MET 330
HOMEWORK 1.5

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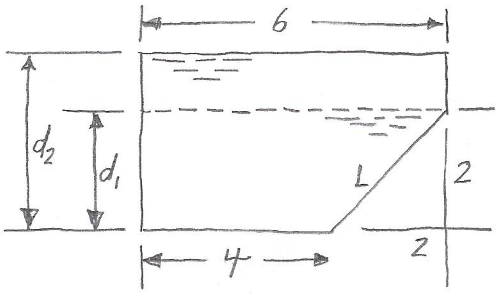
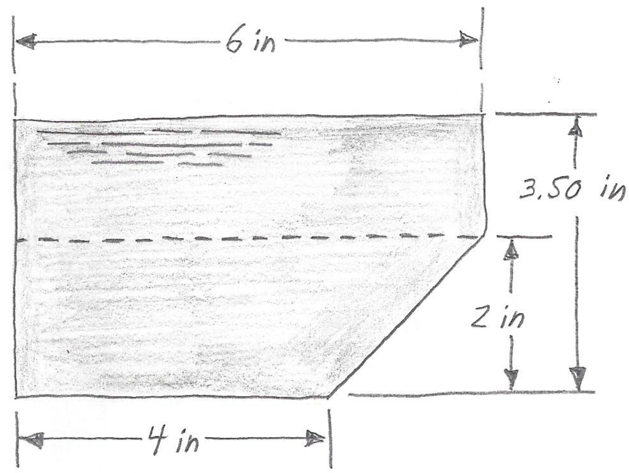
CHAPTER 14

14-6) GIVEN: WATER FLOWS AT A DEPTH OF 2.0 in = $d_1$
DETERMINE: HYDRALIC RADIUS FOR THE SECTION SHOWN




$d = d_1 = 2.0$ in

$a^2 + b^2 = c^2 \longrightarrow L = \sqrt{2^2 + 2^2}$

$L = 2.828$ in

$A = (4)(2) + \frac{1}{2}(2)(2) = 10 \text{ in}^2$

HYDRALIC RADIUS $\longrightarrow R = \dfrac{A}{WP} = \dfrac{\text{AREA}}{\text{WETTED PERIMETER}}$

$WP = 4 + 2 + 2.828 = 8.828$ in

$R = \dfrac{A}{WP} = \dfrac{10 \text{ in}^2}{8.828 \text{ in}} = 1.133$ in

$R = 1.133$ in = HYDRALIC RADIUS

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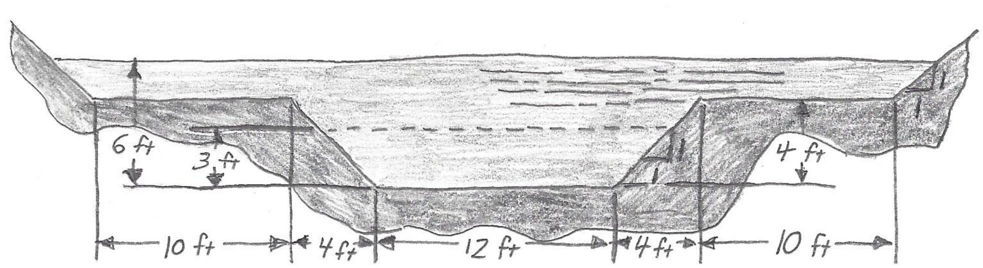
14-15) GIVEN: RESISTANCE FACTOR = $n$ = 0.04
AVERAGE SLOPE = 0.00015
DETERMINE: NORMAL DISCHARGE (Q) FOR DEPTHS OF 3 ft AND 6 ft

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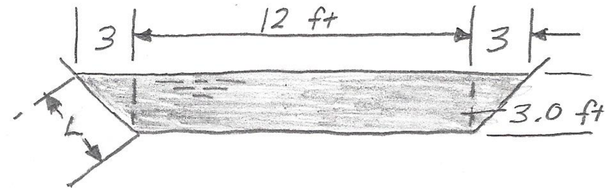
14-15) CONTINUED

