Al-Mustaqbal University

Department of Biomedical Engineering

Third Stage / 1st Course

“Transport Phenomena for BME”

Dr. A.Najah Saud

amir_Najah@uomus.edu.iq

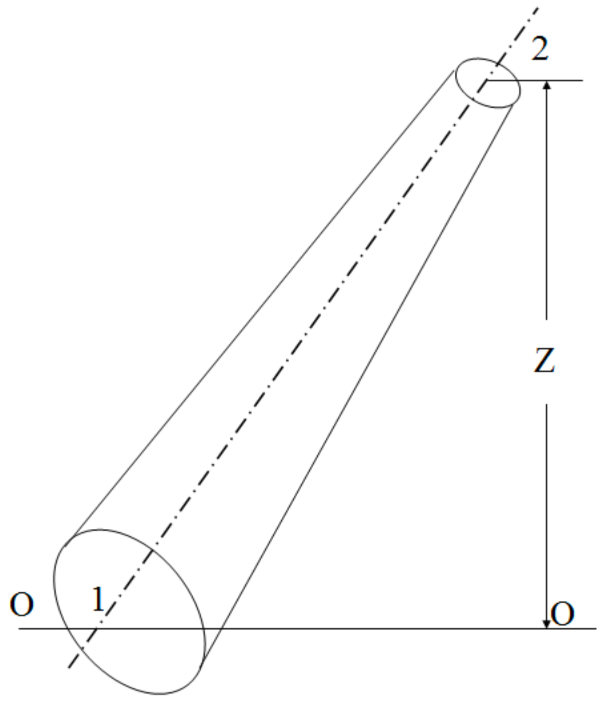
Problems and solution *(Bernoulli equation)*

Example

a pipe gradually tapers from a diameter of (0.3 m) to (0.1 m) over the length shown in the figure it conveys water at (50 L/s) the pressure at the bottom end is (196 KN/m^2) if the pressure at the upper end is (98.1 KN/m^2), find the value of (Z)?

- **Sol//**

$$Q = 50\ L/s = 50 \times 10^{-3} = 0.05\ m^3/s$$



$$Q = A_1V_1 = A_2V_2$$

$$0.05 = \left(\frac{\pi}{4}(0.3)^2\right)V_1$$

$$V_1 = 0.707\ m/s$$

$$0.05 = \left(\frac{\pi}{4}(0.1)^2\right)V_2$$

$$V_2 = 6.365\ m/s$$

Applying Bernoulli's eq. along the axis of pipe between (1 and 2) taking (OO) as datum:

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2$$

$$\frac{196000}{9806} + \frac{(0.707)^2}{2 \times 9.81} + 0 = \frac{98100}{9806} + \frac{(6.365)^2}{2 \times 9.81} + z$$

$$z = 7.944\ m$$

Example

Water flows steadily up the vertical *0.1 m* diameter pipe and out the nozzle, which is *0.05 m* in diameter, discharging to atmospheric pressure. The stream velocity at the nozzle exit must be *20 m/s*. Calculate the minimum gage pressure required at section①.

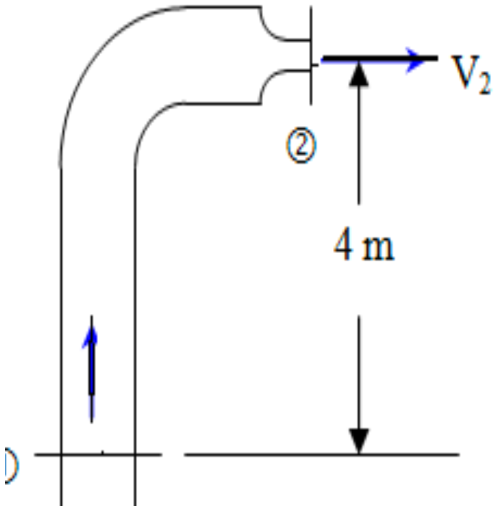
<u>Solution</u>: applying continuity equation between 1 and 2 we have $u_1 A_1 = u_2 A_2$ and $u_1 = u_2 A_2 / A_1$

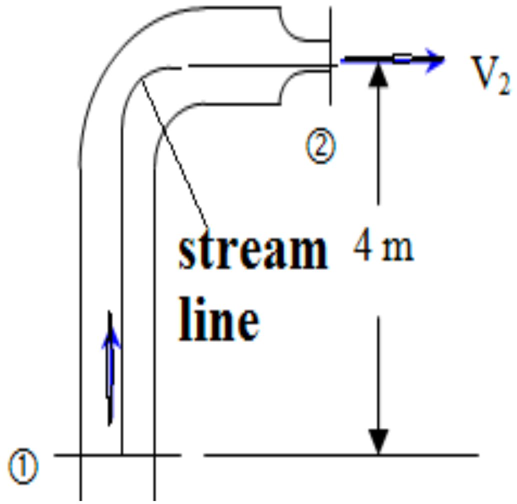
The Bernoulli's equation can be applied between any two points on a streamline provided that the all assumptions are satisfied. The result is

$$\frac{p_1}{\rho} + \frac{u_1^2}{2} + gz_1 = \frac{p_2}{\rho} + \frac{u_2^2}{2} + gz_2 \text{ and } \frac{p_1 - p_2}{\rho} = \frac{1}{2}\left[u_2^2 - u_1^2\right] + g(z_2 - z_1) \text{ also}$$

$$\frac{p_1 - p_2}{\rho} = \frac{1}{2}\left[u_2^2 - \left(\frac{A_2}{A_1}u_2\right)^2\right] + g(z_2 - z_1) \text{ and finally } p_{1gage} - p_{2gage} = \rho\left\{\frac{1}{2}u_2^2\left[1 - \left(\frac{D_2^2}{D_1^2}\right)^2\right] + g(z_2 - z_1)\right\}$$

