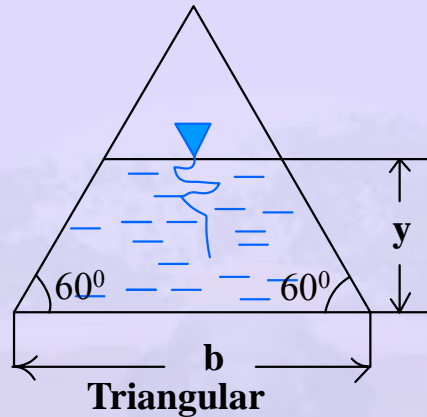


19.1 Problem: Maximum Discharge

In partially full channel having an equilateral triangular cross section, the rate of discharge is $Q = KAR^{2/3}$ in which K is a constant, A flow area, R is the hydraulic mean radius. Determine the depth at which the discharge is maximum, for a triangular channel. $A = (b - y/\sqrt{3}) * y$ and $P = (b + 4y/\sqrt{3})$



Solution:

$$\begin{aligned} \text{Area } A &= (b - y/\sqrt{3}) * y \\ &= by - 0.58y^2 \end{aligned}$$

$$\begin{aligned} \text{Perimeter } P &= (b + 4y/\sqrt{3}) \\ &= b + 2.31y \end{aligned}$$

For a given depth, the discharge is to be maximum.

According to Manning formula,

$$Q = \left(\frac{1}{n}\right) * AR^{2/3}S_o^{1/2}$$

Where n and S_o are constants

$$\text{Now, } R = A/P = \frac{(by - 0.58y^2)}{(b + 2.31y)}$$

Substituting the values in the above expression, then,

$$Q = \left\{ \frac{(by - 0.58y^2)^5}{(b + 2.31y)^2} \right\}^{1/3}$$

differentiating the right hand side of the equation, then,

$$\frac{(b + 2.31y)^2 * 5 * (by - 0.58y^2)^4 * \frac{dA}{dy} - (b + 2.31y) * 2 * (by - 0.58y^2)^5 * \frac{dP}{dy}}{(b + 2.31y)^4} = 0$$

But $dA/dy = (b - 1.16y)$ and $dP/dy = 2.31$.

Then the above equation reduces to

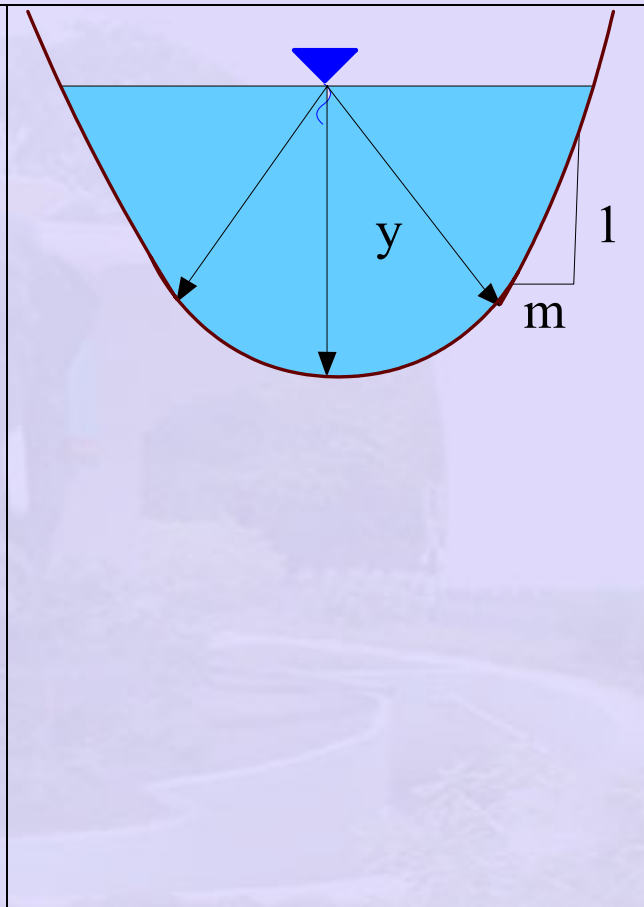
$$5b^2 - 10.72y^2 - 10.37 = 0$$

$$y^2 = \frac{5b^2 - 10.37}{10.72}$$

$$y = (0.466b^2 - 0.97)^{1/2}$$

is the depth at which the discharge is maximum.