a) DEPTH = 3.0 ft




$$A = (3)(12) + 2\left[\tfrac{1}{2}(3)(3)\right] = 45\ ft^2$$

$$L = \sqrt{3^2 + 3^2} = 4.243\ ft$$

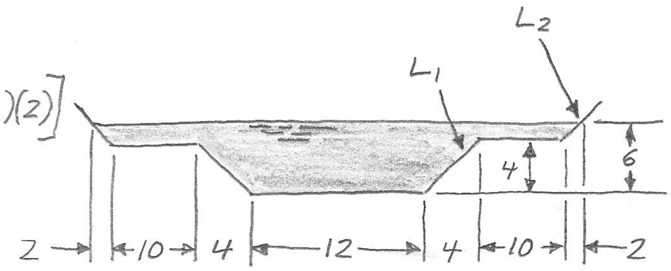
$$WP = 12 + 2(4.243) = 20.485\ ft$$

$$R = \frac{A}{WP} = \frac{45\ ft^2}{20.485\ ft} = 2.197\ ft$$

$$Q = \frac{1.49}{0.04}(45)(2.197)^{2/3}(0.00015)^{1/2} = 34.7\ ft^3/s$$

$Q = 34.7\ ft^3/s$

b) DEPTH = 6.0 ft




$$A = (4)(12) + 2\left[\tfrac{1}{2}(4)(4)\right] + (2)(40) + 2\left[\tfrac{1}{2}(2)(2)\right]$$

$$A = 148\ ft^2$$

$$L_1 = \sqrt{4^2 + 4^2} = 5.657\ ft$$

$$L_2 = \sqrt{2^2 + 2^2} = 2.828\ ft$$

$$WP = 2(2.828) + 2(10) + 2(5.657) + 12$$

$$WP = 48.97\ ft$$

$$R = \frac{A}{WP} = \frac{148\ ft^2}{48.97\ ft} = 3.022\ ft$$

$$Q = \frac{1.49}{0.04}(148)(3.022)^{2/3}(0.00015)^{1/2} = 141.1\ ft^3/s$$

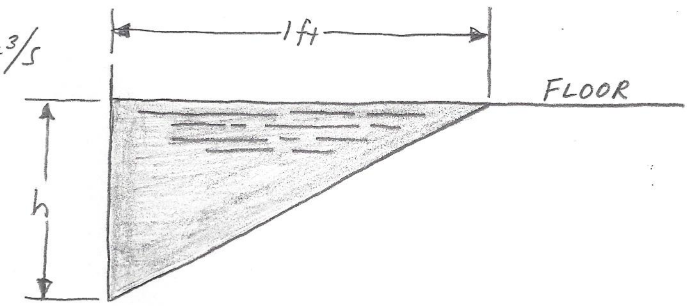
$Q = 141.1\ ft^3/s$

14-21) GIVEN: FLOW RATE $= Q = 500$ gal/min

SLOPE $= S = 0.1\%$

DETERMINE: SIZE OF ROUND COMMON CLAY DRAINAGE TILE REQUIRED TO CARRY THE FLOW (500 gal/min) WHEN RUNNING HALF FULL

$$Q = 500\ \text{gal/min}\left(\frac{1\ \text{ft}^3/\text{s}}{449\ \text{gal/min}}\right) = 1.114\ \text{ft}^3/\text{s}$$

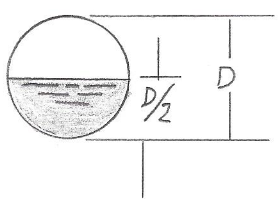



$$AR^{2/3} = \frac{nQ}{1.49 S^{1/2}}$$

$n$ VALUE FOR COMMON CLAY DRAINAGE TILE (TABLE 14.1)

$n = 0.013$

$$AR^{2/3} = \frac{(0.013)(1.114)}{(1.149)(0.001)^{1/2}} = 0.307$$




$$A = \frac{\pi D^2}{8}$$

$$WP = \frac{\pi D}{2}$$

$$R = \frac{A}{WP} = \left(\frac{\pi D^2}{8}\right)\left(\frac{2}{\pi D}\right) = \frac{D}{4}$$

$$AR^{2/3} = \frac{\pi D^2}{8}\left(\frac{D}{4}\right)^{2/3} = \frac{\pi D^2 (D)^{2/3}}{8(4)^{2/3}} = \frac{\pi (D)^{8/3}}{8(2.52)} = 0.156\,(D)^{8/3} = 0.307$$

$$D = \left[\frac{0.307}{0.156}\right]^{3/8}$$

$$D = 1.29\ \text{ft}$$

14-36) GIVEN: VOLUMETRIC FLOW RATE (DESIRED) = $Q = 1.25\ ft^3/s$

VELOCITY = $V = 2.75\ ft/s$

DETERMINE: APPROPRIATE CHANNEL CROSS-SECTION AREAS GIVEN SHAPES

$Q = 1.25\ ft^3/s$

$V = 2.75\ ft/s$

$A = \frac{Q}{V} = 0.4545\ ft^2$

RECTANGLE: $y = \sqrt{\frac{A}{2.0}} = \sqrt{\frac{0.4545}{2.0}} = 0.4767\ ft = y$

$b = 2y = 0.9535\ ft$

$R = \frac{y}{2} = 0.4767\ ft/2 = 0.2384\ ft$

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TRIANGLE: $y = \sqrt{A} = \sqrt{0.4545} = 0.674\ ft = y$

