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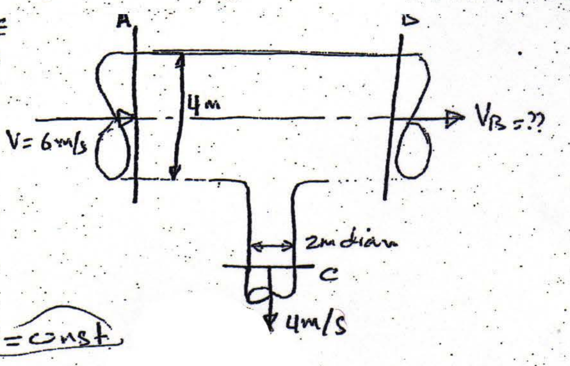
P1 Fluid داعي الفلوين

5.58 WHAT IS THE VELOCITY OF THE FLOW OF WATER IN LEG B OF THE TEE DRAWN IN THE FIG:



→ CONTINUITY EQN.

$\dot{m}_A = \dot{m}_B + \dot{m}_C$

$\rho Q_A = \rho Q_B + \rho Q_C$

for incompressible flow ⇒ $\rho = const$

$Q_A = Q_B + Q_C$

$Q_B = Q_A - Q_C$

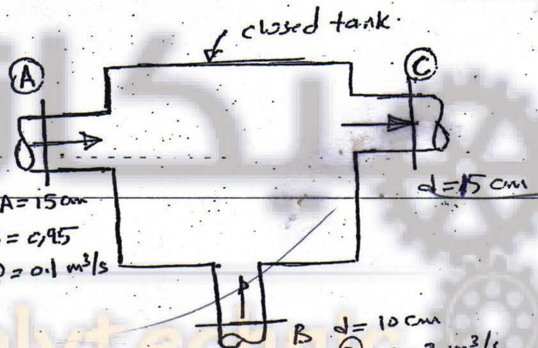
$V_B A_B = V_A A_A - V_C A_C$

$V_B (\frac{\pi}{4})(4)^2 = V_A (\frac{\pi}{4})(4)^2 - V_C (\frac{\pi}{4})(2)^2$

$V_B = \frac{(6)(16) - (4)(4)}{16} = 5.0\ m/s.$

5.66

Assume that complete mixing occurs between the two inflows before the mixture discharge from the pipe at C



$d_A = 15cm$
$S = 0.95$
$Q = 0.1\ m^3/s$

$d = 10cm$
$Q = 0.02\ m^3/s$
$S = 0.85$

find ① the mass rate of flow
② The velocity
③ The specific gravity.

$\dot{m}_c$
$\rho_c Q_c$
SG, ρ_{H_2O} V_A

Continuity Eqn :-

$\sum \dot{m}_i = \sum \dot{m}_{out}$

$\dot{m}_A + \dot{m}_B = \dot{m}_C \Rightarrow \dot{m}_C = \rho_A Q_A + \rho_B Q_B$

① $\dot{m}_C = (SG)_A \rho_{H_2O} Q_A + (SG)_B \rho_{H_2O} Q_B$

$= (0.95)(1000)(0.1) + (0.85)(1000)(0.02) = 112\ kg/s.$

$V_c = \frac{Q_c}{A} = \frac{0.12}{(\frac{\pi}{4})(0.15)^2}$

② $\boxed{V_c = 6.79\ m/s}$

for incompressible flow $Q_A + Q_B = Q_C$

$\boxed{Q_C} = 0.10 + 0.02 = 0.12$

③ $\dot{m}_c = \rho Q_c \Rightarrow \rho_c = \frac{\dot{m}_c}{Q_c} = \frac{112}{0.12} = 933.3\ kg/m^3$

$S.G = \frac{\rho}{\rho_{H_2O}}$

$= 0.933$

5.76 A Pitot tube used to measure air velocity is connected to a differential pressure gage. If the air temp. is 20°C at standard atmospheric pressure at sea level, and if the differential gage reads a pressure difference of 3 kPa, what is the air velocity?

Soln: $V = \sqrt{2g\Delta h} = \sqrt{2g\frac{\Delta P}{\rho g}} = \sqrt{\frac{2\Delta P}{\rho}}$

we have to find ρ from eqn of state

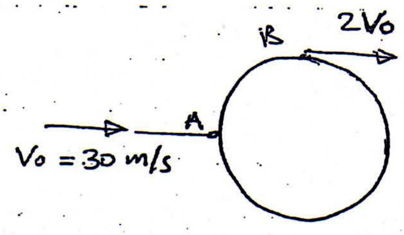
$Pv = \frac{P}{\rho} = RT \Rightarrow \rho\,(\text{rho}) = \frac{P}{RT} = \frac{101.325 \times 10^3 \text{ Pa}}{(287)(20+273)}$

$\Rightarrow \rho = 1.205 \text{ kg/m}^3$

$V = \sqrt{\frac{(2)(3000)}{1.205}} = 70.564 \text{ m/sec.}$

5.61 The max. velocity of the flow past a circular cylinder, as shown, is twice the approach velocity. What is ΔP between the point of highest pressure and point of lowest pressure in a 30 m/sec. wind? assume irrotational flow and standard atmospheric conditions.

NOTE THAT MAX. PRESS IS EXPECTED AT POINT A



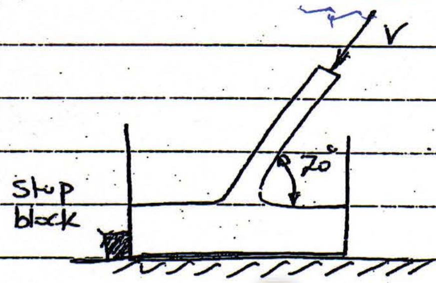
$P_{STAG} = P_{st} + \frac{1}{2}\rho V_0^2$

$P_A + \gamma z_1 = P_B + \frac{1}{2}\rho V_B^2 + \gamma z_2$

$P_A - P_B = \frac{1}{2}\rho V_B^2 + \underbrace{\gamma(z_2 - z_1)}_{\text{This term may be neglected}}$

$\Delta P = (\frac{1}{2})(1.206)(60)^2 = 2170.8 \text{ Pa}$

Example:- A water jet of diameter 30 mm and speed $V = 20\,m/s$ is filling a tank. The tank has a mass of 20 kg and contains 20 Liters of water at the instant shown. The water temp is $15°C$. Find the force acting on the bottom of the tank and the force acting on the stop block neglecting friction.



$\dot{m}_{in} = \rho V A$

$= (999)[20]\left[\frac{\pi}{4}\right][0.03]^2$

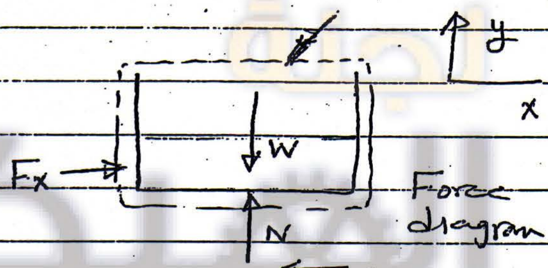
$= 14.116\ kg/s$

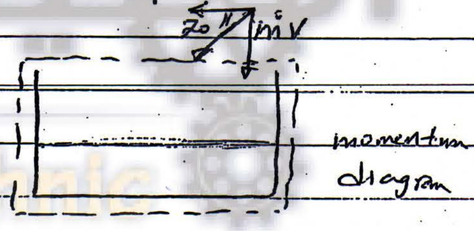
$$\Sigma F_x = \underbrace{\cancel{\frac{\partial}{\partial t}\int_{C.V} \rho U_x\, d\forall}}_{0.0\ \text{steady}} + \underbrace{\cancel{\Sigma \dot{m}_{out} V_{o,x}}}_{0.0} - \Sigma \dot{m}_{in} V_{i,x}$$

$F_x = -14.116[-V_i \cos 70]$

$\boxed{F_x = 96.6\ N}$

Note that the assumed direction is correct.





$$\Sigma F_y = \underbrace{\cancel{\frac{\partial}{\partial t}\int_{C.V} \rho V_y\, d\forall}}_{0.0} + \underbrace{\cancel{\Sigma \dot{m}_{out} V_{o,y}}}_{0.0} - \Sigma \dot{m}_{in} V_{in,y}$$

$N - W = -14.116[-V \sin 70]$

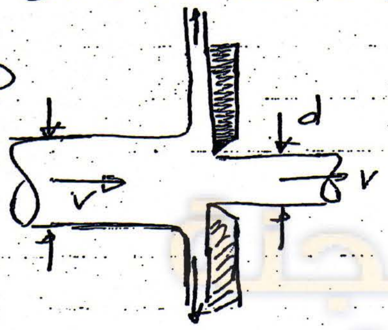
$N = W + 14.116[20 \sin 70]$

$= \underbrace{[20 \times 10^{-3} \times 999 \times 9.81 + 20 \times 9.81]}_{\text{weigh of 20 liters water + weight of the tank}} + 14.116[20 \sin 70]$

$= 392.2 + 265.3$

$= 657.5\ N$

$\boxed{6.22}$ Plate A is 50 cm in diameter and has a sharp-edged orifice at its center. A water jet strikes the plate concentrically with a speed of 30 m/sec. With the plate held stationary, what external force is needed to hold the plate in place if the jet issuing from the orifice also has a speed of 30 m/sec? The diameters of the jets are D = 10 cm and d = 5 cm.