Computation of uniform flow depth in CBI&P channel

<p> $Q = 30\text{m}^3\text{s}^{-1}$, $S_0 = \frac{1}{1600}$, $m = 1.25$, $n = 0.015$ $A = 2\left(\frac{1}{2}y^2 \cot\theta\right) + \frac{1}{2}y^2 2\theta$ $= y^2(\theta + \cot\theta)$ $P = 2y(\theta + \cot\theta)$ $R = \frac{A}{P} = \frac{y}{2}$ $\cot\theta = 1.25$ $\theta = 38.6^\circ = 0.644$ radians $\therefore A = 1.894y^2$ $Q = \frac{1}{n}AR^{2/3}S_0^{1/2}$ $30 = \frac{1.894}{0.015}y^2\left(\frac{y}{2}\right)^{2/3}\sqrt{1/1600}$ $\therefore y^{8/3} = \frac{0.015 \times 30}{1.894\sqrt{1/1600}}\left(\frac{1}{2}\right)^{2/3}$ $y = (14.1)^{3/8} = 2.70\text{m}$ </p>	
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Problems:

1. A trapezoidal channel has a bottom width of 6.00 m, side slopes of 1 to 1, and water flows upto a depth of 915 mm. For $n = 0.015$, and a discharge of $10.20\text{ m}^3/\text{s}$, calculate
 - (a) the normal slope,
 - (b) the critical slope and critical depth for $10.20\text{ m}^3/\text{s}$, and
 - (c) the critical slope at the normal depth of 915mm.

2. A cement lined laboratory channel of rectangular shape is laid at a bed slope of 0.0004. If it is 150 cm wide, what discharge can be expected at uniform depth of 60 cm in the channel? Take n to be 0.011. [Answer: $0.78 \text{ m}^3 \text{ s}^{-1}$]

3. Water flows at a uniform depth of 1.25m in a rectangular channel 4 m wide laid at a slope of 1 in 1000. Compute the average shear stress on bottom of the channel.

$$(\tau_o = \gamma \mathbf{R} \mathbf{S}_f)$$

4. A discharge of $40.0 \text{ m}^3/\text{s}$ flows in a trapezoidal channel with bottom width 4.0 m and side slopes 2 H: 1 V. If the normal depth at a bottom slope of 0.0016 is 2.0 m, determine the values of n and C . Is the flow sub critical or supercritical? (Answer: $n = 0.0184$, $C=56.22$, $F<1$).

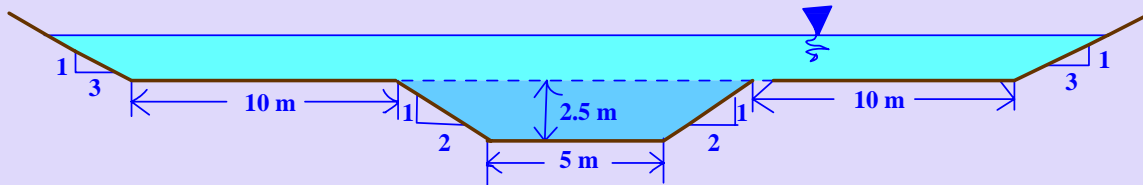
5. A circular pipe of reinforced concrete is to be used as a storm drainage conduit. It has to carry a discharge of $2.5 \text{ m}^3/\text{s}$ at a slope of 1 in 2500, when running 0.9 full, determine the required size. Assume $n = 0.013$. ((Answer: $d_o = 1.81 \text{ m}$)

6. A trapezoidal channel excavated in earth has to carry a discharge of $5.0 \text{ m}^3/\text{s}$ at a velocity of 0.75 m/s. The channel is 5.0 m wide at the base and has side slope of 1:2. At what slope should it be laid? Take n to be 0.02.

7. The normal depth of flow in a trapezoidal concrete lined channel is 2 m. The channel bed width is 5 m and has side slopes of 1:2. Manning n is 0.015 and the bed slope is 0.001. Determine the discharge Q , mean velocity, \bar{V} and Reynolds Number, R_e . Classify the flow according to Froude Number.

