Hydraulic Problems

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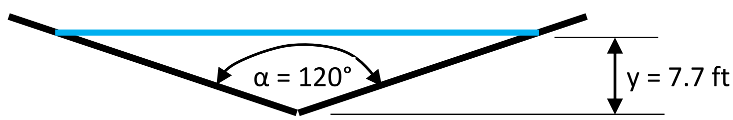
1) The City of Lake Worth is improving its potable water supply system. They are building a 150-ft diameter cylindrical tank. The capacity (volume) of the tank is designed based on emergency operation (no inflow into the tank). Half of its capacity will have to provide potable water for 5 days for 15,000 people with an average supply of 88.12 gallons/day/person.

1.1) Calculate the height of the tank.

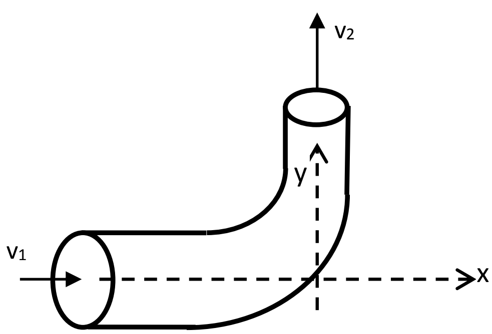
The design of the inflow pump discharge into the tank will be estimated based on normal operation of the tank with a water supply (Q_{out}) of 1836 gallons/min to serve 30,000 people. Tank is empty and has to be filled up in 4 days.

1.2) Calculate the flow rate of the inflow pump (Q_{in}) into the tank.

2) Compute the uniform flow discharge (Q) of a long triangular canal. The cross section is shown below and has an angle α = 120°. The bottom slope of the canal (S) is 0.000362280, Manning roughness (n) is 0.013 and the normal water depth (y) is 7.7 ft.



3) A 90-degree horizontal reducing elbow carries a flow, Q = 12 ft^3/sec. Sections 1 and 2 have the following characteristics:

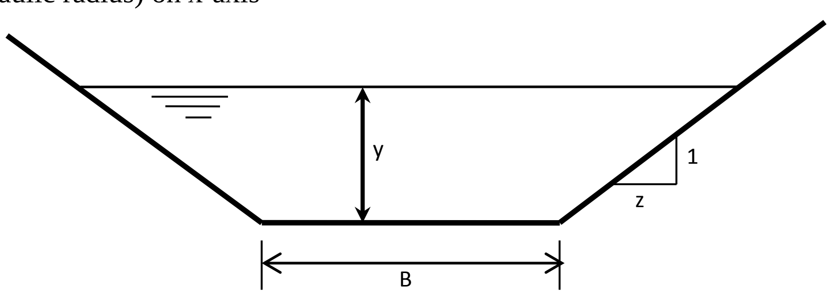


D_1 = 24-in D_2 = 12-in
p_2 = 58 psi
K = 0.36
Neglect friction losses
Compute:
1) The head losses (h_L) around the elbow and p_1.
Is this p_1 value the one you were expecting to get? Explain
2) The hydrodynamic force on the pipe in magnitude and direction

4) Develop and plot a function for the Hydraulic Radius (R_h) of a trapezoidal cross section channel with the following characteristics: B = 15 ft, z = 1.5 (side slope, 1.5:1 = H:V). Water depths (y) from 0.5 to 8 ft (every 0.5 ft)