$R = 0.354y = 0.2387\ ft$

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TRAPEZOID: $y = \sqrt{\frac{A}{1.73}} = \sqrt{\frac{0.4545}{1.73}} = 0.5126\ ft = y$

$R = \frac{y}{2} = 0.2563\ ft$

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SEMICIRCLE: $A = \frac{\pi y^2}{2}$

$y = \sqrt{\frac{2A}{\pi}} = \sqrt{\frac{2(0.4545)}{\pi}} = 0.5379\ ft = y$

$R = \frac{y}{2} = 0.269\ ft$

14-42) GIVEN: TRAPEZOIDAL CHANNEL

$z = 0.75$

$Q = 0.80 \ ft^3/s$

$n = 0.013$

$b = 3.00 \ ft$

| $y$ (ft) | $A$ (ft²) | $V$ (ft/s) | $T$ (ft) | $Y_h$ (ft) | $N_F$ | $E$ (ft) | |
|---|---|---|---|---|---|---|---|
| **0.05** | **0.152** | **5.267** | **3.08** | **0.049** | **4.177** | **0.481** | GIVEN Y |
| 0.1 | 0.308 | 2.602 | 3.15 | 0.098 | 1.467 | 0.205 | |
| **0.1288** | **0.399** | **2.006** | **3.19** | **0.125** | **1.000** | **0.191** | CRITICAL DEPTH |
| 0.20 | 0.630 | 1.270 | 3.30 | 0.191 | 0.512 | 0.225 | |
| 0.25 | 0.797 | 1.004 | 3.38 | 0.236 | 0.364 | 0.266 | |
| 0.30 | 0.968 | 0.827 | 3.45 | 0.280 | 0.275 | 0.311 | |
| 0.40 | 1.320 | 0.606 | 3.60 | 0.367 | 0.176 | 0.406 | |
| **0.4770** | **1.602** | **0.499** | **3.72** | **0.431** | **0.134** | **0.481** | ALTERNATIVE DEPTH |
| 0.50 | 1.688 | 0.474 | 3.75 | 0.450 | 0.125 | 0.503 | |
| 0.60 | 2.070 | 0.386 | 3.90 | 0.531 | 0.093 | 0.602 | |
| 0.70 | 2.468 | 0.324 | 4.05 | 0.609 | 0.073 | 0.702 | |
| 0.80 | 2.880 | 0.278 | 4.20 | 0.686 | 0.059 | 0.801 | |
| 0.90 | 3.308 | 0.242 | 4.35 | 0.760 | 0.049 | 0.901 | |
| 1.00 | 3.750 | 0.213 | 4.50 | 0.833 | 0.041 | 1.001 | |
| 1.065 | 4.046 | 0.198 | 4.60 | 0.880 | 0.037 | 1.066 | |
| 1.10 | 4.208 | 0.190 | 4.65 | 0.905 | 0.035 | 1.101 | |
| 1.20 | 4.680 | 0.171 | 4.80 | 0.975 | 0.031 | 1.200 | |
| 1.30 | 5.168 | 0.155 | 4.95 | 1.044 | 0.027 | 1.300 | |
| 1.40 | 5.670 | 0.141 | 5.10 | 1.112 | 0.024 | 1.400 | |
| 1.50 | 6.188 | 0.129 | 5.25 | 1.179 | 0.021 | 1.500 | |

SLOPES AT GIVEN DEPTH AND ALTERNATIVE DEPTH:

| Y (ft) | R (ft) | S | |
|---|---|---|---|
| 0.05 | 0.0486 | 0.264 | ← SLOPE FOR GIVEN DEPTH |
| 0.477 | 0.3820 | 0.000152 | ← SLOPE FOR ALTERNATIVE DEPTH |

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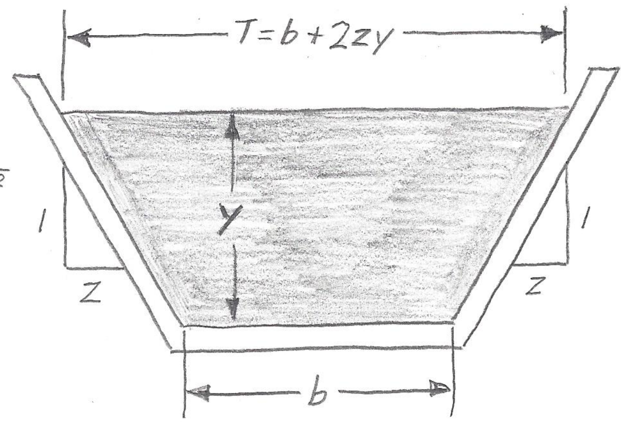
14-42) CONTINUED