$$\Sigma F_x = \Sigma U_x \rho V \cdot A$$

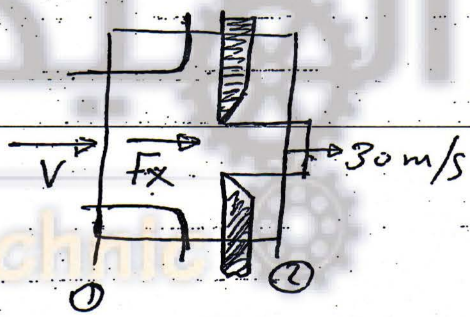
$$= -V_{1x}(\rho V_1 A_1) + V_{2x}(\rho V_2 A_2)$$

$$= \cancel{\rho Q (V_{2x} - V_{1x})}$$

$$= V_{2x}\,\rho V_2 A_2 - V_{1x}\,\rho V_1 A_1$$

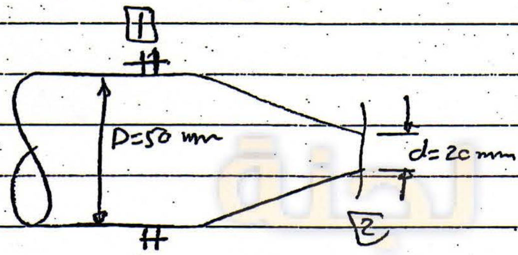
$$= (30)^2(1000)\left(\frac{\pi}{4}\right)(0.05)^2 - (30)^2(1000)\left(\frac{\pi}{4}\right)(0.10)^2$$

$$= -5.3\ \text{kN}.$$



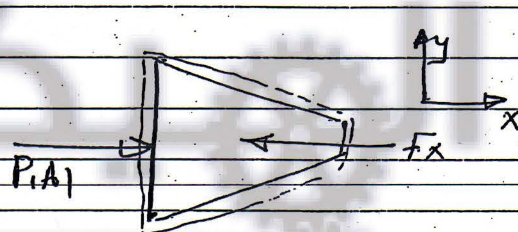
6.37 Fox.

A smoothly contoured nozzle, with outlet diameter $d = 20\,mm$, is coupled to a straight pipe by means of flanges. Water flows in the pipe, of diameter $D = 50\,mm$, and the nozzle discharges to the atmosphere. For steady flow and neglecting the effects of viscosity, find the volume flow rate in the pipe corresponding to a calculated axial force of 45.5 N needed to keep the nozzle attached to the pipe.



x-momentum

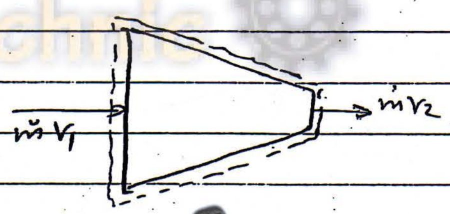
$$P_1 A_1 - F_x = \dot{m}\,[V_2 - V_1]$$
$$= \rho Q\,[V_2 - V_1]$$



$$V_1 = \frac{Q}{A} = \frac{Q}{(\frac{\pi}{4})(0.05)^2} = 509.6\,Q$$

$$V_2 = \frac{Q}{A} = \frac{Q}{(\frac{\pi}{4})(0.02)^2} = 3184.7\,Q$$

Bernoulli Eqn.



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

$$P_1 = \frac{1}{2}\rho\,[V_2^2 - V_1^2]$$

$$= 500\,[\,3184.7^2 Q^2 - 509.6^2 Q^2\,]$$

$$P_1 = 4.941 \times 10^9\,Q^2$$

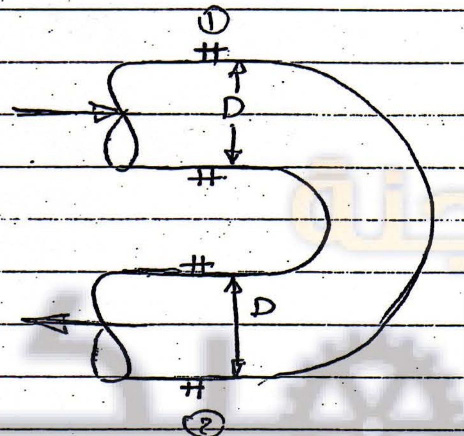
Applying in momentum Eqn. $4.941 \times 10^9 Q^2 (\frac{\pi}{4})(0.05)^2 - 45.5 = 2.675 \times 10^6 Q^2$

$$[Q^2]\;7.022 \times 10^6 = 45.5 \Rightarrow Q = 2.545 \times 10^{-3}\,m^3/s.$$

6.32 Assume that the gage pressure p is the same at section 1 and 2 in this horizontal bend. The fluid flowing in the bend has density ρ, discharge Q, and velocity V. The cross sectional area of the pipe is A. Then the magnitude of the force (neglecting gravity) required at the flanges to hold the bend in place will be

a) pA b) $pA+\rho QV$ (c) $2pA+\rho QV$ d) $2pA+2\rho QV$

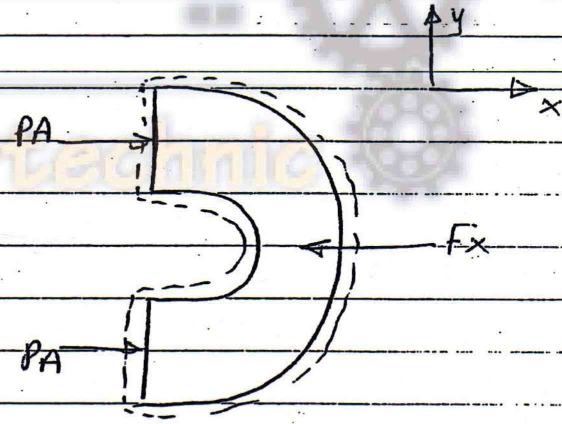
$$\Sigma F_x = \underbrace{\frac{\partial}{\partial t}\int_{c.v} \rho U_x \, d\forall}_{0.0 \text{ steady}} + \Sigma \dot{m}_{out} V_{ou,x} - \Sigma \dot{m}_{in} V_{ix}$$



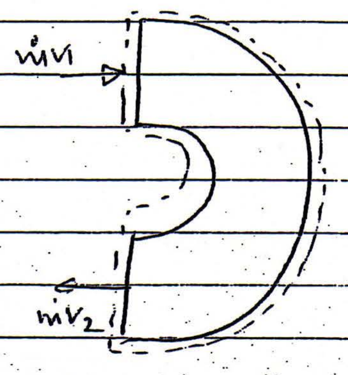
$$PA + PA - F_x = \dot{m}[V] - \dot{m}(-V]$$
$$= -2\dot{m}V$$

$$F_x = 2PA + 2\dot{m}V$$

$$\boxed{F_x = 2PA + 2\rho QV}$$

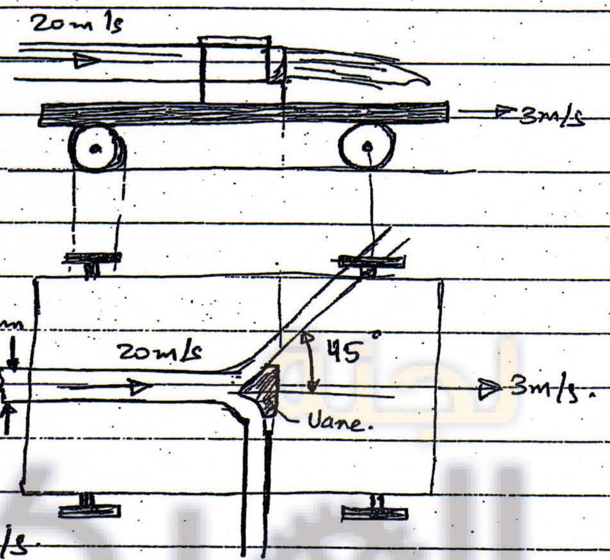


Correct answer: (d)



6.73 7th
6.30

A vane on this moving cart deflects a 10-cm water jet as shown. The initial speed of the water in the jet is 20 m/s, and the cart moves at a speed of 3 m/s. If the vane splits the jet so that half goes one way and half the other, what force is exerted on the vane by the jet?



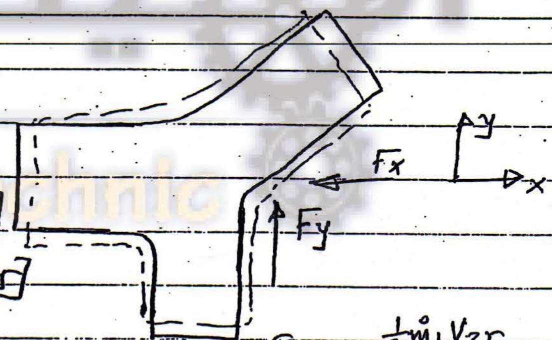
$V_{1rel} = V_{2re} = V_{3r} = V_j - V_v$
$= 20 - 3 = 17$ m

$\dot{m}_{1rel} = \rho Q_{rel}$
$= (1000)\left[\frac{\pi}{4}\right][0.1]^2[17]$
$= 133.45$ kg/s.

$\dot{m}_{2rel} = \dot{m}_{3rel} = \frac{1}{2}\dot{m}_{1rel} = 66.73$ kg/s

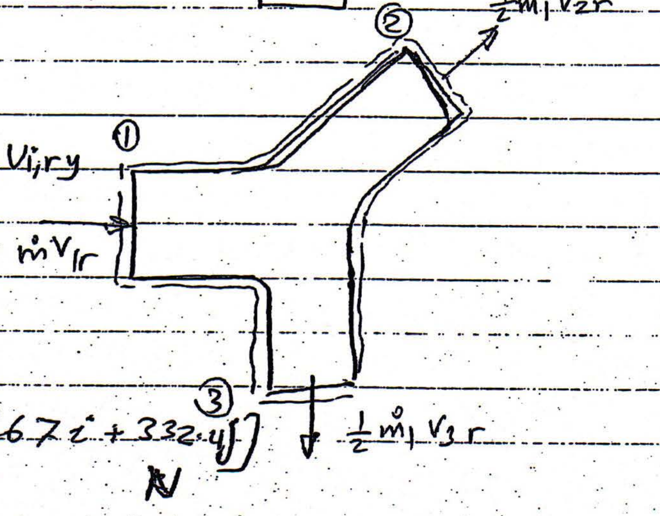
X-momentum [for steady flow].

