HORIZONTAL CURVE SETTING BY OFFESETS OR ORDINATES FROM LONG CHORD

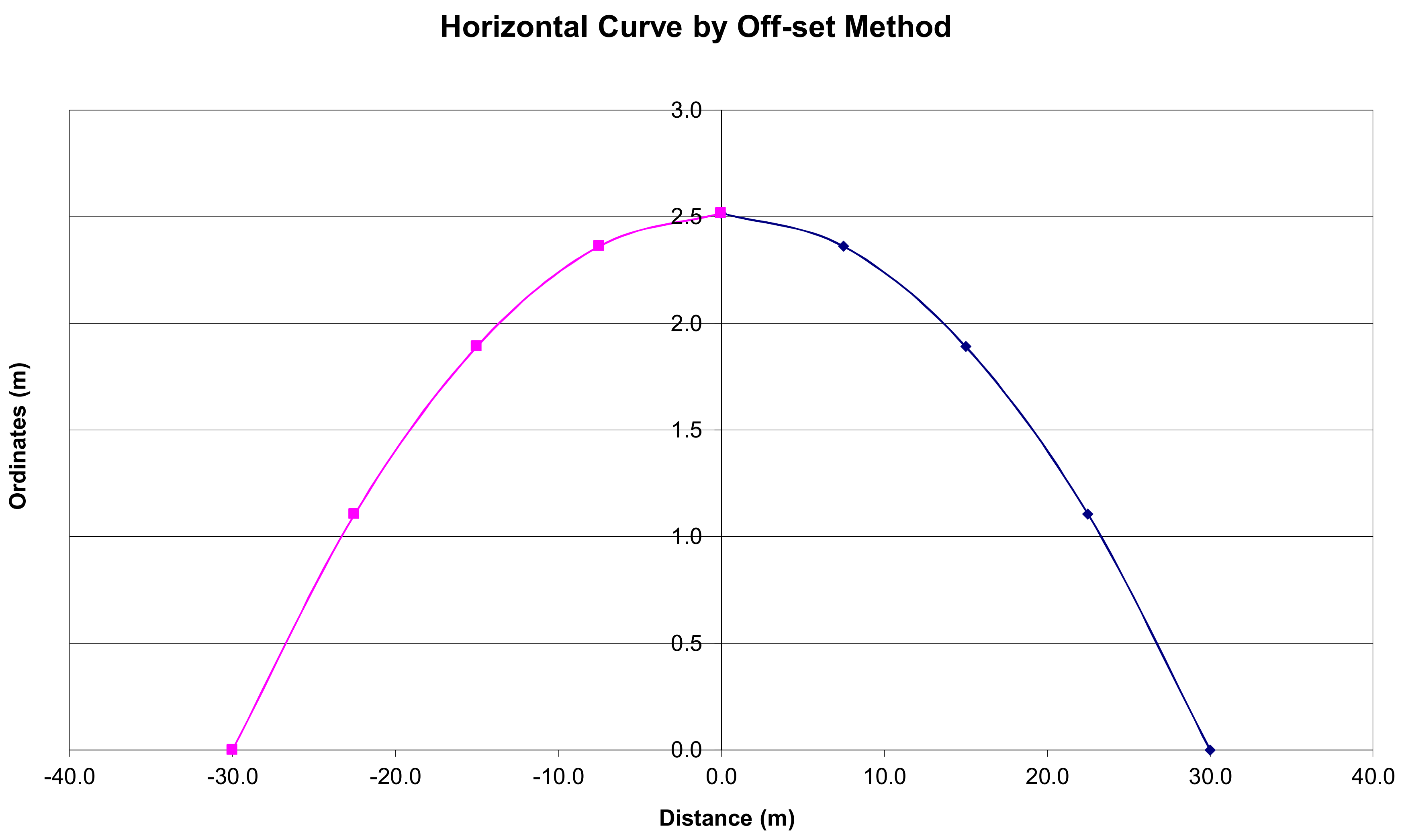
INPUT

INTERVAL FOR ORDINATES IN METERS (m) =	7.5
LENGTH OF LONG CHORD IN METERS (m) =	60
RADIUS OF CURVE IN METERS (m) =	180

SOLUTION

ORDINATE AT THE MIDDLE OF LONG CHORD 2.518 m

Distance x from Mid Point	Ordinate in m $\sqrt{R^2 - x^2} - \sqrt{\left[R^2 - \left(L/2\right)^2\right]}$	Distance x from Mid Point
x (m)	y (m)	-x (m)
0.00	2.518	0.00
7.50	2.361	-7.50
15.00	1.892	-15.00
22.50	1.106	-22.50
30.00	0.000	-30.00



Horizontal Curve by Off-set Method
Ordinates (m)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-40.0
-30.0
-20.0
-10.0
0.0
10.0
20.0
30.0
40.0
Distance (m)

In a Road curve between two straights, having deflection angle 108^o, Bernoulli's lamniscate is used as throughout. Make necessary calculations for setting out curve if the apex distance is 20 m.