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

WETTED PERIMETER $= WP = b + 2y\sqrt{1+z^2}$

HYDRALIC RADIUS $= R = \dfrac{(b+zy)y}{b + 2y\sqrt{1+z^2}}$

CRITICAL DEPTH:

a) FOR GIVEN $Q, b, z$ AND $y$: COMPUTE $A, T$ USING EQUATIONS FOR TRAPEZOID. COMPUTE $N_F = \dfrac{V}{\sqrt{g y_h}} = \dfrac{Q}{(A\sqrt{g y_h})}$

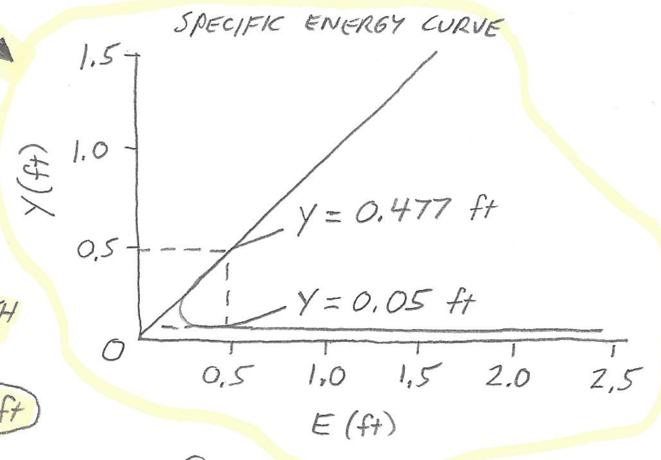
FROM SPREADSHEET: $y_c = 0.1288$ ft WHEN $N_F = 1.000$

b) MINIMUM SPECIFIC ENERGY: $E = y + \dfrac{V^2}{2g} = y + \dfrac{Q^2}{(2gA^2)}$

FROM SPREADSHEET, WITH $y = y_c = 0.1288$ ft: $E_{MIN} = 0.191$ ft

c) SPECIFIC ENERGY VERSUS $y$:

$E = y + \dfrac{V^2}{2g} = y + \dfrac{Q^2}{(2gA^2)}$




d) SPECIFIC ENERGY FOR $y = 0.05$ ft

FROM SPREADSHEET: $E = 0.481$ ft

SPECIFIC ENERGY FOR ALTERNATIVE DEPTH WHERE $E = 0.481$ ft

FROM SPREADSHEET: $y_{ALT} = 0.4770$ ft

e) VELOCITY $= V = \dfrac{Q}{A} \longrightarrow N_F = \dfrac{V}{\sqrt{g y_h}} = \dfrac{Q}{(A\sqrt{g y_h})}$

FROM SPREADSHEET:

FOR $y = 0.05$ ft $\rightarrow$ $V = 5.267$ ft/s $\rightarrow$ $N_F = 4.177$ $\rightarrow$ SUPERCRITICAL

FOR $y = 0.4770$ ft $\rightarrow$ $V = 0.499$ ft/s $\rightarrow$ $N_F = 0.134$ $\rightarrow$ SUPERCRITICAL

f) REQUIRED SLOPES OF THE CHANNEL:

$WP = b + 2y\sqrt{1+z^2}$ (FROM EQUATIONS FOR TRAPEZOID)

$R = \dfrac{A}{WP}$

COMPUTE $S$: $\left[\dfrac{nQ}{AR^{2/3}}\right]^2 \longrightarrow$

FROM SPREADSHEET:

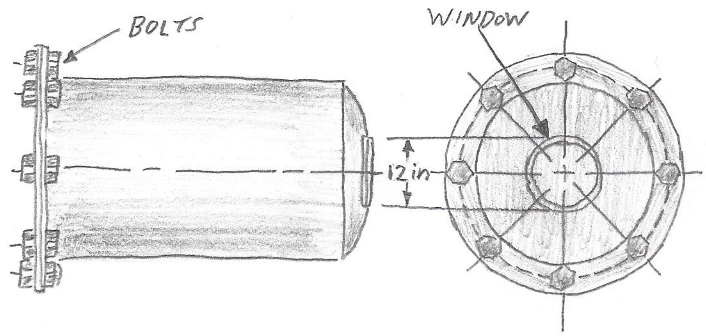
FOR $y = 0.05$ ft $\rightarrow$ $S = 0.264$

