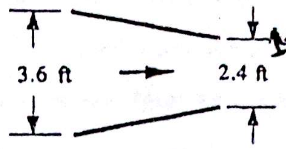
Assignment-5 (Solution)
14 civil - scB, C

5.2.1 *Assume frictionless flow in a long, horizontal, conical pipe, where the diameter is 3.6 ft at entrance and 2.4 ft at exit. The pressure head at the smaller end is 15 ft of water. If water flows through this cone at the rate of 95 cfs, find the velocities at the two ends and the pressure head at the larger end.*

(1) BG

Eq. 4.6: $V_1 = \dfrac{Q}{A_1} = \dfrac{95}{\pi(1.8)^2} = 9.33$ fps ◄



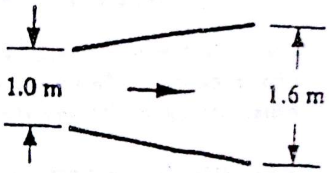
$V_2 = \dfrac{Q}{A_2} = \dfrac{95}{\pi(1.2)^2} = 21.0$ fps ◄

Eq. 5.7 with $z_1 = z_2$: $\dfrac{p_1}{\gamma} + z + \dfrac{9.33^2}{2(32.2)} = 15 + z + \dfrac{21.0^2}{2(32.2)}$; $\dfrac{p_1}{\gamma} = 20.5$ ft ◄

5.3 *Water flows through a long, horizontal, conical diffuser at the rate of 4.2 m³/s. The diameter of the diffuser changes from 1.0 m to 1.6 m. The pressure at the smaller end is 9.5 kPa. Find the pressure at the downstream end of the diffuser, assuming frictionless flow. Assume also, that the angle of the cone is small enough that the flow does not separate from the walls of the diffuser.*

(2) SI

Eq. 4.6: $V_1 = \dfrac{Q}{A_1} = \dfrac{4.2}{\pi(0.5)^2} = 5.35$ m/s



$V_2 = \dfrac{Q}{A_2} = \dfrac{4.2}{\pi(0.8)^2} = 2.09$ m/s

Eq. 5.7 with $z_1 = z_2$: $p/\gamma + V^2/2g$ = constant

ie: $\dfrac{9.5 \text{ kN/m}^2}{9.81 \text{ kN/m}^3} + \dfrac{5.35^2}{2(9.81)} = \dfrac{p}{\gamma} + \dfrac{2.09^2}{2(9.81)}$; $0.968 \text{ m} + 1.458 \text{ m} = p/\gamma + 0.222$

$p/\gamma = 2.20$ m ; $p = 2.20(9.81) = 21.6$ kN/m² ◄

5.3.2 *A vertical pipe of 1.5 m diameter and 20 m long has a pressure head at the upper end of 6.3 m of water. When the flow of water through it is such that the mean velocity is 5.6 m/s, the pipe friction head loss is h_f = 1.09 m. Find the pressure head at the lower end of the pipe when the flow is (a) downward (b) upward.*

(3) SI

(*a*) Eq. 5.14: $6.3 + 20 + \dfrac{5.6^2}{2(9.81)} - 1.09 = \dfrac{p_2}{\gamma} + 0 + \dfrac{5.6^2}{2(9.81)}$ (velocity heads cancel)

$\dfrac{p_2}{\gamma} = 25.2$ m for downflow ◄

(*b*) Eq. 5.14: $\dfrac{p_2}{\gamma} + 0 + \dfrac{5.6^2}{2(9.81)} - 1.09 = 6.3 + 20 + \dfrac{5.6^2}{2(9.81)}$ (velocity heads cancel)

$\dfrac{p_2}{\gamma} = 27.4$ m for upflow ◄

5.3.3 *A conical pipe has diameters at the two ends of 1.2 and 4.2 ft and is 48 ft long. It is vertical, and the pipe friction head loss is h_f = 7.6 ft for flow of water in either direction when the velocity at the smaller section is 28 fps. If the smaller section is at the top and the pressure head there is 6.4 ft of water, find the pressure head at the lower end when the flow is (a) downward; (b) upward.*

