MINISTRY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF
TECHNICAL AND VOCATIONAL EDUCATION

Sample Questions & Worked Out Examples for CE-04016 HYDRAULIC ENGINEERING

B.Tech. (Second Year)

Civil Engineering

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CE-04016
HYDRAULIC ENGINEERING
Sample Questions

B.Tech. (Second Year)

Civil Engineering

Yangon Technological University
Department of Civil Engineering

Course No – CE 07026 + CE 08026 Hydraulic Engineering
Sample Question

Chapter 1 Open Channel Flow and It's Classifications

1. What is open channel flow? Differentiate between open channel flow and pipe flow.
2. What are the types of open channel flow ?
3. What are the states of open channel flow ?

Chapter 2 Energy and Momentum Principles.

1.* Water flows at a velocity of 3 ft/sec and a depth of 5 ft in a rectangular channel. There is a smooth upward step 6 in. in the channel bed; find the depth of water over the step and the change in the absolute level of water surface.

2.* Water is flowing at a velocity of 10ft/sec and a depth of 9.5 ft in a 12 ft wide rectangular channel.

(1) Find the change in depth produced by a smooth to a width of 11 ft.
(2) Find the greatest allowable contraction in width for the upstream flow to be possible as specified.
(3) There is a smooth upward step of 2 ft in a channel bed. What expansion in width must simultaneously take place for the upstream flow to be possible as specified?

3.* Water is flowing at a velocity of 8 ft/sec and a depth of 10 ft in a 12 ft wide rectangular channel.
(1)Find the change in depth produced by a smooth contraction to a width of 10 ft.
(2)Find the greatest allowable contraction in width for the upstream flow to be possible as specified.
(3)There is a smooth upward step of 2.75 ft in a channel bed and What expansion in width must simultaneously take place for the upstream flow to be possible on specified?

4.* Water is flowing at a velocity of 10 ft/sec and a depth of 10 ft in a channel of rectangular section. Find the change in depth and in absolute water level produced by (a) a smooth upward step of 1 ft; (b) the smooth downward step of 1 ft in the channel bed. Also (c) Find the max: allowable size of upward step for the upstream flow to be possible as specified.

5.* Water is flowing at a velocity of 12 ft/sec and a depth of 10 ft in a channel of rectangular section. Find the change in depth & in absolute water level produced by (a) a smooth upward step of 0.5 ft; (b) the smooth downward step of 1 ft in the channel bed. Also (c) find the max: allowable size of upward step for the upstream flow to be possible as specified.

6.* Water is flowing at a velocity of 9 ft/sec and a depth of 12 ft in a rectangular channel of 10 ft wide. Find (1) the max: allowable size of smooth upward step for the upstream flow to be possible as specified, (2) the greatest allowable smooth contraction in width for the upstream flow to be possible an specified.

7.** A horizontal rectangular channel of width 15 ft conveys 450 cusec. A sluice gate is incorporated in the channel the gate is regulated until the depth of flow just upstream is 10 ft. Assuming no losses of energy during the passage of water through the gate, find the depth of flow downstream. If the local temporary rise in the bed of the channel is created a short distance downstream of the gate, find the height of rise which could be tolerated before the sluice becomes drown out.

A permanent rise is introduced and this extends for some distance downstream, the depth of flow over the rise being 1.6 ft. Find the height of this permanent rise above the original bed level. Further, if the hydraulic jump is created, in this reach, what would be the depth of water downstream of the jump ?

8.** Water is flowing at a velocity of 10 ft/sec, a depth of 10 ft and a width of 10 ft in a channel of rectangular section. Find the change in depth and in absolute water level produced by (a) a smooth contraction to a width of 9 ft, (b) a smooth expansion in width to 11 ft. Also (c) find the greatest allowable contraction in width for the upstream flow to be possible as specified.

9.** Water is flowing in a rectangular channel with a velocity of 10 ft/sec, depth of 10 ft and a width of 10 ft. If there is a smooth upward step of 2 ft in the channel bed, what expansion in width must simultaneously take place for the up-stream flow to be possible as specified?

10.** Water is flowing in a rectangular channel with a velocity of 10 ft/sec, depth of 10 ft and a width of 10 ft. If the width of the channel is gradually expanded to 11 ft, What height of the smooth upward step must simultaneously take place for the upstream flow to be possible as specified?

11.*** Water is flowing at a velocity of 15 ft/sec and depth of 3 ft in a 8 ft wide channel of rectangular section. There is a smooth upward step of 1 ft in the channel bed. What expansion in width must simultaneously take place for the upstream flow to be possible as specified? There is a energy loss of 0.25 ft uniformly distributed through out the transition.

12.*** An open channel of constant width has its floor raised 0.15 ft at a given section. If the depth of the approaching flow is 1.5 ft, calculate the rate of flow indicated by (a) a 0.25 ft drop in water surface elevation over the raised bottom; (b) 0.25 ft rise in water surface elevation over the raised bottom. Calculated the critical depth .in each case & plot it relative to the water surface profile.

13.*** An open channel of constant width has its floor raised 0.36 ft at a given section. If the depth of the approaching floor is 4.8 ft, calculate the rate of flow per unit width indicated by a 0.44 ft drop in the water surface elevation over the raised bottom. Neglect losses at the sudden change of section.

14.*** A rectangular channel 10 ft wide is narrowed down to 8 ft by a contraction 50 ft long, built of straight walls and a of floor. It the discharge is 100 cusec and the depth of floor is 5 ft on the upstream side of the transition section, determine the flow-surface profile in the contraction (a) allowing no, gradual hydraulic drop in the contraction & (b) allowing a gradual hydraulic drop having its points of inflection at the mid-section of the contraction. The friction loss through the contraction is negligible.