Delta = 108
VM 20
Pi = 3.14159

In triangle T_1VM, Angle AVM = 36 0.6283 Rad

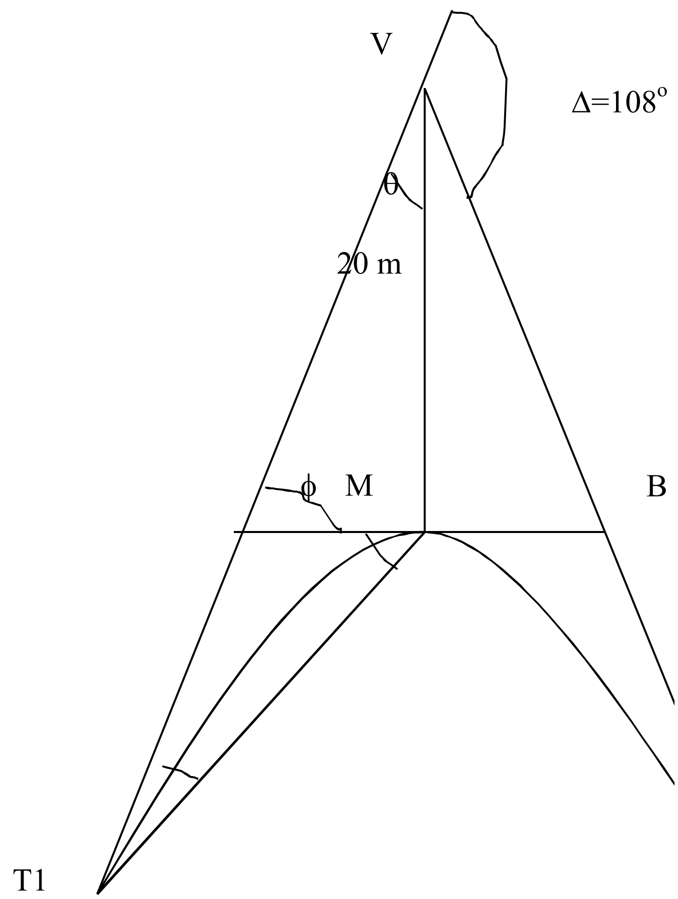
From Bernoulli's lamniscate method, we have $VT_1M = \alpha = \Delta/6 =$ 18

VMT_1 = 126

By Sine rule
T1M = b = 38.042

b = K*sqrt(Sin 2 Alpha)

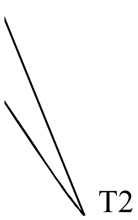
K = 49.62



Alpha		b
Degrees	Rad	m
0	0	0.00
2	0.0349	13.11
4	0.0698	18.51
6	0.1047	22.63
8	0.1396	26.05
10	0.1745	29.02
12	0.2094	31.65
14	0.2443	34.00
16	0.2793	36.12
18	0.3142	38.04

a transitional curve

0.3142 Rad



b

α

T_1

T_2

DESIGN OF THE LENGTH OF THE VERTICAL CURVE

An ascending gradient of 1 in 100 meets a desceiding gradient of 1 in 120. A summit curve is to be designed for a speed of 80 kmph. Assume coefficient of friction as 0.35 and reaction time of the driver as 2 Seconds.