(4) BG

$Q = AV = (\pi/4)D^2V$; so $V_b = V_t\,(D_t/D_b)^2 = 28(1.2/4.2)^2 = 2.29$ fps

(*a*) Eq. 5.14: $6.4 + 48 + \dfrac{28^2}{2(32.2)} - 7.6 = \dfrac{p_2}{\gamma} + 0 + \dfrac{2.29^2}{2(32.2)}$; $p_2/\gamma = 58.9$ ft for downflow ◄

(*b*) Eq. 5.14: $\dfrac{p_2}{\gamma} + 0 + \dfrac{2.29^2}{2(32.2)} - 7.6 = 6.4 + 48 + \dfrac{28^2}{2(32.2)}$; $\dfrac{p_2}{\gamma} = 74.1$ ft for upflow ◄

5.3.4 *In Figure X5.3.4, the pipe AB is of uniform diameter and h = 28 ft. The pressure at A is 30 psi and at B is 40 psi. In which direction is the flow, and what is the pipe friction head loss in feet of the fluid if the liquid has a specific weight of (a) 35 lb/ft³; (b) 92 lb/ft³?*

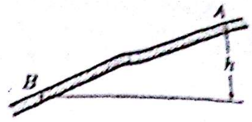


Figure X5.3.4

BG

Assume flow is from A to B.

(a) For $\gamma = 35$ lb/ft³, and $V_1 = V_2$

$$\text{Eq. 5.14:}\quad \frac{30(144)}{35} + 28 + \frac{V^2}{2g} - h_f = \frac{40(144)}{35} + 0 + \frac{V^2}{2g}$$

$h_f = -13.14$ ft ◄ ; so the flow is from B to A ◄

(b) For $\gamma = 92$ lb/ft³, and $V_1 = V_2$

$$\text{Eq. 5.14:}\quad \frac{30(144)}{92} + 28 + \frac{V^2}{2g} - h_f = \frac{40(144)}{92} + 0 + \frac{V^2}{2g}$$

$h_f = +12.35$ ft ◄ ; so the flow is from A to B ◄

5.3.5 *If h = 10.5 m in Fig. X5.3.4 and the pressures at A and B are 170 and 275 kPa respectively, find the direction of flow and the pipe friction head loss in meters of liquid. Assume the liquid has a specific gravity of 0.85.*

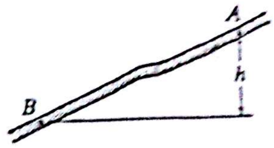


Figure X5.3.4

SI

Assume the flow is from A to B. Eq. 5.14:

$$\frac{170\ \text{kN/m}^2}{(0.85)9.81\ \text{kN/m}^3} + 10.5 + \frac{V^2}{2g} - h_f = \frac{275\ \text{kN/m}^2}{(0.85)9.81\ \text{kN/m}^3} + 0 + \frac{V^2}{2g}$$

$h_f = 20.39 + 10.5 - 32.98 = -2.09$ m ◄ so the flow is from B to A ◄

5.2.3 *Refer to Fig. X5.2.2. Assume a = 1 m, b = 4 m, and the flow to be frictionless in the siphon. Find the rate of discharge in m³/s and the pressure head at B if the pipe has a uniform diameter of 150 mm.*

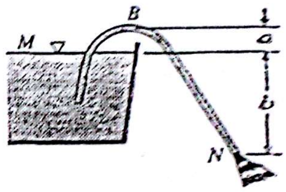


Figure X5.2.2

SI

Eq. 5.7 from M to N (elevation datum at N):

$0 + 4 + 0 = 0 + 0 + V_N^2/2g$; $V_N = V_B = 8.86$ m/s

$Q = \pi(0.15/2)^2 8.86 = 0.1565$ m³/s ◄

Eq. 5.7 from M to B:

$0 + 4 + 0 = p_B/\gamma + 5 + V_B^2/2g$; $p_B/\gamma = -5.00$ m ◄

5.13.1 *Assume there is friction head loss in the siphon of Fig. X5.13.1, where a = 1 m, b = 4 m. The loss between the intake and B is 0.6 m and between B and N is 0.9 m. What is the rate of discharge and pressure head at B when the diameter is 150 mm?*