$\Sigma F_x = \Sigma \dot{m}_{out,rel} V_{or\,x} - \Sigma \dot{m}_{in,re} V_{ij,rx}$



$-F_x = 66.73[V_{2r}\cos 45] - [V_{1r}][133.45]$
$= (66.73)(17)(0.707) - [17][133.45]$
$= -1467$ N

$F_x = 1.467$ kN



$\Sigma F_y = \Sigma \dot{m}_{outr} V_{0,ry} - \Sigma \dot{m}_{in,re} V_{i,ry}$

$F_y = (66.73)(17)(0.707) - (66.73)(17)$

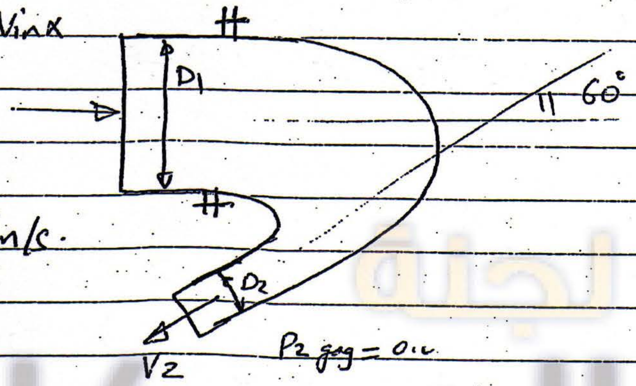
$F_y = -332.4$ N.

F (water on vane) $= [1467\,i + 332.4\,j]$ N

6.45

6.38 / 7 This bend discharges water into the atmosphere. Determine the force components at the flange required to hold the bend in place. The bend lies in a horizontal plane. Assume viscous forces are negligible. The interior volume of the bend is 0.25 m³, $D_1 = 60$ cm, $D_2 = 30$ cm, and $V_2 = 10$ m/s the mass of the bend material is 250 kg.

$\Sigma F_x = \Sigma \dot{m}_{out} V_{ox} - \Sigma \dot{m}_{in} V_{inx}$



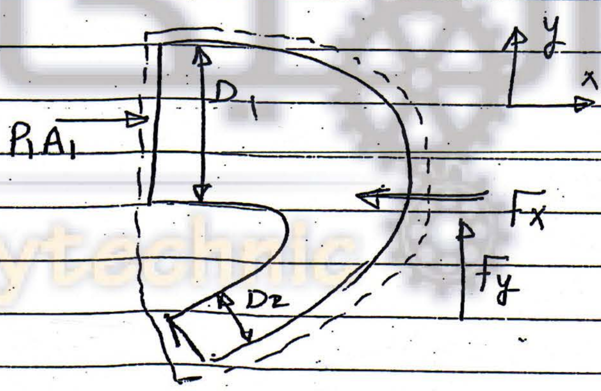
$Q = V_2 A_2 = (10)(\frac{\pi}{4})(0.3)^2$

$= 0.7065$

$V_1 = \frac{Q}{A_1} = \frac{0.7065}{(\frac{\pi}{4})(0.6)^2} = 2.5$ m/s.

Bernoulli Eqn to find P_1

$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$



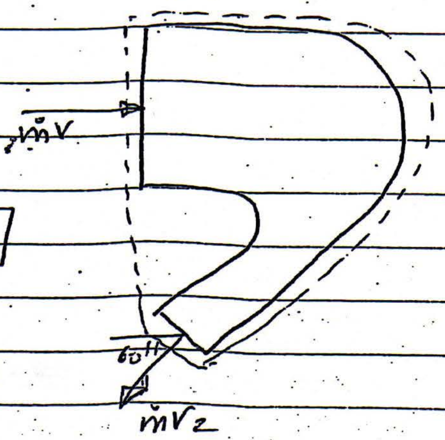
note that $Z_1 = Z_2$

since the reduced bend located (lies in x-y plane)

$P_1 = \frac{1}{2}\rho(V_2^2 - V_1^2)$

$= (\frac{1}{2})(1000)(10^2 - 2.5^2)$

$= 46875$ Pa.



$(46875)(\frac{\pi}{4})(0.6)^2 - F_x =$

$(1000)(0.7065)[-10\cos 60 - 2.5]$

$F_x = 18.54$ kN

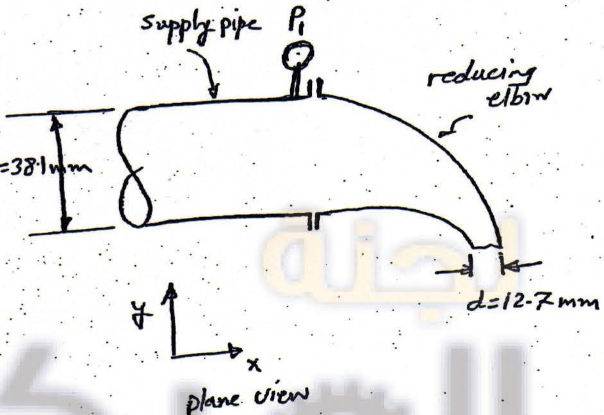
$\Sigma F_y = \Sigma \dot{m}_{out} V_{oy} - \Sigma \dot{m}_{in} V_{iny}$

$$F_y = +\dot{m}(-V_2 \sin 60)$$
$$= +1000\,(0.7065)\,(-10)(0.866)$$
$$= -6.118 \text{ kN}$$

$$\Sigma F_z = 0.0$$
$$F_z - W_{bend} - W_{water} = 0.0$$
$$F_z = (250)(9.81) + (0.25)(9810)$$
$$= 4.905 \text{ kN}$$

$$F = (-18.6\,\hat{i} - 6.12\,\hat{j} + 4.91\,\hat{k}) \text{ kN}$$

6.38 Fox. Water flows steadily through the reducing elbow shown. The elbow is smooth and short, and the flow accelerats, so the effect of friction is small. The volume flow rate is $Q = 1.27\ \frac{L}{s}$. The elbow is in a horizondal plane. Estimate the gage pressure at section ①. Calculate the x-component of the force exerted by the reducing elbow on the supply pipe.



$$Q = 1.27\ \frac{L}{s} = 1.27 \times 10^{-3}\ \frac{m^3}{s}.$$

$$V_1 = \frac{Q}{A} = \frac{1.27 \times 10^{-3}}{\left(\frac{\pi}{4}\right)(0.0381)^2}$$

$$= 1.114\ m/s.$$

$$V_2 = \frac{Q}{A} = \frac{1.27 \times 10^{-3}}{\left(\frac{\pi}{4}\right)(0.0127)^2}.$$

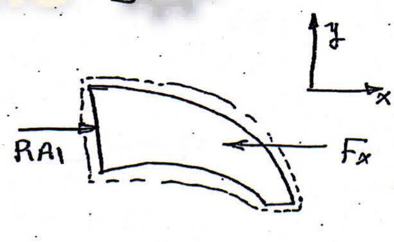
$$= 10.026\ m/s.$$

Bernoulli Eqn.

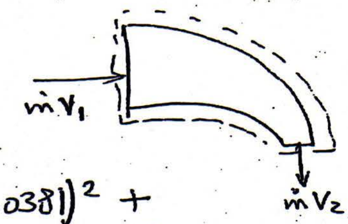
$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + \cancel{Z_1} = \cancel{\frac{P_2}{\gamma}}_{0.0} + \frac{V_2^2}{2g} + \cancel{Z_2}$$

$$P_1 = \frac{1}{2}\rho\left(V_2^2 - V_1^2\right) = \left(\frac{1}{2}\right)(1000)\left[10.03^2 - 1.11^2\right]$$

$$= 49.684\ kPa$$



$$\Sigma F_x = \underbrace{\cancel{\frac{\partial}{\partial t}\int_{c.v} \rho\, u_x\, d\forall}}_{0.0} + \Sigma \dot{m}_{out} U_{ox} - \Sigma \dot{m}_{in} U_{ix}$$



$$P_1 A_1 - F_x = \dot{m}\left[0 - V_1\right]$$

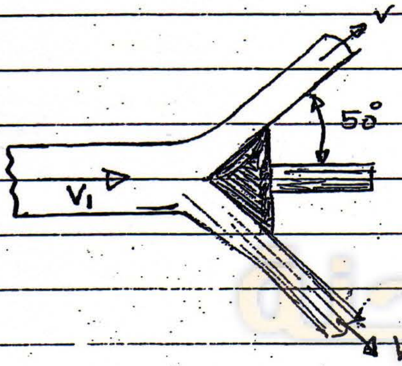
$$P_1 A_1 - F_x = \rho Q\left[-V_1\right]$$

$$F_x = P_1 A_1 + \rho Q V_1 = (49684)\left(\frac{\pi}{4}\right)(0.0381)^2 + (1000)(1.27 \times 10^{-3})\left[1.114\right]$$

$$= 58.03\ N$$

6.32

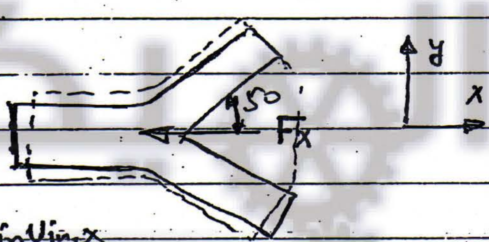
~~6.75~~ 7th. The water in this jet has a speed of 30 m/s to the right and is deflected by a cone that is moving to the left with a speed of 13 m/s. The diameter of the jet is 10 cm. Determine the external horizontal force needed to move the cone. Assume negligible friction between the water and the cone.



$$V_{rel} = V_j + V_v$$
$$= 30 + 13 = 43 \text{ m/s}$$

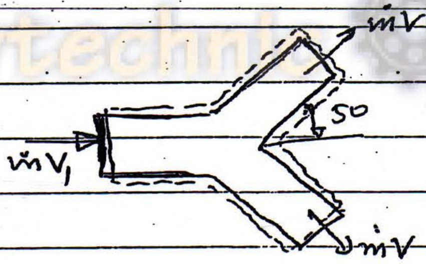
$$Q_{rel} = V_{rel} A = \left(\frac{\pi}{4}\right)(0.1)^2(43)$$
$$= 0.338 \text{ m}^3/\text{s}$$

$$\dot{m}_{rel} = \rho Q = 338 \text{ kg/s}$$



X - Momentum.