FOR $y = 0.4770$ ft $\rightarrow$ $S = 0.000152$

## CHAPTER 4

**4-2)** GIVEN: INSIDE DIAMETER OF TANK = 30 in
INTERNAL PRESSURE = +14.4 psig

DETERMINE: TOTAL FORCE THAT MUST BE RESISTED BY BOLTS IN FLANGE




$$F = pA$$

$$F = (14.4\ \text{lb/in}^2)\left[\pi\left(\frac{30\ \text{in}^2}{4}\right)\right]$$

$$F = 10180\ \text{lb}$$

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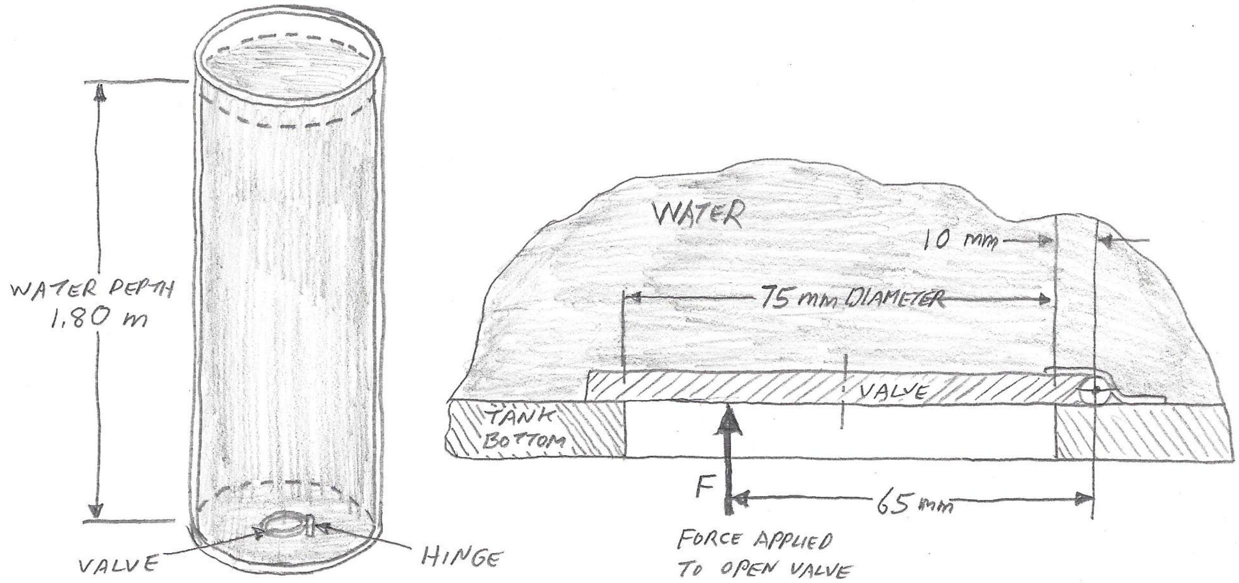
**4-10)** GIVEN: CYLINDRICAL TANK DIAMETER = 500 mm
CYLINDRICAL TANK HEIGHT = 1.80 m
FLAPPER VALVE OPENING = 75 mm (DIAMETER)




(a) GENERAL VIEW OF SHOWER TANK AND VALVE

(b) DETAIL OF VALVE

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4-10) CONTINUED

FORCE ON VALVE = $pA$

$$A = \pi\left[\frac{(0.095\ m)^2}{4}\right] = 7.088 \times 10^{-3}\ m^2$$

$$p = \gamma_w h = \frac{9.81\ kN}{m^3} \times 1.80\ m = 17.66\ kN/m^2$$

$$F = (17.66 \times 10^3\ N/m^2)(7.088 \times 10^{-3}\ m^2) = 125\ N \text{ (ACTS AT CENTER)}$$

$$\Sigma M_{HINGE} = 0 = (125\ N)(47.5\ mm) - F_0(65\ mm)$$

$$F_0 = 5946\ N\cdot mm / 65\ mm$$

OPENING FORCE = $F_0 = 91.5\ N$

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4-17) GIVEN: WALL IN DIAGRAM = 4 m IN LENGTH

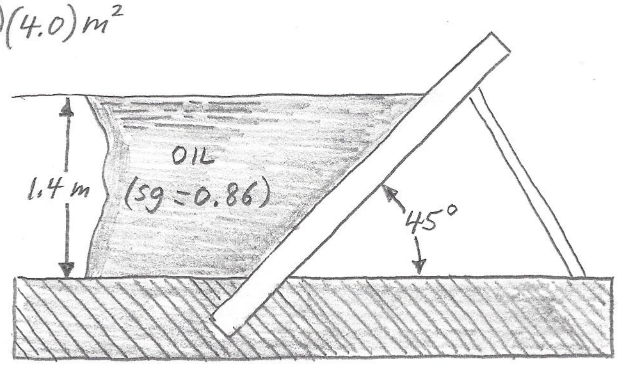
DETERMINE: TOTAL FORCE ON WALL DUE TO OIL PRESSURE, CENTER OF PRESSURE, AND RESULTANT FORCE ON WALL.