10.* A horizontal rect: channel of width 20 ft conveys 600 cusec. A sluice gate incorporated in the gate is regulated until the depth of flow just upstream is 10 ft. Assuming no losses of energy during the passage of water through the gate, find the depth of flow down-stream. Further, if the hydraulic jump is created a short distance downstream, what would be the depth, the head loss and the h.p dissipated in the jump?

Chapter 3 Development of Uniform Flow and Its Formulas.

1.* A channel has a vertical walls 1.2 m apart and a semicircular invert. If the center-line depth is 0.9 m and the bed slope is 0.0004. What would be the value of C in the Chezy formula if the discharge is 0.55 m^3/ s?

2.* An open channel is V-shaped, each side being inclined at 45° to the vertical. If the rate of flow Q is 0.0425 m^3/sec, when the depth of water at the center is 0.225 m. Calculate the slope of the channel using Chezy formula, assuming that C is 49 in S.I unit.

3.* An open channel has a U-shaped cross-section, semi-circular at the bottom with vertical sides. If the channel is 4 ft wide, calculate the depth of the channel when the flow is 25 cusec and the bed slope is 1:2500. Assume C in Chezy formula is 96.

4.* In a channel of rectangular cross-section with slope of 1in 1000, the discharge is to be 1.4m^3 /sec, when the channel, whose depth is half its breadth, is running full.

5.* A circular pipe of 1m radius in laid at an inclination of 5° with horizontal. Calculate the discharge through the pipe, if the depth of water in the pipe is 0.75 m. Take $C = 65$.

6.* A circular channel conveys 3.25 m^3 / sec of water, when 3/4 of the vertical dia: is immersed. The slope of the channel is 0.2 meter per kilometre. Determine the diameter of the channel, using Manning's $n = 0.012$.

7.* An open channel of trapezoidal cross-section cut in earth has a bottom width of 6m, sides slopes 2 horizontal to 1 vertical, and bed slope 1 in 1000. Determine the mean velocity V, and the discharge for uniform flow when the depth of water at the center is 2.4 in. Manning's $n = 0.025$. Also find the corresponding value of C in the Chezy formula.

8.* A water channel is V-shaped with each side making an angle of 45° to the vertical. Calculate the volume of water passing per second when the depth of water in the channel is 0.25 m and the slope of the channel is 1 in 500. Take the coefficient C in the Chezy formula as 56 SI units. What would be the depth of water in the channel to pass twice this volume per second if the slope and value of C are unaltered?

9.* A cement-lined rectangular channel 6 m side carries water at a rate of 10 m^3 / s. Assuming Manning's $n = 0.12$. Calculate (1) Slope required to maintain a depth of 1.5 m and (2) slope required to maintain a depth of 0.75 m.

14.** A rectangular channel which is laid on a bottom slope of 0.0064 is to carry 20 m^3 / s of water. Determine the width of the channel when the flow is in critical condition. Take Manning's n = 0.015.

15.** A trapezoidal channel having bottom width 5m and side slopes 1:1 carries a discharge of $12m^3$ / sec. Compute the critical depth & critical velocity. If Manning's n = 0.02 determine the bottom slope required to maintain the critical depth.

16.** A rectangular open channel 18 ft wide& 4 ft deep has a slope of 0.001 and is lined with rubble masonry (Manning's n = 0.017). We wish to increase the amount of water discharge as much as possible without changing the channel slope or the rectangular form of the section. The dimensions of the section may be changed but the amount of excavation is unchanged.
Determine
(1) the discharge of the original channel,
(2) new dimensions of the channel to give the max: discharge,
(3) the ratio of the new discharge to the original discharge. What is the new discharge?

17.** A trapezoidal channel has a bottom width of 20ft, side slopes of 2: 1, and n = 0.025.

- (a) Determine the normal slope of a normal depth of 3.36 ft when the discharge is 400 cusec.
- (b) Determine the critical slope and corresponding normal depth when the discharge is 400 cusec.
- (c) Determine the critical slope at a normal depth of 3.36 ft, and compute the corresponding discharge.

18.** A rectangular channel 20 ft wide has a roughness coefficient n = 0.015.

- (a) Determine the normal slope at a normal depth of 1.23 ft when the discharge is 200 cusec.
- (b) Determine the critical slope & corresponding normal depth when the discharge is 200 cusec.,
- (c) Determine the critical slope at the normal depth of 1.23 ft & compute the corresponding discharge.

19.** Show that the theoretical discharge of the open channel flow may be expressed by

$$Q = A_2 \sqrt{\frac{2g.\,(\Delta y - h_f)}{1 - (A_2 / A_1)^2}}$$

where A_1 & A_2 are two cross-sectional areas of the flow at section (1) & (2) respectively, and Δy is the drop in water surface between two-sections.

20.** Prove the following equation for a discharge in a triangular highway gutter having one side vertical and the other side slope at z : 1 (SI units)

$$Q = \frac{0.316}{h} \; f(Z) \; y^{2/3} \; S^{1/2}$$

$$\text{where } f(Z) = \frac{Z^{5/3}}{[1 + 1 + Z^2]^{2/3}}$$

Compute the discharge if Z = 12; Manning's n = 0.015 ; y = 0.1 m and S = 0.03

23.*** A circular sewer of 60 cm inside dia: has a slope of 1 in 400. Find the depth when the discharge is 0.283 m^3/s, taking C in Chezy formula as 50.

24.*** 3 ft. dia. conduit, 12000 ft long is laid at a uniform slope of 1 in 1500 and connects two reservoir. When the levels in the reservoirs are low the conduit runs partly full and it is found that a normal depth of 2 ft gives a rate of flow of 11.5 ft^3 / sec. The Chezy coeff: C is given by $K R^{1/6}$, where K is constant and R is the hydraulic radius. Neglect losses of head at the entry and exist, obtain (a) the value of K; (b) the discharge when the conduit is running full and the difference, in levels between the two reservoirs is 15 ft.