8. In the previous problem if the discharge is changed to $30 \text{ m}^3/\text{s}$, what would be the normal depth of flow?

9. During large floods, the water level in the channel shown in figure exceeds the bank level of 2.5 m. The flood banks are 10m wide and are grassed with side slope of 3: 1 (H: V). The estimates of Manning n for these flood banks is 0.035. Estimate the discharge for a maximum flood level of 4m and the velocity coefficient. Draw a stage discharge relationship curve, given $S_o = 0.001$, and n for main section as 0.015

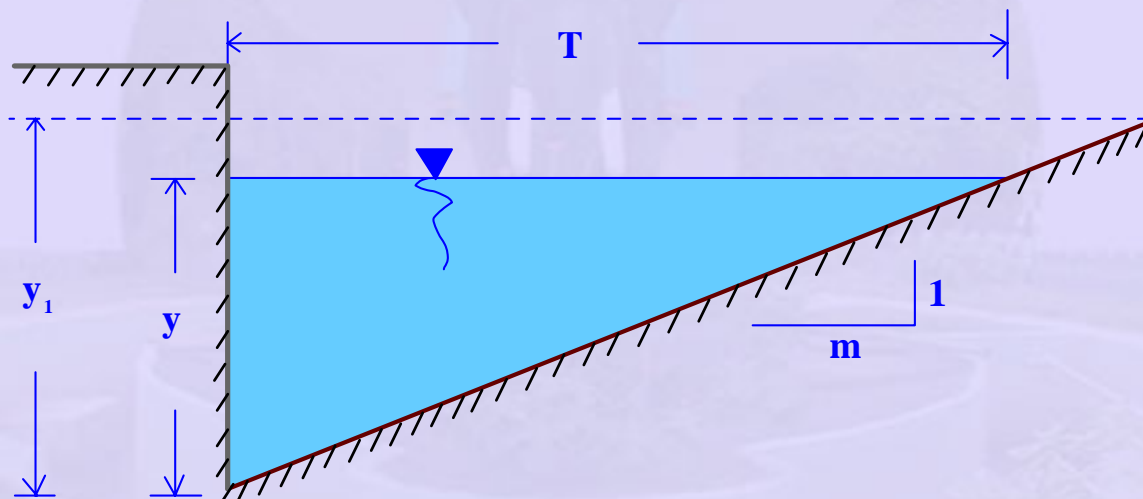


10. A concrete pipe 750mm diameter is laid on a gradient of 1:200. The estimated value of Manning n is 0.012 and pipe full discharge is estimated to be $0.85 \text{ m}^3/\text{s}$.

(a) Calculate the discharge for a proportional depth of $0.938 d_o$ using Manning equation. Explain why the discharge in (a) is larger than the pipe full discharge?

11. A trapezoidal channel having bottom width 6 m and side slope of 2.5 horizontal to 1 vertical is laid on a bottom slope of 0.0025. If it carries a uniform flow of water at the rate of $10 \text{ m}^3/\text{s}$, compute the normal depth and the mean velocity of flow. Take Manning n as 0.025. What is the value of Froude Number?

12. The figure shows a highway gutter having one side vertical, one side sloped at 1 on m .



Manning n , depth of flow y , and longitudinal slope S_o are given. Express discharge as a function of side slope, depth, n and bed slope.

Answer

$$Q = (1/n) f(m) y^{8/3}$$

$$f(m) = \frac{0.3142 m^{5/3}}{(1 + \sqrt{1 + m^2})^{2/3}}$$

(a) Compute the discharge when $n = 0.017$, $y = 6.5 \text{ cm}$ and $S_o = 0.03$, $m = 24$.

(b) Compute the discharge when $m = 24$, $n = 0.015$, $y = 8.00 \text{ cm}$, $S_o = 0.04$.

13. Water flows at a velocity of 1 m /s in a rectangular channel 1.0 m wide. The bed slope is 2×10^{-3} and $n = 0.015$.

Find the depth of flow under uniform flow condition.

14. Find the discharge in a trapezoidal channel with a bed width of 10 m. Side slopes 1:1 and depth of flow of 2.0 m under uniform flow conditions. $S_0 = 10^{-4}$ and $n = 0.02$. Also find Chezy coefficient at this depth.