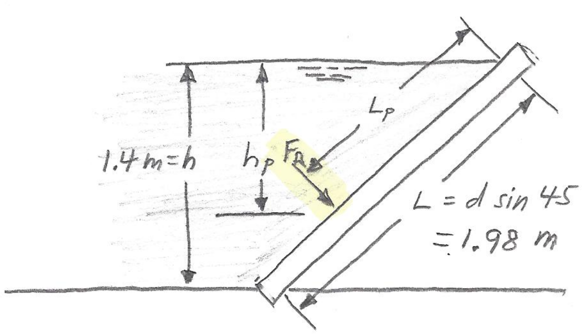
$$F_R = \gamma_o\left(\frac{h}{2}\right)A = (0.86)\left(\frac{9.81\ kN}{m^3}\right)(0.7\ m)(1.98)(4.0)\ m^2$$

$F_R = 46.8\ kN$

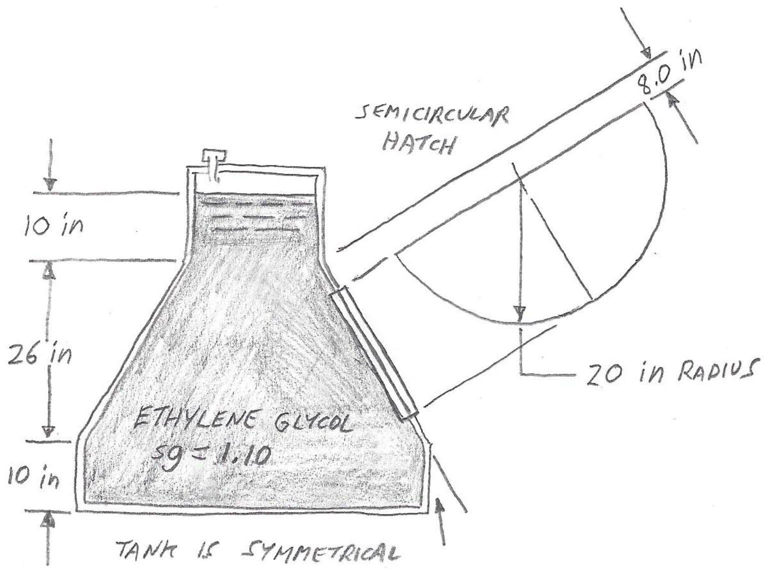
$h_p = 2/3\ h = (2/3)(1.4\ m) = 0.933\ m = h_p$

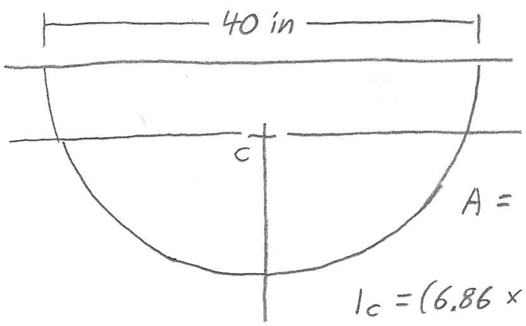
$L_p = 2/3\ L = (2/3)(1.98\ m) = 1.32\ m = L_p$



4-28) DETERMINE: THE RESULTANT FORCE ON THE INDICATED AREA AND THE LOCATION OF THE CENTER OF PRESSURE. SHOW THE RESULTANT FORCE ON THE AREA AND ITS LOCATION.

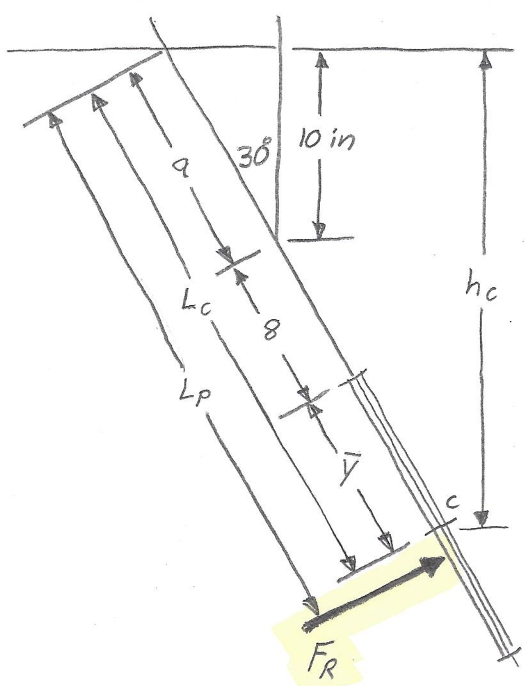



$\bar{y} = 0.212D = 8.48 \text{ in}$

$A = \dfrac{\pi D^2}{8} = 628.3 \text{ in}^2$

$I_c = (6.86 \times 10^{-3})D^4 = (6.86 \times 10^{-3})(40)^4 = 17562 \text{ in}^4$