25.*** Determine the radius of an open channel of semi-circular cross-section which is required to convey water with a flow of 280 litres / sec. The slope of the channel is 1 in 2500. Take C = 56 in the Chezy formula. If the channel is rectangular in form, but of the same total width and depth, what would be the flow with the same value of C and the same slope?

Chapter 4 Design of Channels for Uniform Flow.

1.* A trapezoidal channel carrying 400 cfs is built with non-erodible bed having a slope of 0.0016 & n = 0.015. Proportion the section dimension.

2.**A channel which is to carry 350 ft^3/s through moderately rolling topography an a slope of 0.0016 is to be excavated in course alluvium with 25% of the particles being 3cm (1.18 in) or more in diameter. The material, which will compose the perimeter of this channel, can be described as being moderately rounded. Assuming that the channel is to be unlined & of trapezoidal section, find suitable values of b & z (n = 0.025).

3.**Compute the bottom width and the depth of flow of a trapezoidal channel laid on a slope of 0.0016 and carrying a design discharge of 400 cfs. The channel is to be excavated in earth containing non colloidal coarse gravels and pebbles. n = 0.025 (use maximum permissible velocity method)

11.* Design an economical earthen trapezoidal channel with velocity of 1 m/s and to discharge 3 m^3 / s having side slope 1 in 2. Take C = 55.

12.* A brick lined trapezoidal channel has side slopes of 1: 1.5. It is required to carry 15 m^3/ s of water. If the average velocity of flow is not to exceed 1 m/s. Find.

(a) the wetted perimeter for min: amount of lining ;

(b) bed slope assuming Manning's n = 0.015

13.* A circular channel of 1.8 m diameter is laid at a slope of 0.001. Find (a) the max: discharge through the channel, if Chezy's C= 55. Find (b) the max: discharge, if Manning's n = 0.016

26.*** The water supply for a turbine passes through a conduit, which for convenience has its X' section in the form of square with one diagonal vertical.

If the conduit is required to convey 8.4 m^3/s , under condition of max discharge, atmospheric press. when the slope S is 1 in 4900, determine its size , assuming that the velocity of flow is given by $V= 80 R^{2/3} S^{1/2}$.

28.*** A special sewer consists of a semicircular top and bottom of radius r jointed by parallel vertical sides of length r so that the overall height is 3r.

(a) If that for maximum flow of a given X's sectional area, the angle subtended by the water surface at the center of the curvature of the upper semi-circle is approximately 64°.

(b) If the water now rises until it reaches the top of the sewer, find the percentage decrease in flow. Take Chezy coefficient = $KR^{1/6}$.

29.*** Compare the discharge at max: velocity with that when the channel is running full, assuming that the Chezy coefficient is unaltered, and that the pressure remains atmospheric.

Chapter 5 Theoretical Concepts of Boundary Layer, Surface Roughness, Velocity Distribution, and Instability of Uniform Flow.

1.* A concrete overflow spillway of indefinite length has a surface slope angle $\theta = 53° 8'$ and a roughness such that $K = 0.005$ ft when the discharge is 360 cfs per foot of spillway width, compute the length of the boundary layer development, the profile of the boundary layer, and the water surface.

Chapter 6 Gradually Varied Flow.

1.* An open rectangular channel 6 m. Wide conveys 100 m^3/s of water. The channel bottom slope is 0.003 for the first stretch and then there is a sudden break and the slope becomes 0.01. Determine the normal depth of flow in the first and second stretches respectively and also the critical depth. Draw the sketch of the water surface profile in the transition. Manning's n = 0.015

2.* A trapezoidal channel having b = 20 ft, z = 2 , S_0 = 0.0016 and n = 0.025 carries a discharge of 400 cfs compute the backwater profile created by a dam which back up the water to a depth of 5 ft immediately behind the dam. The upstream end of the profile is assumed at a depth equal to 1% greater than the normal depth. Compute the flow profile by using direct step method. The energy coefficient $\alpha = 1.10$

3.* A trapezoidal channel having b = 20 ft, z = 2 , S_0 = 0.0016 and n = 0.025 carries a discharge of 400 cfs compute the backwater profile created by a dam which back up the water to a depth of 5 ft immediately behind the dam. The upstream end of the profile is assumed at a depth equal to 1% greater than the normal depth. Compute the flow profile by using standard step method. The energy coefficient $\alpha = 1.10$

4.* Water flows from under a sluice into a trapezoidal channel having b = 20 ft, z = 2, S_0 = 0.0036, α = 1.10, and n = 0.025. The sluice gate is regulated to discharge 400 cfs with a depth equal to 0.55 ft at the vena contracta. Compute the flow profile. If a hydraulic jump occurs at a downstream end, starting with a depth of 1.6 ft, determine the distance from the vena contracta to the foot of the jump by using direct step method

5.* Water flows from under a sluice into a trapezoidal channel having b = 20 ft, z = 2, S_0 = 0.0036, α = 1.10, and n = 0.025. The sluice gate is regulated to discharge 400 cfs with a depth equal to 0.55 ft at the vena contracta. Compute the flow profile. If a hydraulic jump occurs at a downstream end, starting with a depth of 1.6 ft, determine the distance from the vena contracta to the foot of the jump by using standard step method

6.** A wide rectangular channel with n = 0.025 is laid with change in slope from 0.09 to0.002. The depth of uniform flow in the mild channel is 2 m. Determine the location of the jump. Use direct Step Method.

7.** A wide rectangular channel with n = 0.025 is laid with change in slope from 0.01 to0.002. The depth of uniform flow in the mild channel is 2 m. Determine the location of the jump. Use direct Step Method.