n1 =	0.01	
n2 =	-0.00833	
V =	80	kmph
f =	0.35	
t =	2	Seconds
H =	1.2	m (Assumed)
h =	0.1	m (Assumed)

Solution

Stopping Sight Distance = SSD = S

S = $0.278Vt+(V^2/254f)$ 116.471 m

N = n1-n2 0.01833

Length of the summit curve (L)

1) $L >= S$ $L = NS^2/[Sqrt(2H)+Sqrt(2h)]^2$

2) $L < S$ $L = 2S-[Sqrt(2H)+Sqrt(2h)]^2/N$

$L = NS^2/[Sqrt(2H)+Sqrt(2h)]^2$ 62.399 m

$L = 2S-[Sqrt(2H)+Sqrt(2h)]^2/N$ 15.543 m

Length = 15.543 m

VERTICAL CURVE SETTING

INPUT			
Up Grade	n_1	0.50%	
Down Grade	n_2	-0.70%	
Chainage at Intersection	Ch_i	500.00	m
R.L. at Intersection	RL_i	330.75	m
Rate of change of grade per m	G	0.0033	%
Chain Length	ChL	30.00	m

I. Length of the Vertical Curve

1. Total change of Grade =	$n_1 - n_2$	1.20%	
2. Length of Vertical Curve =	L_v	360.00	L_v = (r
the apex	L_a	180.00	L_a =

II. Chainage

1. Chainage of the beginning of the curve	Ch_b	320.00	$Ch_i - L_a$
2. Chainage at the end of the curve	Ch_e	680.00	$Ch_i + L_a$
3. Total No. of Station =	n	12	$(Ch_e - Ch_b)$/
4. Apex Station Number		6	n/2

III. Reduced Levels

1. RL of the beginning of the curve	RL_b	329.85	$RL_i - L_a$ x n
2. RL of the end point of the curve	Rl_e	329.49	$RL_i + L_a$ x r
3. RL of the mid point of the curve	Rl_m	329.67	Average of
4. RL of the vertex of the curve	Rl_v	330.21	Average of

IV. RL of the points on the curve

1. RL of the First point on the tangent	RL_{1T}	330.00	$RL_b + n_1$ x Cl
2. Tangent correction for the first point	T_{1c}	0.015	$(1/6)^2(RL_i$ -
3. RL of the points on the curve	RL_{1c}	329.99	$RL_{1T} - T_{1c}$

Output

Station	Chainage	Grade Elevation	Tangent Correctn	Curve Elevn	Remarks
0	320.00	329.85	0.000	329.850	Beginning of curve
1	350.00	330.00	0.015	329.985	

2	380.00	330.15	0.060	330.090	Upward gradient with n_1
3	410.00	330.30	0.135	330.165	
4	440.00	330.45	0.240	330.210	
5	470.00	330.60	0.375	330.225	
6	500.00	330.75	0.540	330.210	Vertex of curve
7	530.00	330.54	0.375	330.165	Downward gradient with n_2
8	560.00	330.33	0.240	330.090	
9	590.00	330.12	0.135	329.985	
10	620.00	329.91	0.060	329.850	
11	650.00	329.70	0.015	329.685	
12	680.00	329.49	0.000	329.490	End of curve

Note:

1. Grade elevation increases upto chainage intersection and decreases there onw
   Grade elevation = Previous Grade elevation + n_1 x Chain Length (Up to Apex)
   Grade elevation = Previous Grade elevation + n_2 x Chain Length (After Apex)

2. Tangent correction increases upto chainage intersection and decreases there c
   Tangent correction = (Stn. No. $(1/(n/2)))^2(RL_1-RL_v)$ upto Apex
   Tangent Correctin for stations after Apex is Mirror image of stations upto Apex

3. Curve elevation = Grade elevation - Tangent correction

$_1$ - n_2)/G

= L_v / 2

ChL

1

$_2$

1. and 2.