$a = \dfrac{10 \text{ in}}{\cos 30°} = 11.55 \text{ in}$

$L_c = a + 8 + \bar{y} = 11.55 + 8.0 + 8.48 = 28.03$ i

$h_c = L_c \cos 30° = 24.27 \text{ in} \rightarrow 2.023 \text{ ft}$

$F_R = \gamma h_c A$

$F_R = (1.10)(62.4 \text{ lb/ft}^3)(2.023 \text{ ft})\left[\dfrac{(628.3 \text{ in}^2)(1 \text{ ft}^2)}{144 \text{ in}^2}\right]$

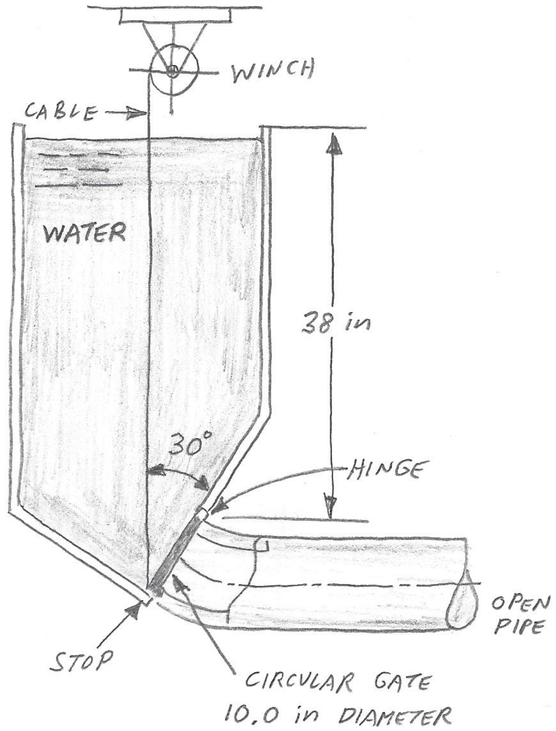
$F_R = 605.8 \text{ lb}$

$L_p - L_c = \dfrac{I_c}{L_c A} = \dfrac{17562 \text{ in}^4}{(28.03 \text{ in})(628.3 \text{ in}^2)} = 0.997$

$= 7.135 \text{ in}$

$L_p = L_c + 7.135 \text{ in} = 29.03 \text{ in} = L_p$

4-42) DETERMINE: THE AMOUNT OF FORCE ($F_c$) THAT THE WINCH CABLE MUST EXERT TO OPEN THE GATE.




$$h_c = 38 + y = 38 + 5\cos 30° = 42.33 \text{ in}$$

$$L_c = \frac{h_c}{\cos 30°} = 48.88 \text{ in}$$

$$F_R = \gamma h_c A$$

$$A = \frac{\pi (10)^2}{4} = 78.54 \text{ in}^2$$

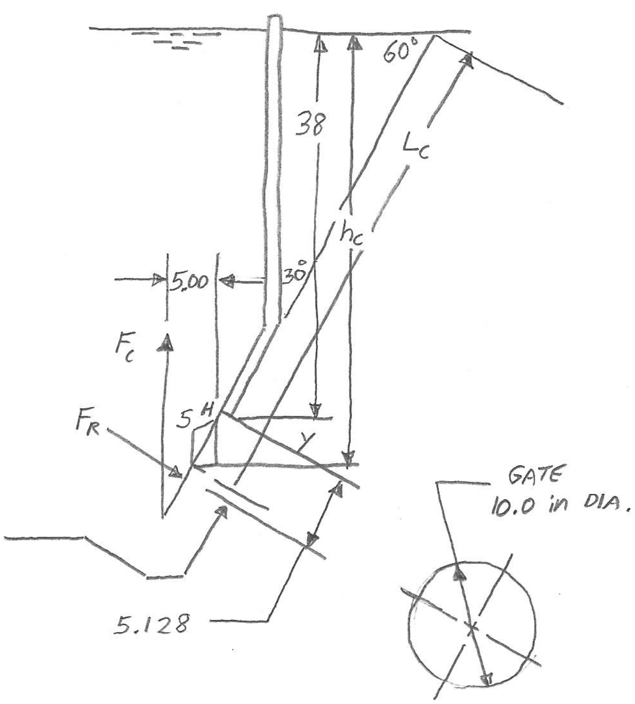
$$F_R = \left(\frac{62.4 \text{ lb}}{ft^3}\right)\left[\frac{(42.33 \text{ in})(78.54 \text{ in}^2)}{1728 \text{ in}^3/ft^3}\right]$$

$$F_R = 120.1 \text{ lb}$$

$$I_c = \frac{\pi (10)^4}{64} = 490.9 \text{ in}^4$$

$$L_p - L_c = \frac{I_c}{L_c A}$$

$$L_p - L_c = \frac{490.9 \text{ in}^4}{(48.88 \text{ in})(78.54 \text{ in}^2)} = 0.128 \text{ in}$$