Plot y (water depth) on y-axis, and R_h (Hydraulic radius) on x-axis

$A = (B+zy)\,y$
$P_w = B+2y\,(1+z^2)^{1/2}$
$R_h = A/P_w$



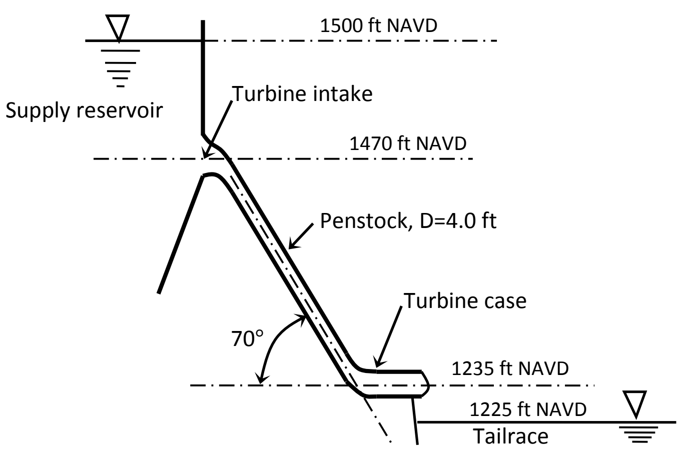
5) Develop and plot functions for the discharge Q (ft^3/sec) through a pipe with D=3.0 ft, and n=0.012. Take water depths every 0.20 ft (y on x-axis) and assume uniform flow (Manning equation, Q on y-axis) for two different slopes:

5.1) $S_o = 0.0003$

5.2) $S_o = 0.0070$

$\theta = 2 \times arc\ cos\left[\frac{2(D-y)}{D} - 1\right]$, $A = 1/8\ [\theta - \sin(\theta)]D^2$, $P_w = 1/2\ (\theta)D$, and $R_h = A/P_w$

6) A hydroelectric plant has 6 turbines each of them with a 290 ft^3/sec discharge. The normal stage (elevation) in the reservoir is 1500 ft NAVD, the C/L of the turbines is at 1235 ft NAVD, and the tailrace is at 1243 ft NAVD. The penstock has a 4-foot diameter and is on a 70-degree angle as shown in the sketch below.



K =2.12 (local losses coefficient includes entrance, exit, and two elbows)

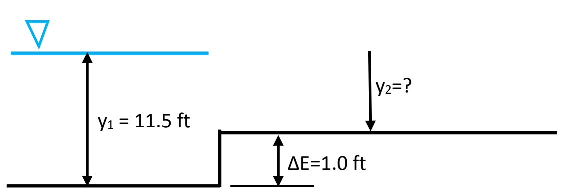
f = 0.0095 (Darcy-Weisbach coefficient)

Calculate the power produced by this hydroelectric plant (HP and KW). The transmission efficiency from a turbine to its generator is estimated as 75%.

Hint: The total energy available for each turbine (H) is given the static head (difference in water elevation in the reservoir and tailrace) minus the total losses (friction through the penstock plus local losses). Kinetic energies at reservoir and tailrace are neglected due to low velocities.

7) A 100 ft pipe with D=3.0 ft (f=0.008) with a steep slope (S = 0.082) discharges into a trapezoidal canal which continues with the same slope. The discharge, Q, through the system is 120 ft^3/sec. The transition loss coefficient, K, from the pipe to the canal is 0.20. A pressure gage at the end of the pipe recorded a pressure of 0.79 psi. A typical S1 profile ($y_c > y_n$, and water depths increase downstream) develops just downstream of the transition. The trapezoidal canal section is 2.0 ft wide (B) with side slopes of 1 (z=1, 45°) and Manning's n =0.011. Apply gradually (spatially) varied flow concept and Manning equation to estimate friction losses and calculate the water depths 50 and 100 ft downstream of the transition. Hint: Remember that the Bernoulli (energy) equation is measured from a different datum for pipe flow (pressure) and open channel flow (i.e., centerline of pipe and bottom slope or invert elevation of canal, respectively).

8) A long rectangular concrete channel 15-ft wide (B=15 ft) has a sudden one foot rise. The water depth, y_1, upstream of the rise is 11.5 ft and its flow discharge, Q, is 1500 ft^3/sec. Calculate the water depth, y_2, downstream of the rise. If Q increases to 4500 ft^3/sec and everything else remains the same, calculate the new value for y_2. This is a typical problem involving the concept of Specific Energy (all losses are neglected and horizontal slope is zero), an important concept in Hydraulics to analyze the water profiles for gravity flow in channels (e.g., supercritical, subcritical, etc.)



$\boldsymbol{E_1 = E_2 + \Delta E}$ $\qquad$ $\boldsymbol{E = y + v^2/2g}$