3. and RL_i

hL

RL_v)

ards

nwards

Computation of Super Elevation for horizontal curves in roads

Input			
Radius of the curve	R (m)	229.0	
Design speed	kmph	288.0	80 m/s
Number of Lanes	n	2.0	
Width of each lane	B	3.5	
Constant	k	150.0	
Wheel base	L	6.0	

Super elevation e =	0.124212	$e = V^2/(225R)$
e =	0.07	If e > 0.07, then e=0.07
We_1 =	0.157205	$We_1 = nL^2/2R$
We_2 =	10.5731	$We_2 = V/(0.5\ Sqrt(R))$
We =	10.7303	$We = We_1 + We_2$
B1 =	14.2	$B_1 = B + We$
C =	0.516129	$C = 80/(75+V)$
Se =	0.996121	Se = B1 x e
LS_1 =	93.13537	$LS_1 = 0.0215\ V^3/(C \times R)$
LS_2 =	74.70909	$LS_2 = Se \times k/2$
LS_3 =	75.45852	$LS_3 = 2.7\ V^2/R$
LS =	93.13537	
LS =	93.13537 Max(C27,C29,C31)	IF (($LS_1 > LS_2$) and $LS_1 > LS_3$) Ther ($LS_2 > LS_1$) and ($LS_2 > LS_3$) Then L

Output		
Super Elevation =	0.07	m
Extra Widening =	10.7303	m

Length of the Transition curve =	93.13537 m

ı LS = LS_1, else IF
S = LS2 else LS = LS_3

Balancing of Error of a Closed Traverse using Bowditch and Transit Ru

An abstract of a traverse sheet for a closed traverse is given below. Balance the traverse by Bowditch's a

INPUT

Line	Length (m)	Latitude	Departure
AB	200	-173.20	100.00
BC	130	0.00	130.00
CD	100	86.60	50.00
DE	250	250.00	0.00
EA	320	-154.90	-280.00

Bowditch's Rule

$\delta L = \sum L \times (l/\sum l)$

$\delta D = \sum D \times (l/\sum l)$

Transit Rule

$\delta L = \sum L \times (l/L)$

$\delta D = \sum D \times (d/D)$

l = Length of any leg
∑l = Total length of traverse
∑L = Total error (Algebraic sum) in Latitude
∑D = Total error (Algebraic sum) in Departure
δL = Correction to the Latitude of the leg
δD = Correction to the Departure of the leg
l = Latitude of any leg
d = Departure of the same traverse leg
L = Arithmetic sum of the Latitudes
D = Arithmetic sum of the Departures

Line	Length (l)	Latitude (L)	Departure (D)	Correction	Correction	Corrected Values	
	(m)			δL	δD	Latitude	Departure
AB	200.0	-173.20	100.00	**1.700**	**0.000**	-174.9	100.0
BC	130.0	0.00	130.00	**1.105**	**0.000**	-1.1	130.0
CD	100.0	86.60	50.00	**0.850**	**0.000**	85.8	50.0
DE	250.0	250.00	0.00	**2.125**	**0.000**	247.9	0.0
EA	320.0	-154.90	-280.00	**2.720**	**0.000**	-157.6	-280.0
Sum	**1000.0**	**8.50**	**0.00**			0.0	0.0

Total Error in Latitude = ∑L = 8.50

Total Error in Departure = ∑D = 0.00

Perimeter of the Traverse = ∑l = 1000.0

Total Arithmetic sum of Latitude = L = **664.7**

Total Arithmetic sum of Departure = D = **560.0**

Line	Length (l)	Latitude (L)	Departure (D)	Correction	Correction	Corrected Values	
	(m)			δL	δD	Latitude	Departure
AB	200.0	-173.20	100.00	**-2.215**	**0.000**	**-175.415**	**100.000**
BC	130.0	0.00	130.00	**0.000**	**0.000**	**0.000**	**130.000**
CD	100.0	86.60	50.00	**1.107**	**0.000**	**85.493**	**50.000**
DE	250.0	250.00	0.00	**3.197**	**0.000**	**246.803**	**0.000**
EA	320.0	-154.90	-280.00	**-1.981**	**0.000**	**-156.881**	**-280.000**
Sum	**1000.0**	**8.50**	**0.00**			**0.000**	**0.000**