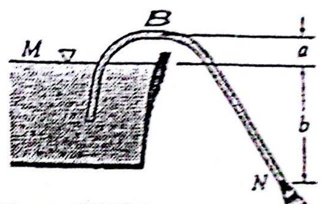


Figure X5.13.1

SI

Energy Eq. 5.14 from M to N: $0 + 4 + 0 - [0.6 + 0.9]$

$= 0 + 0 + V_N^2/2g = 2.5\ \text{m} = V_B^2/2g$; $V_B = 7.00$ m/s

$Q = \pi(0.15/2)^2 7.00 = 0.1238$ m³/s ◄

Energy Eq. 5.14 from M to B: $0 + 4 + 0 - 0.6 = p_B/\gamma + 5 + V_B^2/2g$; $p_B/\gamma = -4.10$ m ◄

.13.3 *Refer to Fig. X5.13.1. Find the maximum value for b if a = 1.1 m. Assume friction is negligible and the minimum pressure allowable in the siphon is a vacuum of −9.8 m of water.*

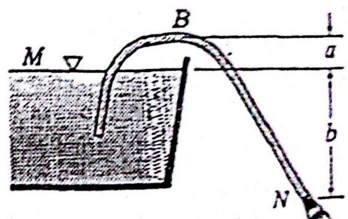


Figure X5.13.1

SI

b = the elevation difference between M and N.

Eq. 5.7 for M to N: $0 + b + 0 = 0 + 0 + V_N^2/2g$

$V_N^2/2g = V_B^2/2g = b$

Eq. 5.7 for M to B: $0 + b + 0 = -9.8 + (b + 1.1) + b$; $b = 8.70$ m ◄

5.13.7 let $a = 7.5$ m, $b = c = 15$ m, and $d = 300$ mm. All the losses of energy are to be ignored when the stream discharging into the air at E has a diameter of 80 mm. What are pressure heads at B, C, and D if the diameter of the vertical pipe is 120 mm?

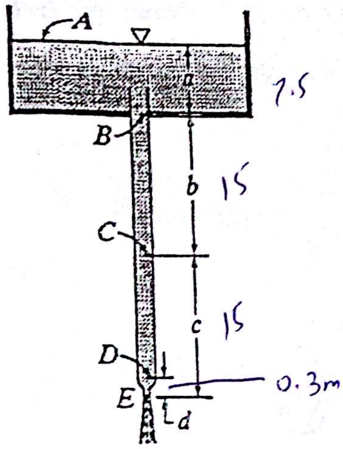


Figure X5.13.7

From A to E: $0 + 37.5 + 0 = 0 + 0 + V_E^2/2g$; $V_E^2/2g = 37.5$ m

$V_B^2/2g = V_C^2/2g = V_D^2/2g = (80/120)^4 V_E^2/2g = 7.41$ m

From A to B: $0 + 37.5 + 0 = \frac{p_B}{\gamma} + 30 + 7.41$; $\frac{p_B}{\gamma} = 0.0926$ m ◀

(10)

From A to C: $0 + 37.5 + 0 = \frac{p_C}{\gamma} + 15 + 7.41$; $\frac{p_C}{\gamma} = 15.09$ m ◀

From D to E: $\frac{p_D}{\gamma} + 0.30 + 7.41 = \frac{V_E^2}{2g} = 37.5$; $\frac{p_D}{\gamma} = 29.8$ m ◀

OR From A to D: $0 + 0 + 37.5 = 0.3 + \frac{P_D}{\gamma} + 7.41$ $\frac{P_D}{\gamma} = 29.8$m

5.9.1 A turbine located at an elevation 750 ft below that of the water surface at intake (Fig. X5.9.1), carries a flow of 120 cfs. The head loss in the pipeline leading to it is 25 ft. Find the horsepower delivered by the turbine if its efficiency is 90 percent.