MOMENTS ABOUT HINGE AT TOP OF GATE:

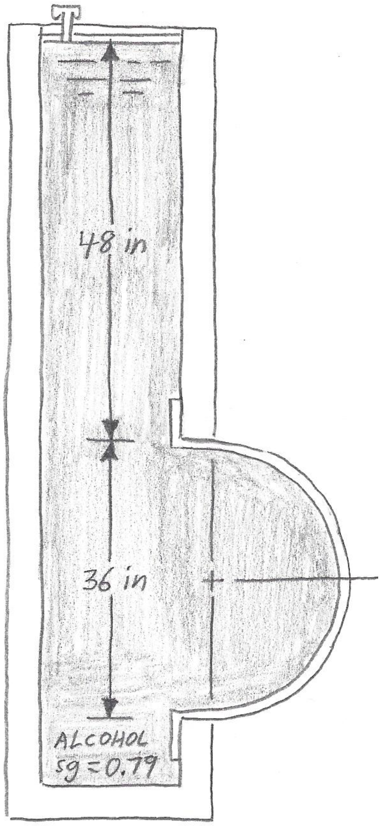
$$\Sigma M_H = 0 = F_R(5.128) - F_c(5.00)$$

$$F_c = \frac{(120.1 \text{ lb})(5.128 \text{ in})}{5.00 \text{ in}}$$

CABLE FORCE:

$$F_c = 123.2 \text{ lb}$$

4-54) GIVEN: THE SURFACE = 60 in IN LENGTH




$$A = \frac{\pi D^2}{8} = \frac{\pi(36)^2}{8} = 508.9 \text{ in}^2 = 3.534 \text{ ft}^2$$

$$F_V = \gamma A w = (0.79)(62.4)(3.534)(5.0) = 871 \text{ lb}$$

$F_V = 871$ lb = VERTICAL FORCE

$$\bar{X} = 0.212D = 0.212(36 \text{ in}) = 7.63 \text{ in}$$

$\bar{X} = 7.63$ in

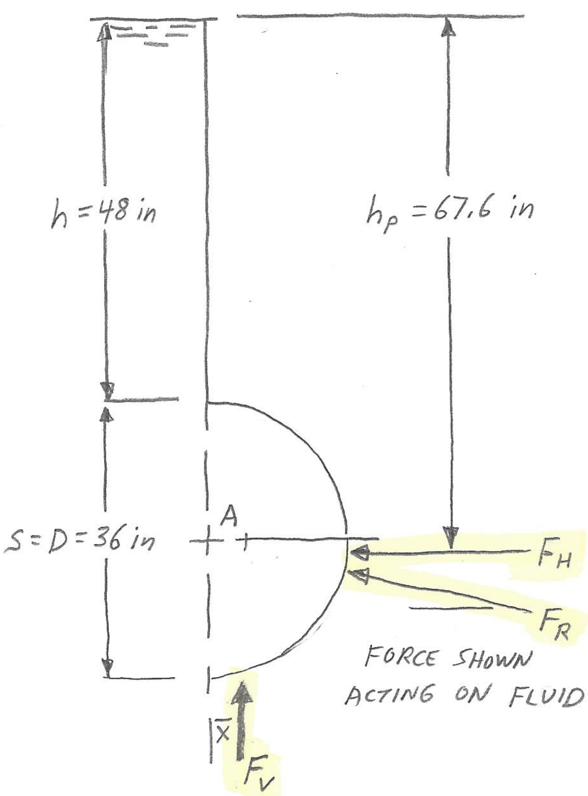
$$h_c = h + \frac{S}{2} = 48 + \frac{36}{2} = 66.0 \text{ in} = 5.50 \text{ ft}$$

$$F_H = \gamma s w h_c = (0.79)(62.4)(3.0)(5.0)(5.50)$$

$F_H = 4067$ lb = HORIZONTAL FORCE

$$h_p = h_c = \frac{S^2}{12h_c} = 66 + \frac{36^2}{12(66)} = 67.64 \text{ in}$$

$h_p = 67.64$ in




$$F_R = \sqrt{F_V^2 + F_H^2} = \sqrt{871^2 + 4067^2} = 4159 \text{ lb}$$

$F_R = 4159$ lb = RESULTANT FORCE

$$\phi = \tan^{-1}\left(\frac{F_V}{F_H}\right) = \tan^{-1}\left(\frac{871}{4067}\right) = 12.1°$$

$\phi = 12.1°$