ıle

ınd Transit rule

Computation of volume of earth work in filling or cutting of a Trapezoidal

Number of Ordinates	n	50	
Interval of Ordinates	x (m)	5	
Road or Bed width	B (m)	4	
Side Slope	1 H : k V	1.5	
Longitudinal Gradient	1 in S	500	
Direction of Gradient		1	(-1 for Downward slope, +1 for Upwarc
Initial Formation R.L	(m)	20	

Distance (m)	FRL	GRL	Y-Ordinate	Area (m^2)	x(A1+A2)/2 Volume (m^3)
0.0	20.000	20.50	-0.500	-1.6250	
5.0	20.010	20.25	-0.240	-0.8736	-6.2465
10.0	20.020	20.30	-0.280	-1.0024	-4.6900
15.0	20.030	20.75	-0.720	-2.1024	-7.7620
20.0	20.040	21.10	-1.060	-2.5546	-11.6425
25.0	20.050	20.80	-0.750	-2.1562	-11.7771
30.0	20.060	20.40	-0.340	-1.1866	-8.3571
35.0	20.070	20.90	-0.830	-2.2866	-8.6831
40.0	20.080	21.20	-1.120	-2.5984	-12.2126
45.0	20.090	21.50	-1.410	-2.6579	-13.1406
50.0	20.100	21.90	-1.800	-2.3400	-12.4946
Total Volume					**-97.0062**

Section

l slope, 0 for Flat)

Computation of volume of earth work in filling or cutting of a Trapezoidal Section

Reduced levels of ground along the centre line of a proposed road from chainage 0 to 200 m is given below. The formation level at the 40 m chainage is 102.75. The formation of road from chainage 0 to 80 has a rising gradient of 1 in 40 and from 80 to 200 m it is falling gradient of 1 in 100. The formation width of road at top is 12.0 m and the side slope of banking are 2:1. Obtain the volume of earth work.

Rising Grad	0.025	
Falling Grad	0.01	
Side Slope(Z)	2	
Top widh (B)	12.0	m

Chainage (m)	RL of Ground (m	RL of formation (m)	Gradient
0	101.50	101.75	Rising 1 in 40
20	100.90	102.25	
40	101.50	102.75	
60	102.00	103.25	
80	102.85	103.75	
100	101.65	103.55	Falling 1 in 100
120	101.95	103.35	
140	100.70	103.15	
160	101.25	102.95	
180	99.90	102.75	
200	100.60	102.55	

Stn or Chainage	Length	Heght	Mean Height	Central Area	Side Area	Total Sectional area	length between two areas	Quantity	
			d	bd	zd2	bd+zd2	l	Filling	Cutting
	m	m	m	m^2	m^2	m^2		m^3	m^3
0	0	0.25	-	-	-	-	-	-	-
20	20	1.35	0.80	9.60	1.28	10.88	20	217.60	
40	40	1.25	1.30	15.60	3.38	18.98	20	379.60	
60	60	1.25	1.25	15.00	3.13	18.13	20	362.50	
80	80	0.90	1.08	12.96	2.33	15.29	20	305.86	
100	100	1.90	1.40	16.80	3.92	20.72	20	414.40	
120	120	1.40	1.65	19.80	5.45	25.25	20	504.90	
140	140	2.45	1.93	23.16	7.45	30.61	20	612.20	
160	160	1.70	2.08	24.96	8.65	33.61	20	672.26	
180	180	2.85	2.28	27.36	10.40	37.76	20	755.14	
200	200	1.95	2.40	28.80	11.52	40.32	20	806.40	
							Total	**5030.84**	**0.00**

Reduced levels of ground along the centre line of a propc
from chainage 0 to 80 has a rising gradient of 1 in 40 and
2:1. Obtain the volume of earth work.