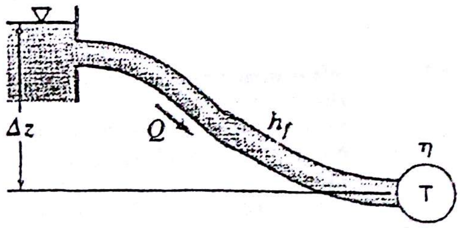


Figure X5.9.1

(11)

Water hp $= \frac{\gamma Q(\Delta z - h_L)}{550}$

$\frac{(62.4)120(750 - 25)}{550} = 9870$ hp

From Eq. 5.42, Output power = 9870(0.90) = 8880 hp ◀

5.9.2 A turbine, located 255 m below the water surface at intake (Fig. X5.9.1), carries a flow of 3.5 m³/s. The head loss in the pipeline leading to it is 10 m. Find the power (kW) delivered by the turbine if its efficiency is 92 percent.

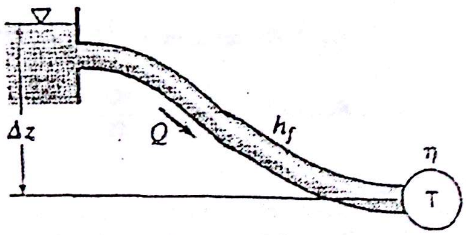


Figure X5.9.1

Sol

Eq. 5.41: Water power, $P = \frac{\gamma Q(\Delta z - h_L)}{1000}$

(12)

$\frac{(9810)3.5(255 - 10)}{1000} = 8410$ kW

From Eq. 5.42, Output power = 8410(0.92) = 7740 kW ◀

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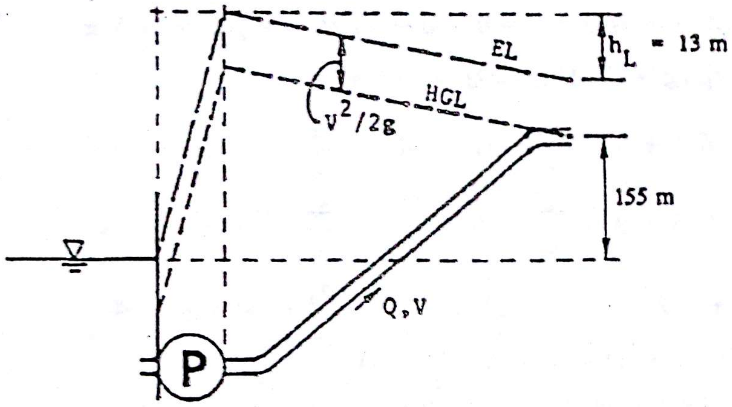
5.13.6 *A pump, having an efficiency of 90%, lifts water to a height of 155 m at the rate of 7.5 m³/s. The friction head loss in the pipe is 13 m. What is the required pump power in kW? Also sketch the energy line and the hydraulic grade line of this system.*

SI

From Eqs. 5.41 and 5.42: Input power = $\gamma Q(\Delta z + h_L)/\eta$ = (9.81)7.5(155 + 13)/0.90 = 13 730 kW ◄



5.9.5 *Water from a reservoir is being supplied to a powerhouse that is located at an elevation 935 ft below that of the reservoir surface. Discharging through a nozzle, the water has a jet velocity of 240 fps and a jet diameter of 6 in. Find the horsepower lost to friction between the reservoir and the jet, and find the horsepower of the jet.*

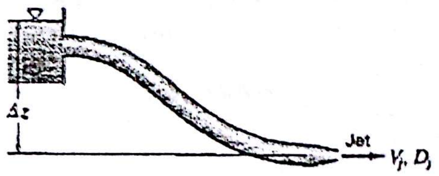


Figure X5.9.5

BG

Eq. 5.28 from reservoir (1) to jet (2) ,

$$0 + 935 + 0 = 0 + 0 + \frac{(240)^2}{2(32.2)} + h_L\ ;\quad h_L = 935.0 - 894.4 = 40.6 \text{ ft}$$

$$Q = A_2V_2 = \frac{\pi}{4}\left(\frac{6}{12}\right)^2 240 = 47.1 \text{ cfs}\ ;\quad h_j = \frac{V_j^2}{2g} = 894 \text{ ft}$$

Eq. 5.40: hp in jet $= \frac{\gamma Q h_j}{550} = \frac{62.4(47.1)894}{550} = 4780$ hp ◄

