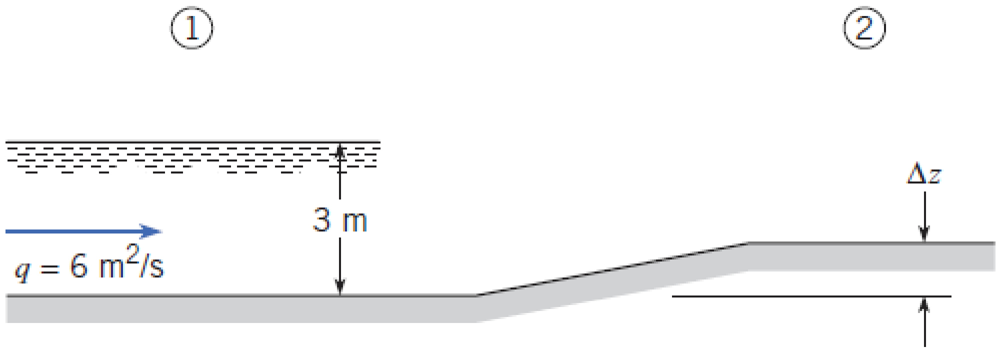
(c) Sequent depth:

$$
\begin{aligned}
y_2 &= (y_1/2)(\sqrt{1+8F_1^2}-1) \\
Fr_1 &= V/\sqrt{gy_1} \\
&= (3/0.3)/\sqrt{9.81 \times 0.30} \\
&= 5.83
\end{aligned}
$$

Hydraulic jump equation

$$
\begin{aligned}
y_2 &= (0.3/2)(\sqrt{1+8\times 5.83^2}-1) = \boxed{2.33 \text{ m}} \\
& \boxed{y_2 = 2.33 \text{ m}}
\end{aligned}
$$

15.40 Assuming no energy loss, what is the maximum value of Δz that will permit the unit flow rate of 6 m^2/s to pass over the hump without increasing the upstream depth? Sketch carefully the water-surface shape from section 1 to section 2. On the sketch give values for Δz, the depth, and the amount of rise or fall in the water surface from section 1 to section 2.



PROBLEM 15.40

15.40: PROBLEM DEFINITION

Situation:

Water flows over a gradual upstep, shown in figure.

Desired: Unit flowrate $q = 6\text{m}^2/\text{sec}$.

Upstream depth $y_1 = 3\text{m}$

Find:

Maximum value of Δz to permit a unit flow rate of 6 m^2/s without increasing the upstream depth (m).

Assumptions:

No energy loss.

SOLUTION

Critical depth equation

$$\begin{aligned} y_c &= (q^2/g)^{1/3} \\ &= (6^2/9.81)^{0.333} \\ y_c &= 1.542 \text{ m} \end{aligned}$$

where y_c is depth allowed over the hump for the given conditions.
Specific Energy Equation

$$\begin{aligned} E_1 &= E_2 \\ V_1 &= q/y_1 = 6/3 = 2 \text{ m/s} \\ V_2 &= q/y_2 = 6/1.542 = 3.891 \text{ m/s} \\ V_1^2/2g + y_1 &= V_2^2/2g + y_2 + \Delta z \\ 2^2/2g + 3 &= (3.891^2/(2 \times 9.81)) + 1.542 + \Delta z \\ \Delta z &= 3.204 - 0.772 - 1.542 \\ & \boxed{\Delta z = 0.89 \text{ m}} \end{aligned}$$