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Water Hammer Analysis

Gradual Closure and Sudden closure of valve at the down stream end

Depends on Time of closure

T = 2L/C

t < T   Sudden Closure
t >= T   Gradual Closure

t is the actual time of closure, L is the length of the pipe and C is Celerity usually 1430 m/s

Gradual Closure

$p = \rho L V / t$

ρ is the mass density of the flowing fluid, V is mean flow velocity

Sudden Closure

$p = \rho V C$	Rigid Pipe
$p = V \text{ Sqrt}\{\rho / (1 / K + D / \delta E)\}$	Elastic pipe

E has to be ignored if the pipe is non-elastic or rigid

E is the youngs modulous of elasticity of pipe material, K is Bulk modulous of fluid, D is diameter of pipe and δ is the thickness of pipe

The water is flowing the rate of 294.524 Litres/s in a pipe of length 2500 m and of diameter 500 mm. Find the rise in pressure if the valve provided at the end of the pipe line is closed in

a) 25 Seconds
b) 2 Seconds   Rigid and Elastic

Take the values of $E = 19.62 \times 10^{10}$ Pa, $K = 19.62 \times 10^{4}$ Pa, Pipe thickness is 10 mm

Also find the Circumferential and Longitudinal stresses

Data

Discharge	Q =	2.945E-01	m^3/s		
Length	L =	2500	m		
Diameter	D =	0.5	m		
Pipe thickness	δ =	1.000E-02	m		
Youngs Modulous	E =	1.962E+11	Pa		
Bulk Modulous	K =	1.962E+09	Pa		
Gradual ClosureTime	t1 =	25.0	Seconds		
Sudden ClosureTime	t2 =	2.0	Seconds		
Mass Density	ρ =	1000	kg/m^3 (assumed)		
Area of flow	A =	$\pi D^2/4$		0.196	m^2
Mean flow velocity	V =	Q / A		1.50	m/s
Celerity	C =	Sqrt(K/ρ)		1400.71	m/s

a) Gradual Closure

T =	3.570	Seconds	< 25 Seconds and Gradual Closure	
p =	149999.97	Pa	150.00	kPa

b) Sudden Closure

i) Rigid Pipe

p =	2101070.71	Pa	2.10	MPa

ii) Elastic Pipe

p =	1715517.051	Pa	1.72	MPa

Circumferential Stress (σ_c)

$\sigma_c = p\ D / 2\ \delta$	42887926.265	Pa	42.89	MPa

Longitudinal Stress (σ_L)

$\sigma_c = p\ D / 4\ \delta$	21443963.133	Pa	21.44	MPa

Head over Ogee Weir

An Ogee weir is constructed in an open channel for its full width (***B***). The crest of the weir is ***Y*** m above the channel bed. The coefficient of discharge is Cd. Determine the head over the weir inclusive of velocity of approach

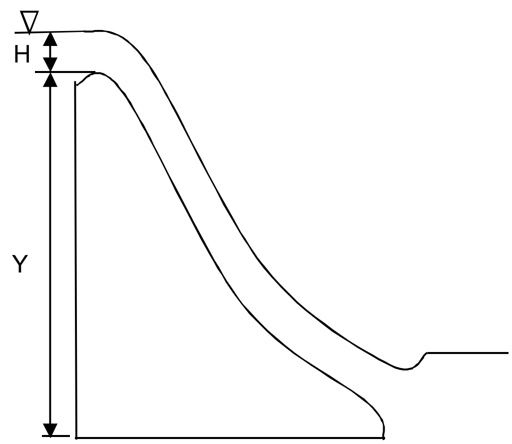
Height of Ogee Weir = Y =	1.20	m
Discharge over Ogee Weir = Q =	18.00	m^3/s
Length of dam = Channel Width = B =	50.00	m
Coefficient of Discharge = C_d =	0.60	
Gravitational acceleration = g =	9.81	m/s^2
Allowable error in Head Calculations = ε =	0.005	