8** Examine the flow conditions in a 10 ft wide open rectangular channel of rubble masonry with n = 0.017 when the flow rate is 400 cusecs. The channel slope is 0.02, and an ogee weir 5 ft high with C_W = 3.8 is located at the downstream end of the channel.

$$Q = C_W L (h + V_o^2/2g)^{3/2}$$

9.** A longitudinal section of a wide river shows a rough length followed by a long relatively smooth reach of the same slope S_o . The ratio of the corresponding coefficient is $1:2\sqrt{2}$. The slope joins a wide horizontal apron. The normal depth of flow on the rough section is 8 ft , for q = 83 ft^2/sec . If the normal depth y_n in the horizontal section is 10 ft, and the Frode No. (v^2/gy_n) is 3/8 , locate the toe of the hydraulic jump which forms on the horizontal apron. Sketch the water surface profile showing the 3 sections of the river. Neglect side effects & take the Chezy coefficient for the horizontal apron as 83 $ft^{1/2}$/sec .

10.** Water flows under a sluice into a rect: channel of large width. The channel is laid with bottom slope S_O = 0.001. The sluice is regulated to discharge 6 m^3/s per metre width of channel, the depth at vena contrata being 0.5 m. Determine the position of hydraulic jump. Take mean value of Chezy coefficient C = 60 $m^{1/2}$/s.

11.** A rectangular flume 1.2 m wide, carries a subcritical flow 0.24 m^3/s. An adjustable sluice gate spans the flume. The opening is so adjusted that the depth of water just after the sluice is 10 cm. Show that the hydraulic jump can be expected downstream of the sluice. If the depth just before the jump is 11 cm, find the height of the jump & the total power lost at the jump. Manning's n = 0.015. Using step method locate the position of the jump.

12.** The triangular channel shown in the figure has an invert slope increasing in the direction of flow with dist: x as follows: -

Dist x (ft)	100	400	700	1000
Invert slope S_O	0.0032	0.0037	0.0041	0.0047

Determine the location of the critical depth control point in this reach, when the discharge Q is 500 cusecs. Take n = 0.016.

13.*** The spillway of a dam discharges 300 ft^3/sec per ft width on to a horizontal stilling apron. The depth of higher velocity flow at the entry point to the apron is 2 ft. Both apron & sills are sufficiently long to permit establishment of normal conditions. The sill is followed by a 1: 10 sloping wide channel. (1) Calculate the height of the hydraulic jump and the height Z_o of the sill necessary for its stabilization at the location shown. Neglect energy dissipation in flow over the sill. (2) Calculate the normal depth of flow in downstream channel. (Manning's n= 0.015). (3) Sketch the surface profile at the various sections.

14.*** In a rectangular channel the side walls converge so that the width decreases from 6m to 5.7 m in a distance of 60 m is dT/dx = -0.005. The invert slope increase with dist: x, as follows.

x.(m)	0	10	20	30	40	50	60
S_O	0.001	0.002	0.003	0.004	0.005	0.006	0.007

Determine the approximate location of a critical depth control point in the length of channel for a discharge of 40 m^3/s. Manning's n = 0.015.

Chapter 7 Flow over Spillways

1.* Determine the crest elevation and the shape of an overflow spillway section having a vertical upstream face, and a crest length of 250ft. The design discharge is 75,000 cfs. The upstream water surface at design discharge is at EL. 1000 and the overage channel floor is at EL 880.0.

2.* Determine the crest elevation and the shape of an overflow spillway section having a vertical upstream face, and a crest length of 250ft. The design discharge is 75,000 cfs. The upstream water surface at design discharge is at EL. 975 and the overage channel floor is at EL 880.0

3.* Determine the crest elevation and the shape of an overflow spillway section if the upstream face has a slope 3 on 2, and a crest length of 250ft. The design discharge is 75,000 cfs. The upstream water surface at design discharge is at EL. 1000 and the overage channel floor is at EL 880.0.

Chapter 8 Hydraulic Jump and Its Use as Energy Dissipater.

1.* Proportion a USBR stilling basin II for the overflow spillway designed in problem. The tail water elevation is at EL 920.0.

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Worked out Example

1.(3-7)* A brick lined trapezoidal channel has side slopes of 1: 1.5. It is required to carry 15 m^3/s of water. If the average velocity of flow is not to exceed 1 m/s. Find.

(a) the wetted perimeter for min: amount of lining ;

(b) bed slope assuming Manning's n = 0.015

Solution

Best hydraulic trapezoidal channel section

$$\frac{b + 2zy}{2} = y\sqrt{1 + z^2}$$

$$b + 2 \times 1.5y = 2y\sqrt{1 + 1.5^2}$$

$$b = 0.6\,y$$

$$Q = AV$$

$$A = \frac{Q}{V} = \frac{15}{1}$$

$$A = 15\ m^2$$

Again,

$$A = (b + zy)\ y$$

$$15 = (0.6y + 1.5y)\ y$$

$$y = 2.67\ m$$

$$b = 0.6y = 1.602\ m$$

$$P = b + 2y\sqrt{1 + z^2}$$

$$= 1.602 + 2 \times 2.67\ \sqrt{1 + 1.5^2}$$

$$= 11.23\ m$$

$$R = \frac{y}{2} = 1.335\ m$$

$$Q = \frac{\phi}{n} AR^{2/3} S_o^{1/2}$$

$$15 = \frac{1}{0.015} (15)\ (1.335)^{2/3} S_o^{1/2}$$

$$S_o = 0.00015$$

2.(3-7) (4-7) * A trapezoidal channel carrying 400 cfs is built with non-erodible bed having a slope of 0.0016 & n = 0.015. Proportion the section dimension.