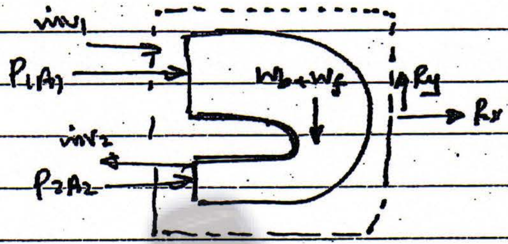
$$\sum F_x = \underbrace{\frac{\partial}{\partial t}\int_{cv} \rho V_x \, d\forall}_{0.0 \text{ steady state condition.}} + \sum \dot{m}_{out} V_{o,x} - \sum \dot{m}_{in} V_{in,x}$$

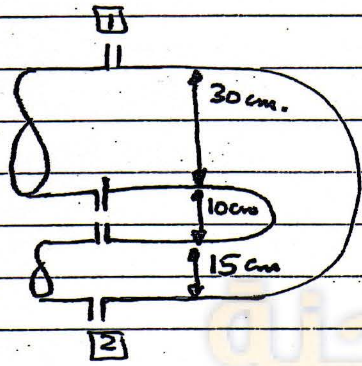


$$-F_x = \dot{m} V \cos 50 - \dot{m} V$$
$$= \dot{m} V [\cos 50 - 1]$$
$$= (338)(43)[0.643 - 1]$$
$$-F_x = -5192 \text{ N}$$

$$\boxed{F_x = 5.192 \text{ kN}}$$

<u>Example:</u>- Water flows through a 180° reducing bend as shown. The discharge is 0,25 m^3/s, and the pressure at the center of the inlet section is 150 kPa gage. If the bend volume is 0.1 m^3, and it is assumed that the Bernoulli eqn is valid, what force is required to hold the bend in place? The metal in the bend weighs 500 N.





Continuity Eqn $\dot{m}_{in} = \dot{m}_{out}$.

$Q_{in} = Q_{out}$ $\quad V_1A_1 = V_2A_2$

$$V_1 = \frac{Q}{A_1} = \frac{0,25}{(\frac{\pi}{4})(0,3)^2} = 3.54 \text{ m/s}$$

$$V_2 = \frac{Q}{A_2} = \frac{0,25}{(\frac{\pi}{4})(0,15)^2} = 14.15 \text{ m/s}.$$

We have to find P_2 @ section 2 using Bernoulli Eqn.

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$$

$$P_2 = P_1 + \frac{1}{2}\rho(V_1^2 - V_2^2) + \gamma(Z_1 - Z_2)$$

$$= 150 \times 10^3 + (\tfrac{1}{2})(1000)(3.54^2 - 14.15^2) + 9810\Big[\underbrace{0.15 + 0.1 + 0.075}_{0,325}\Big]$$

$$= 59.3 \text{ kPa}.$$

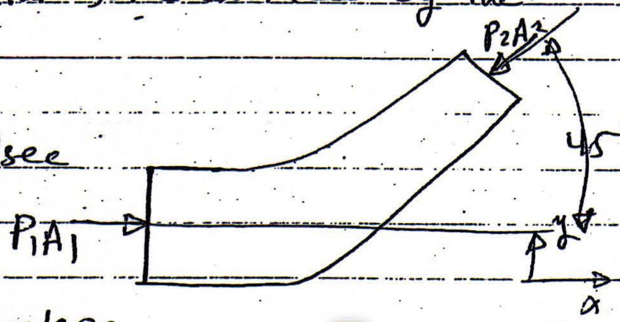
$$\Sigma F_x = \underbrace{\frac{\partial}{\partial t}\int_{c.v} \rho v_x \, d\forall}_{0.0 \text{ steady}} + \Sigma \dot{m}_o v_{ox} - \Sigma \dot{m}_i v_{ix}$$

$$P_1A_1 + R_x + P_2A_2 = \dot{m}[-V_2 - V_1]$$

$$R_x = (-150 \times 10^3)(\tfrac{\pi}{4})(0.3)^2 - (59.3 \times 10^3)(\tfrac{\pi}{4})(0.15)^2 - (1000)(0,25)[3.54 + 14.15] = -16.067 \text{ kN}$$

$$R_y = W_b + W_f = 500 + (9810)(0.1) = 1.48 \text{ kN}.$$

Example: A 45° reducing pipe-bend (in a horizontal plane) tapers from 600 mm diameter at inlet to 300mm diameter at outlet. The gage pressure at inlet is 140 kPa and the rate of flow of water through the bend is 0.425 m³/sec. Neglecting friction, calculate the net resultant horizontal force exerted by the water on the bend.



$$V_1 = \frac{Q_1}{A_1} = \frac{0.425}{\left(\frac{\pi}{4}\right)(0.6)^2} = 1.503 \text{ m/sec}$$

$$V_2 = \frac{Q}{A_2} = \frac{0.425}{\left(\frac{\pi}{4}\right)(0.3)^2} = 6.01 \text{ m/sec}$$

From Bernoulli equ and neglecting elevation diff.

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

$$P_2 = P_1 + \frac{1}{2}\rho(V_1^2 - V_2^2)$$

$$P_2 = 140\times10^3 + \left(\frac{1}{2}\right)(1000)(1.503^2 - 6.01^2) \simeq 123 \text{ kPa}.$$

$$\Sigma F_x = \Sigma u_x \rho (V\cdot A)$$

$$P_1A_1 - P_2A_2\cos 45 + R_x = \rho Q[V_{2x} - V_{1x}]$$

$$R_x = -P_1A_1 + P_2A_2\cos 45 + (1000)(0.425)[6.01\cos 45 - 1.503]$$

$$= -140\times10^3\left(\frac{\pi}{4}\right)(0.36) + 123\times10^3\left(\frac{\pi}{4}\right)(0.09)(0.707) + (1000)(0.425)((6.01)(0.707) - 1.503)$$

$$= -32270 \text{ N.}$$

y-direction

$$F_y - P_2 A_2 \sin 45 = \rho Q V_{2y}$$

$$= (1000)(0.425)(+6.01 \times 0.707)$$

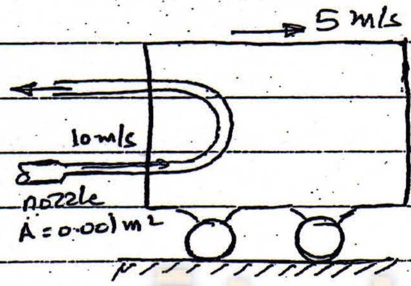
$$F_y = (123 \times 10^3)\left(\frac{\pi}{4}\right)(0.09)(0.707) + 425(6.01)(0.707)$$

$$= 7952.8 \text{ N}$$

$$F = \sqrt{F_x^2 + F_y^2} = \sqrt{32.27^2 + 7.953^2} = 33.23 \text{ kN}$$

6-86

~~6.80~~ 7 A cart is moving along a track at a constant velocity of 5 m/s as shown. Water ($\rho = 1000\ kg/m^3$) issues from a nozzle at 10 m/s and is deflected through 180° by a vane on the cart. The cross-sectional area of the nozzle is 0.001 m². Calculate the resistive force on the cart.

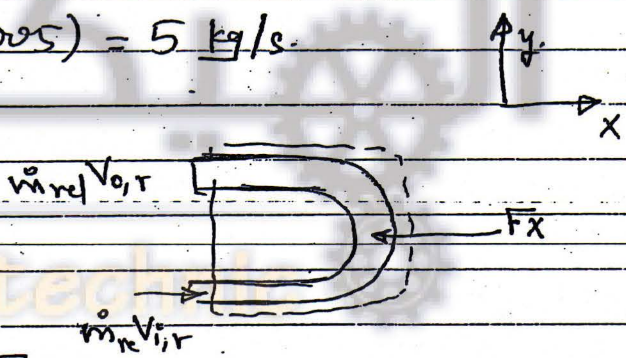


$$V_{relative} = V_j - V_{cart}$$
$$= 10 - 5 = 5\ m/s$$

$$Q_{rel} = V_{relative}\, A$$
$$= (10-5)(A) = (5)(0.001) = 0.005\ m^3/s$$

$$\dot m_{rel} = \rho Q_{rel} = (1000)(0.005) = 5\ kg/s$$

X-momentum.