Weir Coefficient = $C_w = (2/3)C_d$ Sqrt(2g) 1.7718

Discharge = $Q = C_w B \{ [H+h_a]^{1.5} - h_a^{1.5} \}$

Ignoring h_a in the first trial we have $H = [Q/(C_w B)]^{(2/3)}$

1	Head over the Ogee weir = H_1 =	0.34562	m
2	Head = H = H_1 =	0.34562	
3	Velocity of approach = Va = Q/[B (Y+H)]	0.23292	m/s
4	Velocity Head = $h_a = V_a^2/2g$ =	0.00277	
5	Head over the weir crest = $H = [H_1^{1.5}+h_a^{1.5}]^{(2/3)}-h_a$	0.34302	
6	Error = H - H_1	-0.00260	
7	The Final Value of Head over the Weir in metres is	0.34302	



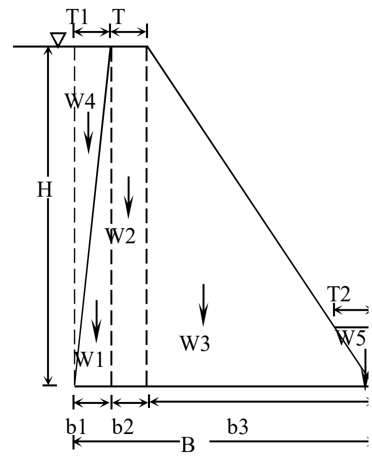
Verification of Stability of a Gravity Dam

A masonry dam 10 m high is trapezoidal in section with a top width of 1 m and bottom width of 8.25 m. The face exposed to water has a batter of 1:10. Test the stability of the dam.

Find out the principal stresses at the toe and the heel of the dam. Assume unit weight of masonry as 22.4kN/m^3.

Mass density of water is 1000 kg/m^3 and permissible shear stress of joint is 1.4 Mpa

Height of dam = H =	10.00	m
Top width of dam = T =	1.00	m
Bottom Width of dam = B =	8.25	m
Water side batter = z V : 1 H	10.00	
Weight Density of Masonry = γ =	22.40	kN/m^3
Mass Density of Water = ρ =	1000.00	kN/m^3
Permissible Shear Stress of joint = τ =	1.40	Mpa
Gravitational acceleration = g	9.81	m/s^2
Base width of water wedge on U/s dam = T_1	1.00	m
Free board	0.00	m
Tail water depth on Down stream = H'	0.00	m
Coefficient of Friction = μ =	0.75	(Assumed)
Water Depth on Up Stream side = H =	10.00	m
Water Depth on Down Stream side = H'	0.00	m
Base width of water wedge on d/s of dam = T_2	0.00	m



Sl. No.	Particulars	Forces (N)		Lever arm	Moment at toe (N-m)	
		Vertical	Horizontal	(m)	+ve	-ve
1	**Self Weight of dam**					
	Weight of Triangular portion on u/s = W1	112,000.00		7.583	849,333.33	
	Weight of Rectangule = W2 =	224,000.00		6.750	1,512,000.00	
	Weight of Triangular portion d/s = W3	700,000.00		4.167	2,916,666.67	
2	Weight of water column (U/s) = W4	49,050.00		7.917	388,312.50	
3	Weight of water column (D/s) = W5	0.00		0.000	0.00	
3	Uplift Force {[(ρgH)-(rgH')]/2}*B	-404,662.50		5.500		2,225,643.75
4	Horizontal Waetr Pressure on U/s		490,500.00	3.333		1,635,000.00
5	Horizontal Waetr Pressure on D/s		0.00	0.000	0.00	
	Sum	680,387.50	490,500.00		5,666,312.50	3,860,643.75
	Algebraic Sum of Moments				1,805,668.75	