Solution

Using Manning formula,

$$Q = \frac{1.49}{n} AR^{2/3} S_o^{½}$$

$$400 = \frac{1.49}{0.015} AR^{2/3}\ (0.0016)^{1/2}$$

$$AR^{2/3} = \frac{0.015 \text{ x } 400}{1.49\ (0.0016)^{1/2}}$$

$$AR^{2/3} = 100.7 \text{ ------------- } (1)$$

Assume $b = 20'$, $z = 2$

$$A = (20 + 2y)\ y$$

$$P = 20 + 2y\sqrt{1+2^2} = 20 + 2\sqrt{5}\ y$$

Equation (1) becomes,

$$\left[(20 + 2y)\ y\right] \left[\frac{(20 + 2y)\ y}{20 + 2y\sqrt{5}}\right]^{2/3} = 100.7$$

by trial & error

$$y = 2.52 \text{ ft}$$

Check minimum velocity

$$A = (20 + 2 \text{ x } 2.52) \text{ x } 2.52 = 62.5 \text{ ft}^2$$

$$Q = AV$$

$$V = \frac{400}{62.5} = 6.4 \text{ ft/s} > 2 \sim 3 \text{ ft/s}$$

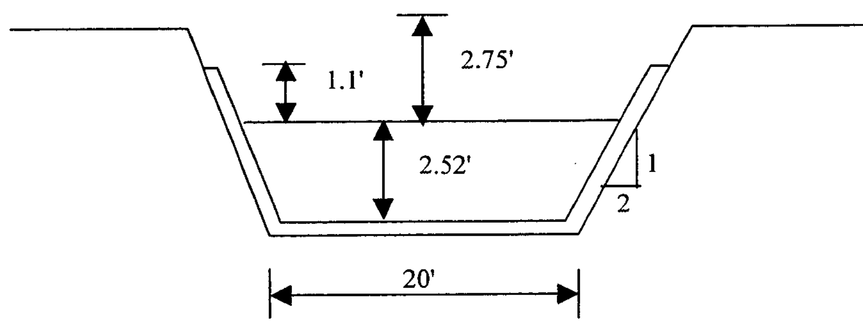
$\therefore$ This velocity should prevent both sedimentation & vegetative growth.

$$T = b + 2zy$$
$$= 20 + 2 \times 2 \times 2.52$$
$$= 30.08 \text{ ft}$$

$$D = \frac{A}{T} = \frac{62.5}{30.08} = 2.08 \text{ ft}$$

$$Fr = \frac{V}{\sqrt{gD}} = \frac{6.4}{\sqrt{32.2 \times 2.08}} = 0.78 < 1$$

$\therefore$ Subcritical



height of canal bank above water surface = 2.75 ft

height of lining above water surface = 1.1 ft

3.(2-7) ** Water is flowing in a rectangular channel with a velocity of 10 ft/sec, depth of 10 ft and a width of 10 ft. If there is a smooth upward step of 2 ft in the channel bed, what expansion in width must simultaneously take place for the up-stream flow to be possible as specified?

Solution

$$E_1 = y_1 + \frac{V_1^2}{2y} = 10 + \frac{10^2}{2 \times 32.2} = 11.56 \text{ ft}$$

$$E_1 = E_2 + \Delta Z + \text{losses}$$
$$E_2 = E_1 - \Delta Z = 11.56 - 2 = 9.56 \text{ ft}$$

For the upstream flow to be possible as specified.

$$E_2 = E_c \text{ (or) } E_{min}$$

$$\therefore \quad E_c = 9.56 \text{ ft}$$

For rectangular channel,

$$y_c = \frac{2}{3} E_c = \frac{2}{3} \times 9.56 = 6.37 \text{ ft}$$

$$V_c = \sqrt{g y_c} = \sqrt{32.2 \times 6.37} = 14.32 \text{ ft/s}$$

$$Q = b_1 y_1 V_1 = b_c y_c V_c$$

$$b_c = \frac{10 \times 10 \times 10}{6.37 \times 14.32} = 10.96 \text{ ft}$$

The minimum expansion required is 10.96 - 10 = 0.96 ft

4. (2-7) (3-7)** A rectangular channel which is laid on a bottom slope of 0.0064 is to carry 20 m^3 / s of water. Determine the width of the channel when the flow is in critical condition. Take Manning's n = 0.015.

Solution

If the flow is in critical correlation, $y = y_c$

$$q = \frac{Q}{b} = \frac{20}{b} \quad m^2/s$$

$$y_c = \sqrt[3]{\frac{q^2}{g}} = \left[\frac{(20/b)^2}{32.2}\right]^{1/3} = 3.44 \; b^{-2/3} \text{ m}$$

$$A = b y_2 = b \times 3.44\, b^{-2/3} = 3.44 \; b^{1/3} \, m^2$$

$$P = b + 2y_2 = b + 2 \times 3.44\, b^{-2/3} = b + 6.88\, b^{-2/3} \text{ m}$$

$$R = \frac{A}{P} = \frac{3.44\, b^{1/3}}{b + 6.88\, b^{-2/3}} \quad m$$

Using Manning Formula

$$Q = \frac{1}{n} \quad A R^{2/3} S_o^{\;1/2}$$

$$20 = \frac{1}{0.015} \left(3.44\, b^{1/3} \right) \left[\frac{3.44\, b^{1/3}}{b + 6.88\, b^{-2/3}}\right] (0.0064)^{1/2}$$

$$b = 2.39 \text{ m}$$

5. (2-7) (3-7) (6-8)** A wide rectangular channel with n = 0.025 is laid with change in slope from 0.09 to0.002. The depth of uniform flow in the mild channel is 2 m. Determine the location of the jump. Use direct Step Method.