Eq. 5.40: hp lost $= \frac{\gamma Q h_L}{550} = \frac{62.4(47.1)40.6}{550} = 217$ hp ◄

5.9.6 *Water from a reservoir is being supplied to a powerhouse that is located at an elevation 325 m below that of the reservoir surface (Fig. X5.9.5). Discharging through a nozzle, the water has a jet velocity of 75 m/s and a jet diameter of 250 mm. Find the kW lost to friction between the reservoir and the jet, and find the power of the jet in kW.*

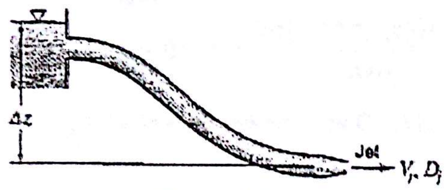


Figure X5.9.5

SI

Eq. 5.28: $0 + 325 + 0 = 0 + \frac{75^2}{2(9.81)} + h_L$

$h_L = 325 - 286.7 = 38.3$ m

$Q = A_2V_2 = (\pi/4)(0.25)^2 75 = 3.68$ m³/s ; $h_j = V_j^2/2g = 287$ m

Eq. 5.41: Power in jet = (3.68 m³/s)(9.81 kN/m³)(287 m) = 10 350 kN·m/s = 10 350 kW ◄

Eq. 5.41: Power lost = 3.68(9.81)38.3 = 1383 kW ◄

5.33 *In the constricted pipe of Fig. P5.33 friction loss between A and B is negligible while between B and C it is $0.15(V_B^2/2g)$. Given $h = 750$ mm, $d_A = d_C = 250$ mm, $d_B = 100$ mm. Find the pressure heads at A and C if the liquid is flowing through the circular pipe from A to C at the rate of 280 L/s.*

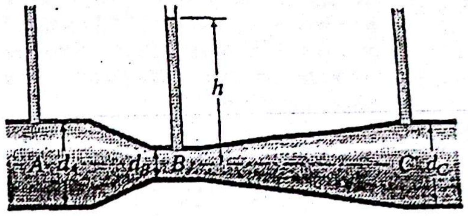


Figure P5.33

SI

$V_A = Q/A_A = (0.28\ \text{m}^3/\text{s})/(\pi 0.125^2) = 5.70\ \text{m/s} = V_c$

$V_B = Q/A_B = 0.28/(\pi 0.05^2) = 35.7\ \text{m/s};$

$p_B/\gamma = 0.750\ \text{m}\quad (= h,\ \text{given})$

$V_A^2/2g = V_C^2/2g = 5.70^2/(2\times 9.81) = 1.658\ \text{m};$

Eq. 5.7 from A to B: $p_A/\gamma + 0 + V_A^2/2g = p_B/\gamma + 0 + V_B^2/2g$

$p_A/\gamma + 0 + 1.658 = 0.750 + 0 + 64.8;\quad p_A/\gamma = 63.9\ \text{m}$ ◄

Eq. 5.28 from B to C: $p_B/\gamma + 0 + V_B^2/2g - 0.15V_B^2/2g = p_C/\gamma + 0 + V_C^2/2g$

$0.750 + (1 - 0.15)64.8 = p_C/\gamma + 1.658;\quad p_C/\gamma = 54.2\ \text{m}$ ◄

5.34 *In Fig. P5.34 assume the tube flows full. At B, the diameter of the tube is 3 in and the diameter of the water jet discharging into the air is 4.5 in. (a) If all friction losses are negligible, what are the velocity and the pressure head at B if h = 10 ft. (b) What is the rate of discharge in cfs? And what would it be if the tube were cut off at B?*

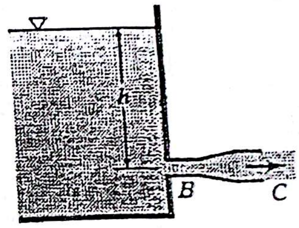


Figure P5.34

BG

(a) Eq. 5.7, from water suface to C: $0 + 10 + 0 = 0 + 0 + V_C^2/2g;$

$V_C^2/2g = 10\ \text{ft}$

Eq. 5.7, from B to C: $p_B/\gamma + 0 + (4.5/3)^4 10 = 0 + 0 + 10;$

$p_B/\gamma = 10(1 - 5.06) = -40.6\ \text{ft}$ ◄

$V_B^2/2g = (4.5/3)^4 10 = 50.6;\quad V_B = \sqrt{2(32.2)50.6} = 57.1\ \text{fps}$ ◄