Water Pressure intensity at the Heel = p = ρgH = 98,100.00 Pa

Safety against Overturning

Eccentricity = e = B/2 - ΣM/ΣV 1.47

Dam is Safe against overturning when the above value is less than B/6 1.38 **UNSAFE**

Safety against Sliding

Factor of Safety = μ ΣV/ΣH >1 1.04 **SAFE**

Shear Friction factor = (μ ΣV+bq) / ΣH 24.59

Stresses

Compressive Stress at Toe is P_n = (ΣV/B)(1+6e/B) 170.71 kPa

Compressive Stress at Heel is P_n = (ΣV/B)(1-6e/B) -5.77 kPa

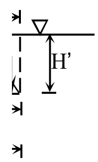
Tan α = U/s Slope 0.1

Tan β = D/s Slope 0.625

Sec α = Sqrt(1+Tan^2 α) 1.005

Sec β = Sqrt(1+Tan^2 β) 1.179

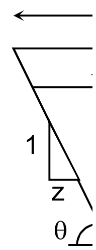
Principal Stress at Toe=$P_n \, Sec^2 \, \beta$	237.390 kPa
Principal Stress at Heel=$P_n \, Sec^2 \, \alpha - p \, Tan^2 \, \alpha$	-986.823 kPa
Shear Stress at Toe = τ = P_n Tan β	106.692 kPa
Shear Stress at Heel = -[P_n - p] Tan α	9810.577 kPa


H'

DESIGN OF BEST TRAPEZOIDAL SECTION OF A CHANNEL

INPUT

Channel Type	Ty	3.0	Rectangular (1), Triang and Trapezoidal (3)
Side Slope	z	1.5	z H : 1 V For Rectan
Bed Slope	S	1800.0	Gradient 1 in S
Chezy's Constant	C	50.0	
Manning's Constant	n	0.000	
Inclination of side slope with Horizontal	Theta		in Degrees
Discharge	Q	30.0	m^3/s



Solution

MES Conditions for Trapezoidal section

1. $B + 2yz = 2y\ Sqrt(1 + z^2)$ — Half top width = one side slope
2. $R = y/2$ — Hydraulic mean radius = half depth

$z = Tan^{-1}(1/z)$

$Q = AC\ Sqrt(RS)$

$A = By + y^2z$

$P = 2y\ Sqrt(1+z^2)$

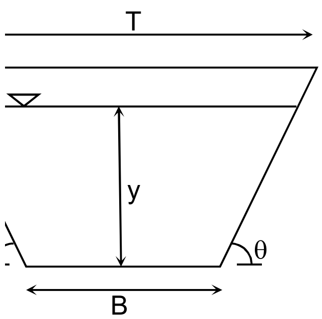
$T = B + 2\ yz$

B =	0.606	y
R =	0.500	y
A =	2.11	y^2
Output		
y =	3.11	m
B =	1.885	m
T =	11.224	m

-

ular (2),

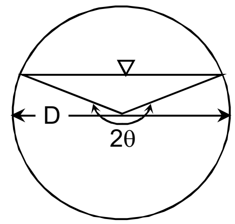
gular Zero



DESIGN OF BEST CIRCULAR SECTION OF A CHANNEL

INPUT

Best Discharge or Maximum Velocity	Ty	2.0	Best Discharge (1) or Maximum Velocity (2)
Bed Slope	S	500.0	Gradient 1 in S
Chezy's Constant	C	50.0	
Manning's Constant	n	0.000	
Diameter	D	3.0	m^3/s



Solution

MES Conditions for Trapezoidal section

For Maximum Discharge $\theta = 154^o$ or 2.688 Radians

For Maximum Velocity $\theta = 128.75^o$ or 2.247 Radians

Q = AC Sqrt(RS) or V = C Sqrt(RS)

$A = R^2 [\theta - 0.5 \sin 2\theta]$	6.934075993
$P = 2 R \theta$	8.063414333
R = A/P =	0.859942911

OUTPUT

V =	2.074	m/s
Q =	14.378	m^3/s