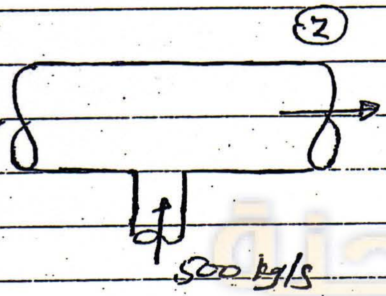


$$\sum F_x = \sum \dot m_{o,r,x} V_{o,r x} - \sum \dot m_{i,r,x} V_{i,r x}$$
$$-F_x = (5)[-5] - [5][5]$$
$$= -25 - 25$$
$$= -50\ N$$

$$\boxed{F_x = 50 N}$$

6.51

~~6.44~~ 7 Water flows in a duct as shown. The inlet water velocity is 10 m/s. The cross-sectional area of the duct is 0.1 m^2. Water is injected normal to the duct wall at the rate of 500 kg/s midway between stations 1 & 2. Neglect frictional forces on the duct wall. Calculate the pressure difference $(P_1 - P_2)$ between stations 1 & 2.



Continuity Eqn:

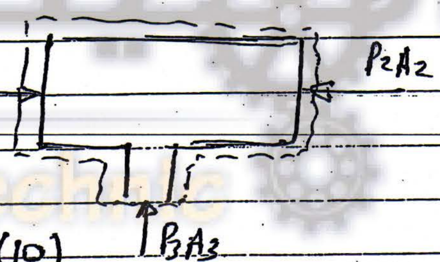
$$\dot{m}_1 + 500 = \dot{m}_2$$

$$\dot{m}_2 = 500 + (10)(0.1)(1000)$$

$$= 1500 \text{ kg/s}$$

$$U_2 = \frac{\dot{m}_2}{\rho A} = \frac{(1500)}{(1000)(0.1)} = 15 \text{ m/s}$$

X-Momentum:



$$P_1A_1 - P_2A_2 = \sum \dot{m}_{out} V_{out\,x} - \sum \dot{m}_{in} V_{in\,x}$$

$$= (1500)(15) - (1000)(10)$$

$$= 22500 - 10000$$

$$(P_1 - P_2)A = 12500 \text{ Pa m}^2$$

$$P_1 - P_2 = 125000 \text{ Pa} = 125 \text{ kPa}.$$

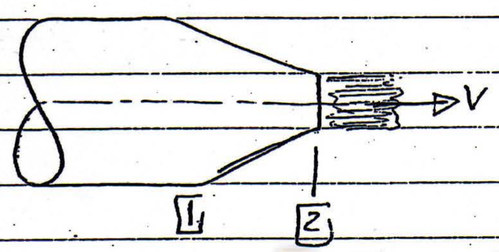
Water at 15°C flow through a nozzle that contracts from a diameter of 10 cm to 2 cm. The exit speed is $V_2 = 25\,m/s$ and atmospheric pressure prevails at the exit of the jet. Calculate the pressure at section 1 and the force required to hold the nozzle stationary. Neglect weight.

From Continuity

$$V_1 A_1 = V_2 A_2$$

$$V_1 = V_2 \frac{A_2}{A_1} = (25)\left[\frac{0{,}02}{0{,}10}\right]^2$$

$$V_1 = 1\,m/s.$$



To calculate pressure at section 1 ⇒

Bernoulli Eqn

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + \cancel{Z_1} = \cancel{\frac{P_2}{\gamma}} + \frac{V_2^2}{2g} + \cancel{Z_2} \qquad Z_1 = Z_2$$

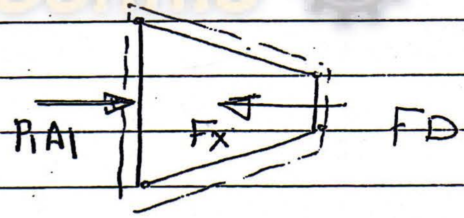
$P_2 = 0$ atmospheric

$$P_1 = \frac{1}{2}\rho\left[V_2^2 - V_1^2\right] = \left(\frac{1}{2}\right)(999)(25^2 - 1^2)$$

$$= 311.7\ kPa.$$

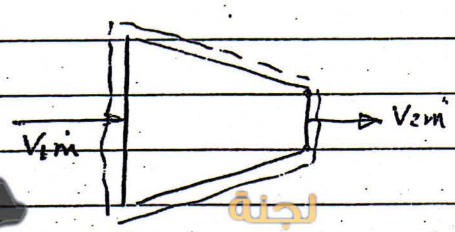
$$\sum F_x = \underbrace{\frac{\partial}{\partial t}\int \rho V_x\, d\forall}_{=0 \text{ steady}} + \sum \dot{m}_{out} V_{ox} - \sum \dot{m}_{in} V_{inx}$$

$$P_1 A_1 - F_x = \dot{m} V_2 - \dot{m} V_1$$



$$F_x = P_1 A_1 + \dot{m}\left[V_1 - V_2\right]$$

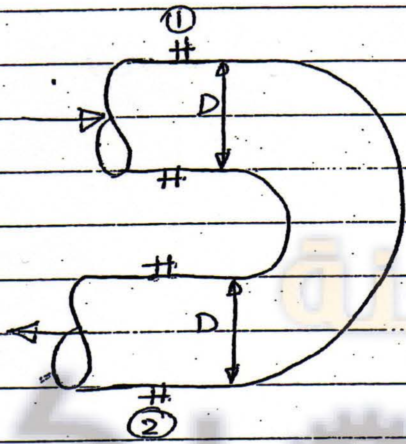
$$= 311.7\times10^3\left(\frac{\pi}{4}\right)(0.1)^2 + (999)(25)(0.02)^2 \times \frac{\pi}{4}\left[1 - 25\right]$$



$$= 2.26\ kN$$

6.34 / 7 The pipe shown in the fig has a 180° horizontal bend in it as shown, and D is 30 cm. The discharge of water in the pipe and bend is 0.6 m^3/s, and the pressure in the pipe and bend is 100 kPa gage. If the bend volume is 0.1 m^3 and the bend itself weighs 500 N, what force must be applied at the flange to hold the bend in place?

$$\Sigma F_x = \Sigma \dot{m}_{out} V_{ox} - \Sigma \dot{m}_{in} V_{ix}$$



$$PA + PA - F_x = -\dot{m}V - (+\dot{m}V)$$

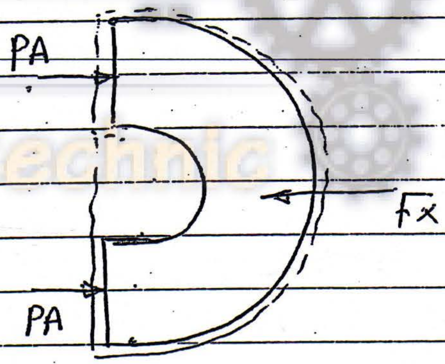
$$= -2\dot{m}V$$

$$2PA - F_x = -2\rho Q V$$

$$F_x = 2PA + 2\rho Q V$$

$$= (2)(100\times10^3)\left(\frac{\pi}{4}\right)(0.3)^2 + 2(1000)(0.6)\left(\frac{0.6}{\left(\frac{\pi}{4}\right)(0.3)^2}\right)$$

$$= 24.318 \text{ kN}$$



$$\Sigma F_z = 0.0 =$$

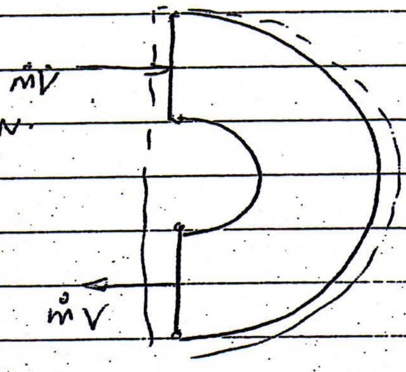
$$F_z - W_{bend} - W_{H_2O} = 0.0$$

$$F_z = W_{bend} + W_{H_2O}$$

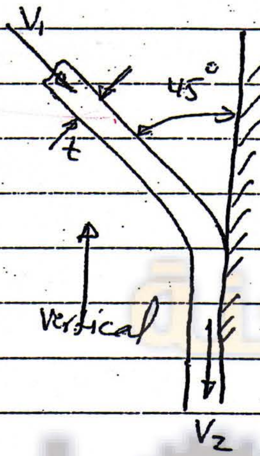
$$= 500 + (0.1)(9810)$$

$$= 1.481 \text{ kN}$$

$$\therefore F = (-24.318\,\hat{i} + 1.481\,\hat{k}) \text{ kN}$$



A two-dimensional liquid jet impinges on a vertical wall. Assuming that the incoming jet speed is the same as the exiting jet speed ($V_1 = V_2$), derive an expression for the force per unit width of jet exerted on the wall. What form do you think the upper liquid surface will take next to the wall? Sketch the shape you think it will take, and explain your reasons for drawing it that way.



x-momentum

$$\sum F_x = \sum \dot{m}_o v_{o,x} - \sum \dot{m}_i v_{i,x}$$

$$-F = -\dot{m} v_1 \sin 45$$

$$F = \rho w t v^2 \sin 45$$

The force acted on the wall will be to the right

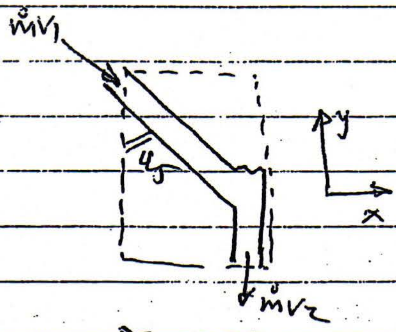
Force per unit width $= \frac{F}{w} = \rho t v^2 \sin 45$

y-momentum:

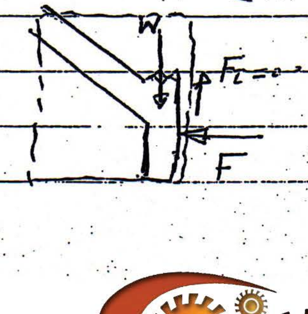
$$\sum F_y = \sum \dot{m}_{out} v_{o,y} - \sum \dot{m}_{in} v_{in,y}$$

$$-W = \dot{m}(-v) - \dot{m}(-v \cos 45)$$

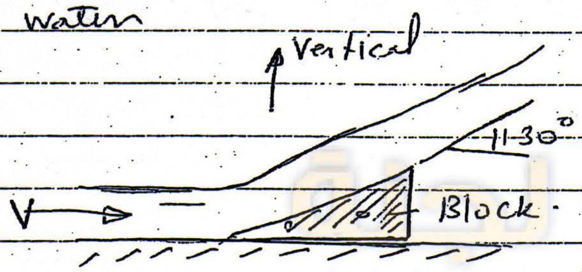
$$W = \dot{m} v [1 - \cos 45]$$



Thus, weight provides the force needed to increase y-momentum flow. This weight is produced by the fluid swirling up to form the shape shown in the sketches.