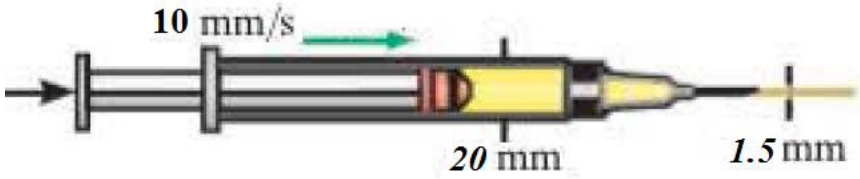
$$p_{1gage} - (0) = (1000)\left\{\frac{1}{2}(20)^2\left[1 - \left(\frac{(0.05)^2}{(0.1)^2}\right)^2\right] + (9.81)[(4m) - (0)]\right\} = 226500 Pa = 226.5 kPa$$



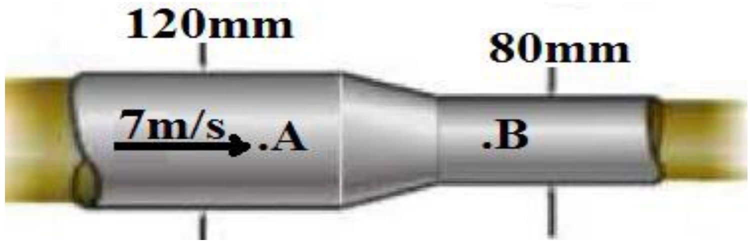


Problems and solution

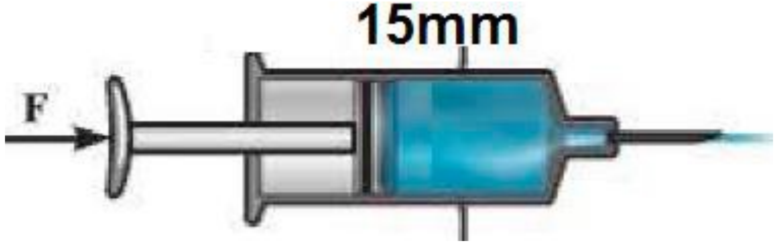
- Q1/ The cylindrical syringe is actuated by applying a force on the plunger. If this causes the plunger to move forward at 10 mm/ s. determine the average velocity of the fluid passing out of the needle



Q2/oil is subjected to a pressure of 300 kPa at A, where its velocity is 7 m/s. Determine its velocity and the pressure at B (ρoil = 940 kg/ m³)

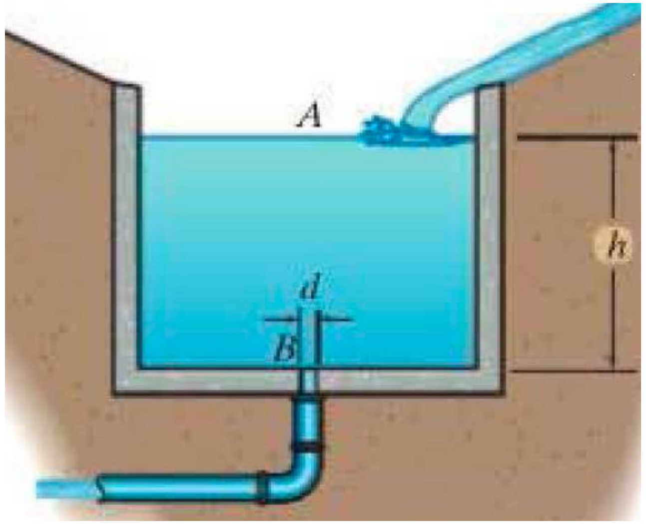


Q3/By applying a force F, a saline solution is ejected from the 15mm diameter syringe through a 0.6-mm-diameter needle. If the pressure developed within the syringe is 60 kPa, determine the average velocity of the solution through the needle. Take ρ = 1050 kg/ m³.



Problems and solution

Q1/ Water is discharged through the drain pipe at *B* from the large basin حوض at 0.03 m^3/s. If the diameter of the drain pipe is d = 60 mm, determine the pressure at *B* just inside the drain when the depth of the water is h = 2 m.



Q2/ The average human lung رئتا الانسان takes in about 0.6 liter of air with each inhalation شهيق , through the mouth and nose, A. This lasts for about 1.5 seconds. Determine the power required to do this if it occurs through the trachea القصبة الهوائية B having a cross-sectional area of 125 mm2. Take ρair= 1.23 kg/m3. (Hint: Recall that power is force * velocity, where force = pressure*area).