(b) $Q = A_B V_B = (\pi/4)(3/12)^2 57.1 = 2.80\ \text{cfs}$ ◄

If tube were cut off at B, $V_B^2/2g = 10$ ft; $V_B = 25.4$ fps ; $Q = (\pi/4)(0.25)^2 25.4 = 1.246$ cfs ◄

5.35 *Referring to Fig. P5.34, assume the tube flows full and all friction losses are negligible. The diameter at B is 60 mm and the diameter of the jet discharging into the air is 80 mm. If h = 5 m, what is the flow rate? What is the pressure head at B? What would be the flow rate if the tube were cut off at B?*

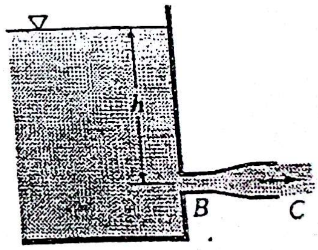


Figure P5.34

SI

Eq. 5.7, from water suface to C: $0 + 5 + 0 = 0 + 0 + V_C^2/2g$

$V_C^2/2g = 5\ \text{m};\quad V_C = \sqrt{2(9.81)5} = 9.90\ \text{m/s}$

$Q = A_C V_C = \pi(0.04)^2 9.90 = 0.0498\ \text{m}^3/\text{s} = 49.8\ \text{L/s}$ ◄

$V_B = 9.90(8/6)^2 = 17.61\ \text{m/s};\quad V_B^2/2g = 15.80\ \text{m}$

Eq. 5.7 from B to C: $p_B/\gamma + 0 + V_B^2/2g = p_C/\gamma + 0 + V_C^2/2g$

$p_B/\gamma + 0 + 15.80 = 0 + 0 + 5;\quad p_B/\gamma = -10.80\ \text{m}$ ◄

If the tube were cut off at B: $V_B^2/2g = 5\ \text{m};\quad V_B = 9.90\ \text{m/s}$

$Q = A_B V_B = \pi(0.03)^2 9.90 = 0.0280\ \text{m}^3/\text{s} = 28.0\ \text{L/s}$ ◄

5.36 *In Fig. P5.36 friction losses in the pipe below pump P are $1.8V^2/2g$ with the barometer pressure at 12.50 psia. The liquid in the suction pipe has a velocity of 7 fps. What would be the maximum allowable value of z if the liquid were (a) water at 70°F; (b) gasoline at a vapor pressure of 9 psia with a specific weight of 47 lb/ft³ ?*

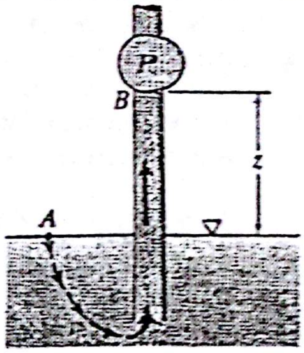


Figure P5.36

BG

From Eq. 5.28 (using absolute pressure heads) from A to B, where, to prevent cavitation, $p_B = p_{min} = p_v$:

✓ $V^2/2g$ h_L

$$\frac{12.50(144)}{\gamma} + 0 + 0 = 144\frac{p_v}{\gamma} + z_{max} + \frac{7^2}{2(32.2)} + \frac{(1.8)7^2}{2(32.2)}$$

$$= 144\frac{p_v}{\gamma} + z_{max} + 2.13$$

from which $z_{max} = (12.50 - p_v)144/\gamma - 2.13$

(a) Table A.1 for water at 70°F: γ = 62.30 pcf, p_v = 0.363 psia from which z_{max} = 25.9 ft ◄

(b) For gasoline (γ = 47 pcf, p_v = 9 psia, given) : z_{max} = 8.59 ft ◄

(a)

$$h_L = \frac{1.8V^2}{2g}$$

P = 12.5 psi

V = 7 fps

Z = !

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