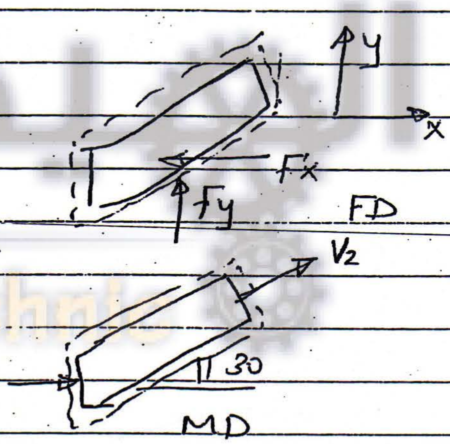


Water strikes a block as shown and is deflected 30°. The flow rate of the water is (1 kg/s), and the inlet velocity is (10 m/s). The mass of the block is 1 kg. The coefficient of static friction between the block and the surface is 0.1 (friction force / normal force). If the force parallel to the surface exceeds the frictional force, the block will move. Determine the force on the block and whether the block will move. neglect the weight of the water



$\dot{m} = 1\ kg/s$

$$\sum F_x = \frac{\partial}{\partial t}\int_{CV} \rho V_x \, d\forall + \sum \dot{m}_{out} V_{o,x} - \sum \dot{m}_{in} V_{i,x}$$



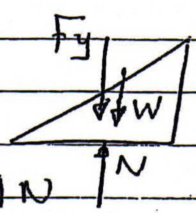
$$-F_x = (1)\left[10\cos 30 - 10\right]$$

$$= -1.34\ N$$

$$\boxed{F_x = 1.34\ N}$$

$$\sum F_y = \frac{\partial}{\partial t}\int_{CV} \rho V_y \, d\forall + \sum \dot{m}_{out} V_{o,y} - \sum \dot{m}_{in} V_{i,y}$$

$$F_y = (1)((10)(0.5) - 0) = 5$$



$$\sum F_{block} = 0.0 \Rightarrow N = F_y + W = 5 + (9.81)(1) = 14.81\ N$$

$$F_{frict} = (0.1)(N) = 1.481$$

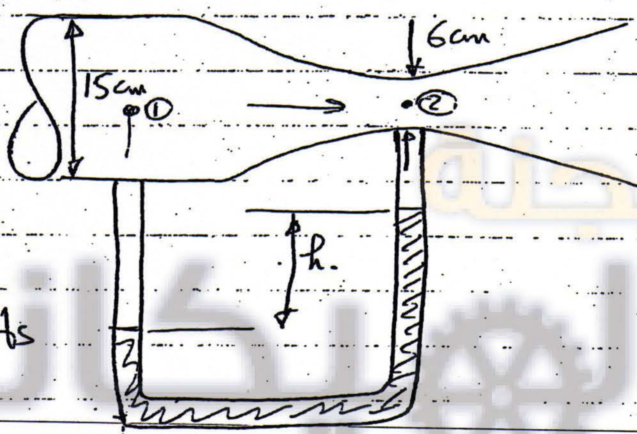
$F_x < F_{friction}$

Block will not slip

The mass flow rate of air at 20°C ($\rho = 1.204\ kg/m^3$) through a 15 cm-diameter duct is measured with a Venturi meter equipped with a water manometer. The Venturi neck has a diameter of 6 cm, and the manometer has a max. differential height of 40 cm. Taking the discharge coefficient to be 0,98, determine the max. mass flow rate of air this Venturi meter can measure.

$P_1 - 0.4\ (9810) = P_2$

hydrostatic pressure of the gas can be neglected.



$P_1 - P_2 = 3924\ Pa$

Bernoulli Eqn between points ① & ②

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + \cancel{Z_1} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \cancel{Z_2}$$

$$A_1V_1 = A_2V_2$$

$$V_1 = \left(\frac{A_2}{A_1}\right)V_2 = \left(\frac{d}{D}\right)^2 V_2$$

$$\frac{P_1 - P_2}{\gamma} = \frac{V_2^2}{2g} - \frac{V_1^2}{2g}$$

$$= \frac{V_2^2}{2g}\left[1 - \left(\frac{d}{D}\right)^4\right]$$

$$V_2^2 = \frac{2\,(P_1 - P_2)}{\rho\left[1 - \left(\frac{d}{D}\right)^4\right]} = \frac{(2)(3924)}{(1.204)\left(1 - \left(\frac{6}{15}\right)^4\right)} = 6689.5$$

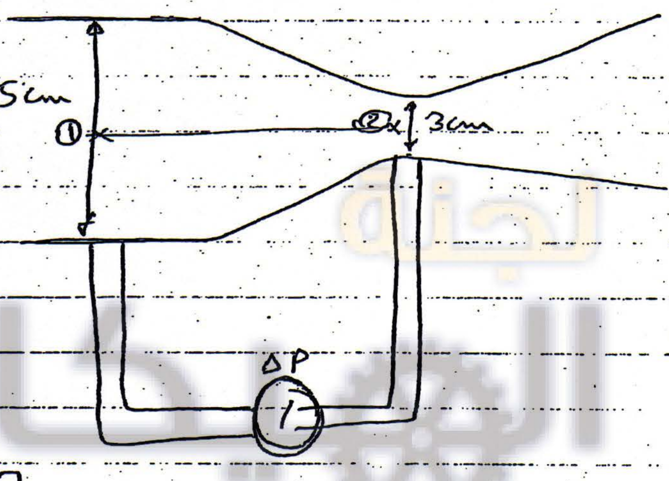
$V_2 = 81.79\ m/sec$

$$Q = V_2 A_2 = (81.79)\left(\frac{\pi}{4}\right)(0.06)^2$$
$$= 0.231\ m^3/s$$

$Q_{actual} = (0.98)(0.231) = 0.2266\ m^3/sec$

$\dot{m} = \rho_{air}\, Q_{actu} = (1.204)(0.2266) = 0.273\ kg/sec$

A Venturi meter equipped with a differential pressure gage is used to measure the flow rate of water at 15°C ($\rho = 999.1\ kg/m^3$) through a 5-cm-diameter horizontal pipe. The diameter of the Venturi neck (throat) is 3 cm, and the measured pressure drop is 5 kPa. Taking the discharge coefficient to be 0.98, determine the volume flow rate of water and the average velocity through the pipe.



$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + \cancel{Z_1} = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + \cancel{Z_2}$$

$$\frac{P_1 - P_2}{\rho g} = \frac{V_2^2}{2g} - \frac{V_1^2}{2g}$$

$$A_1 V_1 = A_2 V_2 \Rightarrow V_1 = \frac{A_2}{A_1} V_2$$
$$= \left(\frac{d}{D}\right)^2 V_2$$

$$\frac{P_1 - P_2}{\rho g} = \frac{1}{2g} V_2^2 \left[1 - \left(\frac{d}{D}\right)^4\right]$$

$$V_2 = \frac{2(P_1 - P_2)}{\rho\left[1 - \left(\frac{d}{D}\right)^4\right]} \Rightarrow V = \sqrt{\frac{(2)(P_1 - P_2)}{\rho\left(1 - \left(\frac{d}{D}\right)^4\right)}}$$

$$V_2 = \sqrt{\frac{(2)(5000)}{(999.1)(1 - 0.6^4)}} = 11.5 \Rightarrow V_2 = 3.391\ m/sec.$$

$$Q = V_2 A_2 = (3.391)\left(\frac{\pi}{4}\right)(0.03)^2 = \cancel{2.3}\ 2.397 \times 10^{-3}\ m^3/s$$

$$Q_{act} = C_d V_2 A_2 = 2.35 \times 10^{-3}\ m^3/sec = 2.35\ L/sec.$$

$$Q_{act} = \bar{V} A \Rightarrow \bar{V} = \frac{2.35 \times 10^{-3}}{\left(\frac{\pi}{4}\right)(0.05)^2} = 1.196\ m/sec.$$

Ch. 4 P23 Continuity.