15. A sewer pipe is proposed to be laid on a slope of 1 in 2500 and is required to carry $1.5 \text{ m}^3/\text{s}$. What size of a circular pipe should be used if the pipe has to flow half full and $n = 0.015$?

16. Design an earthen trapezoidal channel for water having a velocity of 0.6 m / s. Side slope of the channel is 1.5 : 1 and quantity of water flowing is $3 \text{ m}^3/\text{s}$. Assume Chezy coefficient as $65 \text{ m}^{1/2}\text{s}^{-1}$.

17. Design a trapezoidal channel for Carrying $30 \text{ m}^3/\text{s}$ of water. Bed slope of the channel is 1:18,000 and side slope of 2 horizontal to 1 vertical Assume C in Chezy formula as $50 \text{ m}^{1/2}\text{s}^{-1}$.

18. A trapezoidal channel has slope 1.5 horizontal to 1 vertical. It is to discharge $20 \text{ m}^3/\text{s}$ of water with a grade of 0.5 m per km. Find the depth of channel for its best form. Use Manning formula taking $n = 0.01$.

19. A circular pipe of 2.5 m diameter is laid at a slope of 1 in 1200. Find the maximum discharge that can be secured at atmospheric pressure, if the value of C is $50 \text{ m}^{1/2}\text{s}^{-1}$. What would be the depth of the flow for this discharge?

20. Determine the hydraulically efficient section of a trapezoidal channel, given $n = 0.025$, to carry $12.75 \text{ m}^3/\text{s}$.

To prevent scouring, the maximum velocity is to be 920 mm/s and the side slopes of the trapezoidal channel are 1 vertical to 2 horizontal.

What slope S_0 , of the channel is required?

21. Show a correlation between roughness factor f and roughness factor n .

(a) What is the average shear stress at the sides and bottom of a rectangular flume 3.65 m wide, flowing 1.20 m deep and laid on a slope of 1.60 m / 1000 m?

22. What flow can be expected in a 1.20 m wide rectangular cement-lined channel laid on a slope of 4 m in 10,000 m, if the water flows 600 mm deep? Use both Kutter's C and Manning n.
23. In a hydraulic laboratory, a flow of $0.412 \text{ m}^3/\text{s}$ was measured from a rectangular channel flowing 1.20 m wide and 600 mm deep. If the slope of the channel was 0.00040, what is the roughness factor for the lining of the channel?
24. On what slope should a 600 m long vitrified sewer pipe be laid in order that $0.17 \text{ m}^3/\text{s}$ will flow when the sewer is half full? What slope is required if the sewer flows full?
25. A trapezoidal channel, bottom width 6.1 m and side slopes 1 to 1 flows 1220 mm deep on a slope of 0.0009. For a value of $n = 0.025$, what is the uniform discharge?
26. Two concrete pipes ($C = 55$) must carry the flow from an open channel of half-square section 1.83 m wide and 0.915 m deep ($C = 66$). The slope of both structures is 0.00090. (a) Determine the diameter of the pipes.
(b) Find the depth of water in the rectangular channel after it has become stabilised, if the slope is changed to 0.00160, using $C = 66$.
27. An average vitrified sewer pipe is laid on a slope of 0.00020 and is to carry $2.36 \text{ m}^3/\text{s}$ when the pipe flows 0.90 full. What size pipe should be used?
28. How deep will water flow at the rate of $6.80 \text{ m}^3/\text{s}$ in a rectangular channel 6.0 m wide, laid on a slope of 0.00010? Use $n = 0.0149$.
29. How wide must be rectangular channel be constructed in order to carry $14.15 \text{ m}^3/\text{s}$ at a depth of 1.83 m on a slope of 0.00040? Use $n = 0.010$.
30. A channel with a trapezoidal cross section is to carry $25 \text{ m}^3/\text{s}$. If slope $S_0 = 0.000144$, $n = 0.015$, base width $b = 6.0 \text{ m}$ and the side slopes are 1 vertical to 1.5 horizontal, determine the normal depth of flow y_n .
31. Compute the normal depth in a trapezoidal channel having a bottom width of 10 m and side slope of 2H to 1V and carrying a flow of $30 \text{ m}^3/\text{s}$. The slope of the channel bottom is 0.001 and $n = 0.013$.