Solution

For wide channel,

$$q = \frac{1}{n} y^{5/3} s^{1/2}$$

$$= \frac{1}{0.025} (2)^{5/3} (0.002)^{1/2}$$

$$= 5.68 \text{ m}^2/\text{s}$$

Let $y_2 = y_{n2}$

$$Fr_2^2 = \frac{q^2}{gy_2^2} = \frac{(5.68)^2}{9.81 (2)^3} = 0.411$$

$$\frac{y_1}{y_2} = ½ \left[\sqrt{1 + 8\,Fr_2^2} - 1\right]$$

$$y_1 = \frac{2}{2} \left[\sqrt{1 + 8 \times 0.411} - 1\right] = 1.07 \text{ m}$$

For the first stretch,

$$q = 5.68 = \frac{1}{0.025} (y_{n1})^{5/3} (0.04)^{1/2}$$

$$y_n = 0.6384 \text{ m} < y_1$$

∴ Hydraulic jump will form in mild channel.

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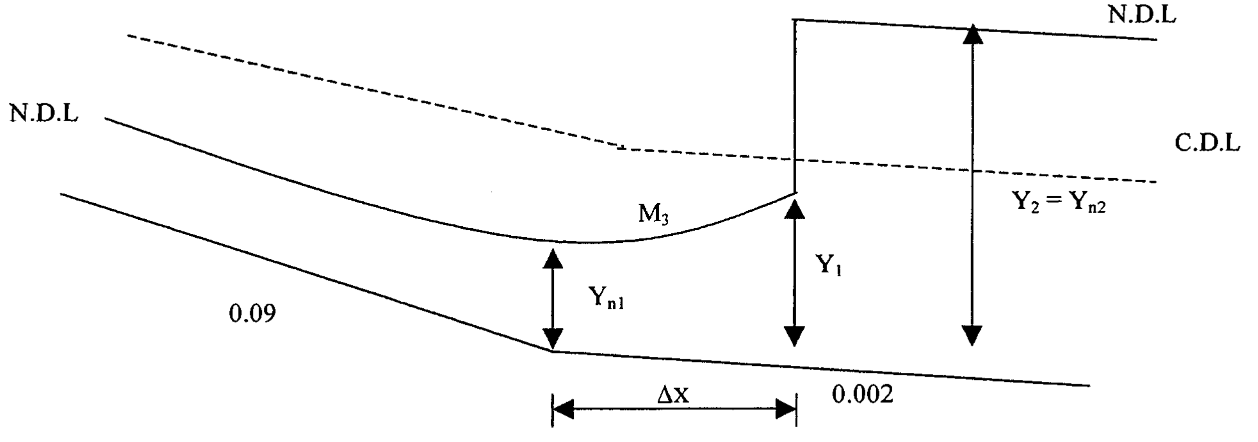

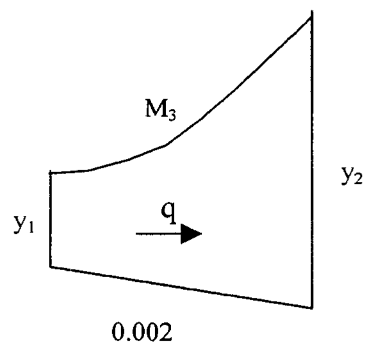

$y_1 = 0.6384 \text{ m} \rightarrow V_1 = \dfrac{5.68}{0.6384} \rightarrow E_1 = y_1 + \dfrac{V_1^2}{2y} = 4.6731 \text{ m}$

$y_2 = 1.07 \text{ m} \rightarrow V_2 = \dfrac{5.68}{0.6384} \rightarrow E_2 = y_2 + \dfrac{V_1^2}{2y} = 2.506 \text{ m}$

$S_o = 0.002$

$S_{f1} = 0.016$

$S_{f2} = 0.09$

$\overline{S_f} = 0.053$

$$\Delta x = \frac{E_2 - E_1}{S_0 - \overline{S}_f} = \frac{2.506 - 4.6731}{0.002 - 0.053} = 42.49 \text{ m}$$

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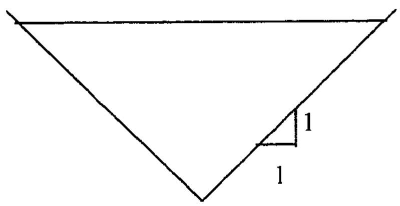
6. (2-7) (3-7) (6-8)** The triangular channel shown in the figure has an invert slope increasing in the direction of flow with dist: x as follows: -

Dist x (ft)	100	400	700	1000
Invert slope S_o	0.0032	0.0037	0.0041	0.0047

Determine the location of the critical depth control point in this reach, when the discharge Q is 500 cusecs. Take n = 0.016.



Solution

$$A = zy^2 = y^2$$

$$P = 2\sqrt{2}\ y$$

$$R = \frac{y}{2\sqrt{2}}$$

$$T = 2y$$

$$D = \frac{A}{T} = \frac{y}{2}$$

For $F_2 = 0$

$$\frac{Q^2 T}{gA^3} = 1$$

$$\frac{Q^2 \times 2y_c}{g\,(y_c^2)^3} = 1$$

$$y_c^5 = \frac{2Q^2}{g}$$

$$y_c = \left[\frac{2Q^2}{g}\right]^{1/5} = \left[\frac{2 \times 500^2}{32.2}\right]^{1/5} = 6.89 \text{ ft}$$

$$A = (6.89)^2 = 47.4721 \text{ ft}^2$$

$$R = \frac{6.89}{2\sqrt{2}} = 2.436 \text{ ft}$$

$$Q = \frac{1.49}{n} AR^{2/3} S_0^{1/2}$$

$$500 = \frac{1.49}{0.016} (47.47) [2.436]^{2/3} S_{fc}^{1/2}$$

$$S_{fc} = 0.0039$$

The value of $S_0 - S_f$ will change from -ive value to +ive value when the slope S_o changes from 0.0037 to 0.0041.

The critical depth control point will be located at a dist: of $x = 400$ ft.