$\boxed{4.81}$ O_2 LEAKS SLOWLY THROUGH A SMALL ORIFICE IN AN OXYGEN BOTTLE. THE VOLUME OF THE BOTTLE IS $\boxed{0.1\ m^3}$, AND THE DIA. OF THE ORIFICE IS $\boxed{0.15\ mm}$. THE TEMP. IN THE TANK REMAINS CONSTANT AT 18°C, AND THE MASS FLOW RATE IS GIVEN BY $\dot{m} = \frac{0.68\,PA}{\sqrt{RT}}$. HOW LONG WILL IT TAKE THE ABSOLUTE PRESSURE TO DECREASE FROM 10 TO 5 MPa.

$$\left.\frac{dm}{dt}\right|_{sy} = 0.0 = \frac{d}{dt}\int_{c.v} \rho\, d\forall + \sum \rho \vec{V}\cdot A$$

$$\sum \rho \vec{V}\cdot A = -\frac{d}{dt}\int_{c.v} \rho\, d\forall$$

$$\dot{m} = -\frac{d}{dt}[\rho \forall] \quad \text{But } \rho = \frac{P}{RT}$$

$$\dot{m} = \frac{0.68\,PA}{\sqrt{RT}} = -\frac{d}{dt}\left[\frac{P}{RT}\forall\right]$$

$$= -\frac{\forall}{RT}\frac{dP}{dt}$$

$$\frac{dP}{P} = -\frac{0.68\,RTA}{\forall\sqrt{RT}}\,dt$$

$$\frac{dP}{P} = -0.68\sqrt{RT}\,A\,dt$$

$$\ln P\Big|_{10}^{5} = -0.68\sqrt{RT}\left(\frac{\pi}{4}\right)(0.15\times10^{-3})^2 (t)$$

$$t = \frac{(0.1)\ln(0.5)}{(-0.68)(\sqrt{260\times291})\left(\frac{\pi}{4}\right)(0.15\times10^{-3})^2}$$

$$= 20981.2 \text{ sec}$$

$$= 5.82 \text{ hr.}$$ (5 hours & 50 minuits)

$\boxed{4.40}$ Given $u = xt + 2y \quad v = xt^2 - yt \quad w = 0$

What is the total acceleration at a point $x = 1\,m$, $y = 1\,m$ and at time $t = 2$ sec?

$$a = a_x\hat{i} + a_y\hat{j}$$

$$a_x = \frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}$$

$$a_y = \frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}$$

$$a_x = \frac{\partial}{\partial t}(xt+2y) + (xt+2y)\frac{\partial}{\partial x}(xt+2y) + (xt^2-yt)\frac{\partial}{\partial y}(xt+2y)$$

$$= x + (xt+2y)(t) + (xt^2-yt)(2)$$

$$= x + xt^2 + \cancel{2yt} + 2xt^2 - \cancel{2yt}$$

$$a_x = x + 3xt^2$$

$$a_x\Big|_{\substack{x=1\\y=1\\t=2}} = 1 + (3)(1)(2)^2 = 13 \quad m/s^2$$

$$a_y = \frac{\partial}{\partial t}(xt^2-yt) + (xt+2y)\frac{\partial}{\partial x}(xt^2-yt) + (xt^2-yt)\frac{\partial}{\partial y}(xt^2-yt)$$

$$= 2xt - y + (xt+2y)(t^2) + (xt^2-yt)(-t)$$

$$= 2xt - y + \cancel{xt^3} + 2yt^2 - \cancel{xt^3} + yt^2$$

$$= 2xt - y + 3yt^2$$

$$a_y\Big|_{\substack{x=1\\y=1\\t=2}} = (2)(1)(2) - (1) + (3)(1)(2)^2$$

$$= 4 - 1 + 12 = 15$$

$$\therefore \vec{a} = a_x\hat{i} + a_y\hat{j} = 13\hat{i} + 15\hat{j} \quad m/s^2$$

4.14 The discharge of water in a 30-cm pipe is 0,4 m³/sec. What is the mean velocity?

<u>Soln:</u> $Q = \bar{V} A \Rightarrow$ Mean velocity $= \dfrac{Q}{A} = \dfrac{Q}{\frac{\pi}{4} d^2} = \dfrac{0,4}{(\frac{\pi}{4})(0,3)^2} = 5,66$

4.16 A pipe with a 2-m diameter carries water having velocity of 3 m/s. What is the discharge Q (m³/s)

<u>Soln</u> $Q = VA = 3 (\frac{m}{s}) (\frac{\pi}{4}) (2)^2 = 9.42 \; m^3/sec.$

4.17 A pipe whose diameter is 8 cm transports air with a temp. of 20°C and pressure of 200 kPa absolute at 20 m/s. Determine the mass flow rate.

<u>Soln:</u> $d = 8\,cm = 0.08\,m$, $T = 20^\circ C = 293\,K$, $V = 20\,m/s$

$P\dot{V} = \dot{m} R T$

$\dot{V}$ = Volume flow rate $= Q = VA = 20 (\frac{m}{s}) (\frac{\pi}{4}) (0.08)^2 = 0.1 \frac{m^3}{s}$

$$\dot{m} = \frac{(200 \times 10^3)\, Pa \; (0.1 \frac{m^3}{s})}{(287)(293)} = 0,2391 \; kg/sec.$$

4.18 Natural gas (methane) flows at 11 m/s through a pipe with a 1-m diameter. The temp. of the methane is 15°C, and the pressure is 150 kPa gage. Determine the mass flow rate.

<u>Soln:</u> $T = 15^\circ C = 288\,K$.

$P_{ga} = 150\,kPa \Rightarrow P_{abs} = P_{gage} + P_{atm}$

$P = 150 + 101.325 = 251.325\,kPa$.

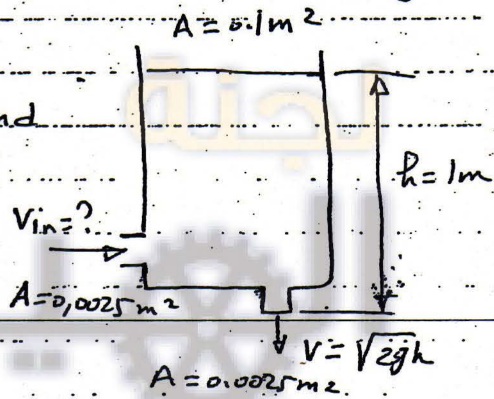
Rember that you have to use absolute pres in the relation $PV = mRT$.

$Q = \dfrac{\forall}{\Delta t} = VA = (11)(\frac{\pi}{4})(1)^2 = 8,64 \; m^3/sec.$

$$PQ = \dot{m} R T \Rightarrow \dot{m} = \frac{(251.325 \times 10^3)(8,64 \frac{m^3}{s})}{(518)(288)} = 14.56$$

From tables

4.54 A tank has a hole in the bottom with a cross-sectional area of $0.0025\ m^2$ and an inlet line on the side with a cross-sectional area of $0.0025\ m^2$, as shown. The cross-sectional area of the tank is $0.1\ m^2$. The velocity of the liquid flowing out the bottom hole is $V=\sqrt{2gh}$ where h is the height of the water surface in the tank above the outlet. At a certain time the surface level in the tank is 1 m and rising at the rate of 0.1 cm/s. The liquid is incompressible. Find the velocity of the liquid through the inlet.



* Let the control surface surround the liquid in the tank and let it follow the liquid surface at the top.

$$\sum \rho V \cdot A = -\frac{d}{dt}\int \rho\, d\forall$$

$$-\rho V_{in} A_{in} + \rho V_{out} A_{out} = -\frac{d}{dt}(\rho \forall_o)$$

$\forall$ volume of the liquid in the tank

$\forall = A_{tank} \otimes h$.

Since incompressible liquid

$$\rho_{in} = \rho_{out} = \rho$$

$$\Rightarrow -V_{in} A_{in} + A_{out}\sqrt{2gh} = -\frac{d}{dt}(A_t \times h) = -A_t \frac{dh}{dt}$$

$$-V_{in}(0{,}0025) + 0{,}0025\sqrt{(2g)(1)} = (-0.1)(0{,}001)$$

$$V_{in} = \frac{0{,}0025 * \sqrt{2g} + 0.0001}{0{,}0025}$$

$$= 4.469\ m/sec.$$

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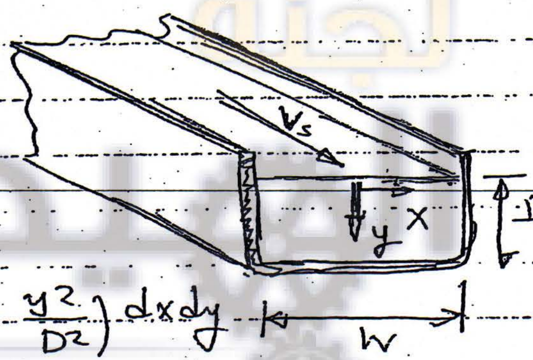
4.22 Water flows in a two-dimensional channel of width W and depth D as shown in the diagram. The hypothetical velocity profile for the water is

$$V(x,y) = V_s\left(1-\frac{4x^2}{W^2}\right)\left(1-\frac{y^2}{D^2}\right)$$

where V_s is the velocity at the water surface midway between the channel walls. The coordinate system is as shown; x is measured from the center plane of the channel and y downward from the water surface. Find the discharge in the channel in terms of V_s, D, W.