7.(6-8)** Determine the crest elevation and shape of an overflow spillway section having a vertical upstream face and a crest length of 250 ft. The design discharge is 75,000 cfs. The upstream water surface at design discharge is at EL 1000.00 and the average channel floor is at EL 880.00

Assuming a high overflow spillway,

$$C_d = 4.03$$

$$Q = C_d LH^{3/2}$$

$$75000 = 4.03 \text{ x } 2500 \text{ x } H^{3/2}$$

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$H = 17.8$ ft

$$V_a = \frac{Q}{A} = \frac{75,000}{250 \times 120} = 2.5 \text{ ft/s}$$

$$\frac{V_a^2}{2g} = 0.1 \text{ ft}$$

Thus

$H_d = 17.8 - 0.1 = 17.7$ ft

height of dam is $h = 120 - 17.7 = 102.3 \text{ ft} > 1.33 \ H_d$

The effect of approach velocity is negligible.

Crest elevation is 1000.00 – 17.0 = 982.3 ft

For upstream vertical face $K = 2.0$, $n = 1.85$

$$x^n = KH_d^{n-1}\ y$$

$$x^{1.85} = 2 \times 17.7^{0.85}\ y$$

$$y = \frac{x^{1.85}}{23}$$

$$\frac{dy}{dx} = \frac{1}{0.8} = \frac{1}{23} \times 1.85\ x^{0.85}$$

$$x = 25.22 \text{ ft}$$

X	0	1	2	3	4	5	6	7	8	9	10
Y	0	0.043	0.157	0.332	0.565	0.854	1.196	1.591	2.037	2.533	3.078

X	12	14	16	18	20	22	24	25
Y	4.313	5.736	7.343	9.131	11.096	13.24	15.55	17.04

8. (3-7) (4-7)*** A channel which is to carry 350 ft^3/s through moderately rolling topography an a slope of 0.0016 is to be excavated in course alluvium with 25% of the particles being 3cm (1.18 in) or more in diameter. The material, which will compose the perimeter of this channel, can be described as being moderately rounded. Assuming that the channel is to be unlined & of trapezoidal section, find suitable values of b & z (n = 0.025).

Solution

For d_{75} = 1.18 in & moderately rounded, from figure $\theta = 34°$

Assume $\frac{b}{y} = 4, \quad z = 2$

From figure

maximum tractive force on side $\tau_s = \alpha\, \omega\, y\, S_0$

$= 0.75 \times 62.4 \times y \times 0.0016$

$= 0.0748\ y\ \ lb / ft^2$

$$\tan\phi = \frac{1}{z}$$

$$\phi = \tan^{-1}(½) = 26.6°$$

$$k = \sqrt{1 - \frac{\sin^2\phi}{\sin^2\theta}} = \sqrt{1 - \frac{\sin^2(26.6°)}{\sin^2(34°)}} = 0.6$$

permissible $\tau_L = 0.4\, d_{75} = 0.4 \times 1.18 = 0.47\ \ lb / ft^2$

for moderately rolling topography, $C_s = 0.75$

corrected permissible $\tau_L = 0.75 \times 0.47 = 0.35\ \ lb / ft^2$

corrected permissible τ_S = k x corrected permissible τ_L

$= 0.6 \times 0.35$

$= 0.21\ \ lb / ft^2$

For equilibrium,

$$0.0748\, y = 0.21$$

$$y = 2.80 \text{ ft}$$

$$b = 4 \times 2.804 = 11.216 \text{ ft}$$

$$A = (b + zy)\, y = (11.216 + 2 \times 2.804)\, 2.804$$

$$= 47.17 \text{ ft}^2$$

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$$P = 11.216 + 2x\, 2.804\sqrt{1 + 22}$$
$$= 23.756 \text{ ft}$$

$$Q = \frac{1.49}{0.025} \times 47.17 \left[\frac{47.17}{23.756}\right]^{2/3} (0.0016)^{1/2}$$

$$= 177.69 \text{ ft}^3/\text{s} < Q_D = 350 \text{ ft}^3/\text{s}$$

$\therefore$ not O.K

Re assume $\frac{b}{y} = 10, \; z = 2$

maximum tractive force on side $\tau_s = 0.78\, \omega\, y\, S_o$
$= 0.78 \times 62.4 \times y \times 0.0016$
$= 0.0779y \text{ lb/ft}^2$

For equilibrium,

$$0.0779\, y = 0.21$$
$$y = 2.696 \text{ ft}$$
$$b = 10 \times 2.696 = 29.696 \text{ ft}$$

$$A = (b + zy)\, y = (29.696 + 2 \times 2.696)\, 2.696$$

$$= 87.22 \text{ ft}^2$$

$$P = 2.696 + 2\times 2.696\sqrt{1 + 2^2}$$
$$= 39.02 \text{ ft}$$

$$Q = \frac{1.49}{0.025} \times 87.22 \left[\frac{87.22}{39.02}\right]^{2/3} (0.0016)^{1/2}$$

$$= 355.59 \text{ ft}^3/\text{s} \approx Q_D = 350 \text{ ft}^3/\text{s}$$

Check minimum velocity

$$Q = AV$$

$$V = \frac{350}{87.22} = 4.013 \text{ ft/s} > 2 \sim 3 \text{ ft/s}$$

$\therefore$ This velocity should prevent both sedimentation & vegetative growth.

$$T = b + 2zy$$
$$= 26.96 + 2 \times 2 \times 2.696$$
$$= 37.74 \text{ ft}$$

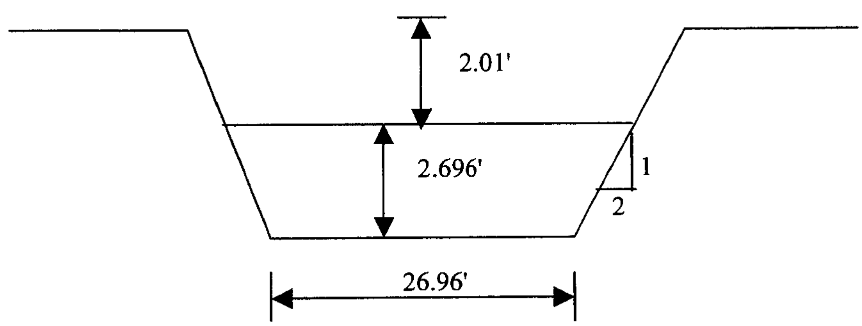
$$D = \frac{A}{T} = \frac{87.22}{37.74} = 2.31 \text{ ft}$$

$$Fr = \frac{V}{\sqrt{gD}} = \frac{4.013}{\sqrt{32.2 \times 2.31}} = 0.485 < 1$$

$\therefore$ Subcritical

Estimate freeboard

$$F = \sqrt{Cy} = \sqrt{1.6 \times 2.696} = 2.01 \text{ ft}$$



9.(2-7)*** An open channel of constant width has its floor raised 0.15 ft at a given section. If the depth of the approaching flow is 1.5 ft, calculate the rate of flow indicated by (a) a 0.25 ft drop in water surface elevation over the raised bottom; (b) 0.25 ft rise in water surface elevation over the raised bottom. Calculated the critical depth .in each case

Solution

(a) $E_1 = E_2 + \Delta Z + \text{losses}$

$$y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g} + \Delta Z$$

$$y_1 + \frac{V_1^2}{2g} = (y_1 - \Delta y - \Delta Z) + \frac{V_2^2}{2g} + \Delta Z$$

$$\frac{V_2^2}{2g} - \frac{V_1^2}{2g} = \Delta y \text{ ---------------- (1)}$$

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Using Continuity Equation,

$$Q = by_1V_1 = by_2V_2$$

$$V_2 = \frac{y_1 V_2}{y_2}$$

$$V_2 = \frac{1.5}{(1.5 - 0.25 - 0.15)}$$

$$V_2 = \frac{1.5}{1.1} V_1$$

Eqn (1) becomes

$$\frac{1}{2g} \left[\left(\frac{1.5}{1.1}\right)^2 V_1^2 - V_1^2 \right] = 0.25$$

$$\frac{V_1^2}{2g} \left[\left(\frac{1.5}{1.1}\right)^2 - 1 \right] = 0.25$$

$$V_1 = 4.32 \text{ ft/s}$$

$$q = V_1y_1 = 4.32 \times 1.5 = 6.49 \text{ ft}^2/\text{s}$$

$$y_c = \sqrt[3]{\frac{q^2}{g}} = \left[\frac{(6.49)^2}{32.2}\right]^{1/3} = 1.093 \text{ ft}$$

(b) $\Delta y = 0.25$ ft (↑) , q = ?, y_2 = ?

$$E_1 = E_2 + \Delta Z + \text{losses}$$

$$y_1 + \frac{V_1^2}{2g} = (y_1 - \Delta y - \Delta Z) + \frac{V_2^2}{2g} + \Delta Z$$

$$\frac{V_2^2}{2g} - \frac{V_1^2}{2g} = \Delta y \quad \text{---------------} (2)$$

$$V_2 = \frac{y_1}{y_2}$$

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$$V_1 = \frac{1.5}{1.5 + 0.25 - 0.15}$$

$$V_2 = \frac{1.5}{1.6} V_1$$

Eqn (2) becomes

$$\frac{1}{2g} \left[V_1^2 - \left(\frac{1.5}{1.6}\right)^2 V_1^2 \right] = 0.25$$

$$V_1 = 11.53 \text{ ft/s}$$

$$q = V_1 y_1 = 11.53 \text{ x } 1.5 = 17.3 \text{ ft}^2/\text{s}$$

$$y_c = \sqrt[3]{\frac{q^2}{g}} = \left[\frac{(17.3)^2}{32.2}\right]^{1/3} = 2.1 \text{ ft}$$

10.(2-7)*** A 20 ft wide horizontal stream flows over a short stretch of stones. The flow upstream of the rough stretch is 3 ft deep and has a speed of 5 ft /sec. If the stones are estimated to experience a drag of 1000 lb-f, determine the depth and speed of the stream down stream of the rough stretch. Calculate the critical depth. Is the flow fast or slow ?

Solution

Discharge per unit width $q = 5 \text{ x } 3 = 15 \text{ ft}^2/\text{s}$

$$y_c = \sqrt[3]{\frac{q^2}{g}} = \left[\frac{25^2}{32.2}\right]^{1/3} = 1.91 \text{ ft}$$

initial depth $y_1 > y_2 \Rightarrow V_1 < V_c$

The flow is initially slow.

When flow over the stretch of stones

by Newton 2nd Law

$$\rho Q (V_2 - V_1) = \rho g (A_1 \overline{y_1} - A_2 \overline{y_2}) - P$$

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$$= \rho g b \left(\frac{y_1^2}{2} - \frac{y_2^2}{2}\right) - P \quad \text{----------} (1)$$

$Q \quad = by_1V_1 \quad = by_2V_2$

$V_2 \quad = V_1y_1 / y_2$

$$300 \left[V_1 \frac{y_1}{y_2} - V_1\right] = 10 \rho g (y_1^2 - y_2^2) - 1000$$

$$3000 V_1 \left[\frac{3}{y_2} - 1\right] = 1000 \rho g (3^2 - y_2^2) - 1000$$

$\rho g = 62.4$ lb / ft^3, and $\rho = 1.94$ Sling / ft^{-3}

$$2900 \left(\frac{3}{y_2} - 1\right) = 4616 - 624 y_2^2$$

$$y_2^3 - 12 y_2 + 14.0 = 0$$

$$y_2 = 2.6 \text{ ft}$$

$$V_2 = \frac{15}{2.6} = 5.77 \text{ ft/s} > 5 \text{ ft/s}$$

The flow is faster than the u/s flow, but still less than the critical fun.