Sol: $Q = \int V\,dA$

dA = differential element area $= dx\,dy$



$$Q = \int_0^D \int_{-\frac{W}{2}}^{\frac{W}{2}} V_s\left(1-\frac{4X^2}{W^2}\right)\left(1-\frac{y^2}{D^2}\right)dx\,dy$$

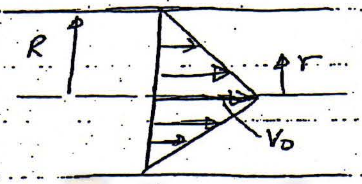
$$= V_s \int_0^D \left[\left(1-\frac{y^2}{D^2}\right)\left(X-\frac{4X^3}{3W^2}\right)\Big|_{-\frac{W}{2}}^{W/2}\right]dy$$

$$= V_s \int_0^D \left[\left(1-\frac{y^2}{D^2}\right)\left(\left(\frac{W}{2}-\frac{4\frac{W^3}{8}}{3W^2}\right)-\left(-\frac{W}{2}+\frac{4\frac{W^3}{8}}{3W^2}\right)\right)\right]dy$$

$$= V_s\left(\frac{2}{3}W\right)\int_0^D\left(1-\frac{y^2}{D^2}\right)dy = V_s\left(\frac{2}{3}W\right)\left(y-\frac{y^3}{3D^2}\right)\Big|_0^D$$

$$= \left(\frac{2}{3}W\right)(V_s)\left(D-\frac{D^3}{3D^2}\right) = \frac{4}{9}V_s W D$$

4.21 The hypothetical velocity distobution in a circular duct is $\frac{v}{V_0} = 1 - \frac{r}{R}$, where r is the radial location in the duct, R is the duct radius, and V_0 is the velocity on the asis. Find the ratio of the mean velocity to the velocity on the asis

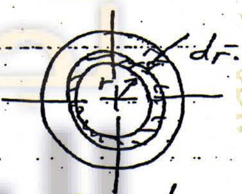


Soln: $Q = \int v\,dA$

$$= \int_0^R (V_0)\left(1 - \frac{r}{R}\right)(2\pi r\,dr)$$

$$= V_0(2\pi)\left(\frac{r^2}{2} - \frac{r^3}{3R}\right)\Big|_0^R$$

$$= 2\pi V_0\left(\frac{R^2}{2} - \frac{R^3}{3R}\right) = 2\pi V_0\left(\frac{R^2}{2} - \frac{R^3}{3R}\right)$$



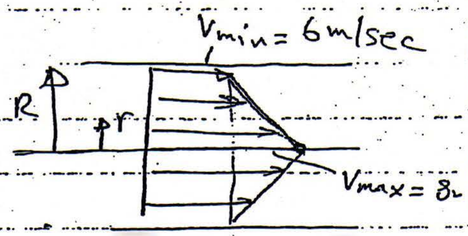
$$= 2\pi V_0\left[\frac{3R^2 - 2R^2}{6}\right] = \frac{1}{3}\pi V_0 R^2 \qquad dA = 2\pi r\,dr$$

$Q = \bar{V} A \qquad \bar{V}$ = average Vebcity.

$$\bar{V} = \frac{Q}{A} = \frac{\left(\frac{1}{3}\right)\pi V_0 R^2}{\frac{\pi}{4}R^2} = \frac{1}{3} V_0$$

$$\boxed{\frac{\bar{V}}{V_0} = \frac{1}{3}}$$

4.24 Water flows in a pipe that has 2-m diameter and the following hypothetical velocity distribution. The velocity is max at the centerline and decreases linearly with r to a min. at the pipe wall. If $V_{max} = 8$ m/sec and $V_{min} = 6$ m/s what is the discharge in (m^3/s) and the mean velocity.



Soln $Q = \int v\, dA$

But u is Variable

$$u = V_{max} - 2\frac{r}{R}$$

$@\ r = 0,0 \Rightarrow V = V_{max}$

$@\ r = r_0 \Rightarrow V = V_{max} - 2(1) = 6 = V_{min}$

$$Q = \int_0^R \left(V_{max} - 2\frac{r}{R}\right) 2\pi r\, dr = 2\pi\left[V_{max}\frac{r^2}{2} - \frac{2r^3}{3R}\right]_0^R$$

$$= 2\pi\left[\frac{R^2}{2}V_{max} - \frac{2R^3}{3R}\right]$$

$$Q = 2\pi\left[\left(\tfrac{1}{2}\right)(8) - \left(\tfrac{2}{3}\right)(1)^2\right] = 20{,}94\ m^3/sec$$

$$\bar{V} = \frac{Q}{A} = \frac{20{,}94}{\left(\frac{\pi}{4}\right)(2)^2} = 6{,}67\ m/sec$$

4.19 An aircraft engine test pipe is capable of providing a flo[w] rate of 200 kg/sec at altitude conditions corresponding to an absolute pressure of 50 kPa and a temp of −18°C. The velocity of air through the duct attached to the engine is 240 m/s. Calculate the diameter of the duct?

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Soln $T = -18°C = 255\ K.$

$$P\dot{V} = \dot{m}RT \Rightarrow \dot{V} = \frac{\left(200\ \frac{kg}{sec}\right)\overset{\text{gas const.}}{(287)}(255)}{50\times10^{3}}$$

$$\dot{V} = Q = 292{,}74\ m^3/sec.$$

$$Q = VA \Rightarrow A = \frac{292{,}74}{240} = 1.219\ m^2$$

$$A = \frac{\pi}{4}d^2 \Rightarrow d^2 = \frac{4A}{\pi} = 1.553\ m^2$$

$$\Rightarrow \boxed{d = 1.246\ m}$$

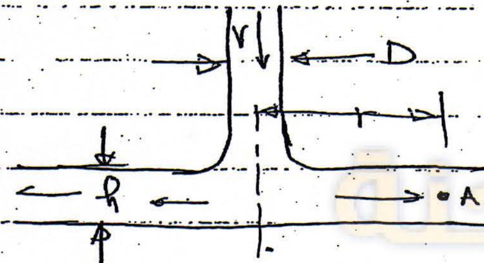
4.20 A heating and Air-conditioning engineer is designing a system to move 1100 m³ of air per hour at 100 kPa and 30°C. The duct is rectangular with cross-sectional ~~area~~ dimensions of 1 m by 20 cm. What will be the air velocit[y] in the duct?

د.الغيث للمدرسين / امتحان ثاني

soln: $Q = 1100\ \frac{m^3}{hr} \times \frac{hr}{3600\ sec} = 0{,}306\ m^3/s.$

$$Q = VA \Rightarrow V = \frac{Q}{A} = \frac{0{,}306}{(1)(0{,}2)} = 1.53\ m/[s]$$

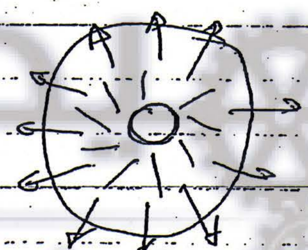
4.52 Air discharges downward in the pipe and then outward between the parallel disks. Assuming negligible density change in the air, derive a formula for the acceleration of air at point A, which is a distance r from the center of the disks. Express the acceleration in terms of the constant air discharg Q, the radial distance r, and the disk spacing h.
If D = 10 cm, h = 1 cm, and Q = 0,38 m³/sec, what are the velocity in the pipe and the acceleration at point A where r = 20 cm?



$V_r = \frac{Q}{A}$ Note that Area A ~~is~~ has a cylindrical Shape

$A = (2\pi r\, h)$

$V_r = \frac{Q}{2\pi r h}$



$a_c = V_r \frac{\partial V_r}{\partial r} = \left(\frac{Q}{2\pi r h}\right)\left(\frac{-Q}{2\pi r^2 h}\right)$

$= \frac{-Q^2}{r(2\pi r h)^2}$

For $D = 0.1\,m$, $h = 0.01\,m$ $Q = 0.38\,m^3/s$

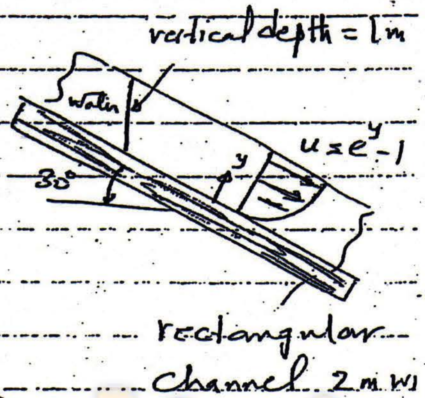
$V_{r} = \frac{0,380}{(2\pi)(0.2)(0.01)} = 30,24\,m/se$

$V_{pipe} = \frac{Q}{A_{pipe}} = \frac{0,38}{\left(\frac{\pi}{4}\right)(0.1)^2} = 48.38\,m/sec$

$a_c = -\frac{V_r^2}{r} = \frac{-(30.24)^2}{0,2} = -4572,3\,m/s^2$

4.28 If the velocity in the channel is given as $u = 10\,[e^{y} - 1]$ m/s, what is the discharge in the channel and what is the mean velocity.

Soln



$$Q = \int u\, dA$$

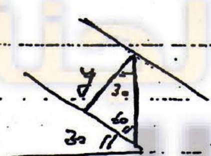
$$dA = (2)\,dy$$

$$Q = \int 10\,[e^{y} - 1]\,(2)\,dy$$

$$= 20\,[e^{y} - y]\Big|_{0}^{0,866}$$

$$= 20\,[(e^{0,866} - 0,866) - (e^{0} - 0)]$$

$$= 10,23\ m^3/sec$$



$$\bar{V} = \frac{Q}{A} = \frac{10,23}{(2)(0,866)} = 5,91\ m/sec$$

$$\cos 30 = \frac{y_{max}}{1.0\ m}$$

$$y_{max} = 0,866\ m$$

4.36 Water flows through a 20 cm pipeline at 1000 kg/min. Calculate the mean velocity in (m/s).

Soln $\dot{m} = 1000\ \frac{kg}{min} \times \frac{min}{60\ sec} = 16,67\ kg/sec$

$$\rho = \frac{\dot{m}}{Q} \Rightarrow Q = \frac{\dot{m}}{\rho} = \frac{16,67}{1000} = 0,01667\ \frac{m^3}{sec}$$

$$Q = \bar{V}A \Rightarrow \bar{V} = \frac{Q}{A} = \frac{0,01667}{\left(\frac{\pi}{4}\right)(0,2)^2} = 0,5305\ \frac{m}{s}$$