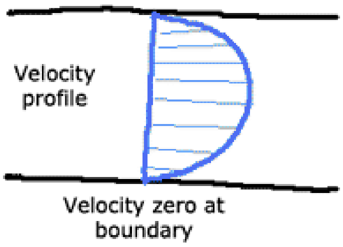
FLUID FLOW

Thursday, 18 August 2011
10:34 AM

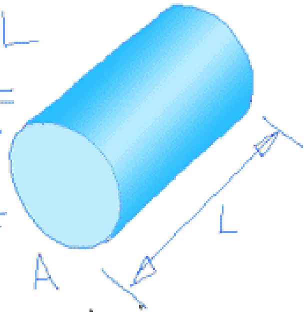
FLUID FLOW: 20100817 cH11 P 235



$V = AL$

$v = \frac{L}{s}$

$\dot{V} = \frac{V}{s} = \frac{AL}{s}$



Fluid Flow $\dot{V} = vA$ (per second)

m^3/s m/s m^2

$\dot{V}$ volume flow rate

Mass Flow rate $\dot{m} = \frac{m}{t} = vA\rho$

kg/s

$\dot{m}$ = Mass flow rate

Continuity: IN = OUT

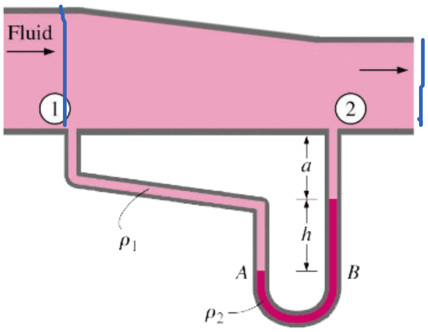
Fluid Flow (p235)

Q2: (cont)The Trans-Alaska oil pipeline carries 2.14 million barrels of crude oil (RD=0.82) in one day. (b) What is the mass flowrate? (1 barrel = 117.3478 litres)

117.3478 litres per barrel
2.14E6 per day
Volume = 2.14E6*117.3478 = 251124292 L/day
= 251124292/1000 = 251124.292 m^3/day
Per second = 251124.292 / (60*60*24) = 2.9065 m^3/s

Mass flow rate: $\rho = m / \dot{V}$ so $m = \rho * \dot{V}$
$\dot{m}$ = 0.82 *1000 * 2.9065 = 2383.33 kg/s
OIL = 820 kg/m3
Diam = 1220: Find velocity of oil.
A = Pi * 1.22^2 / 4 = 1.16898 m^2
$\dot{V} = vA$
$v = \dot{V} / A$ = 2.9065 / 1.16898 = 2.48636 m/s

Continuity Flow (p237)



Q4: Water flows at 3.5 m/s in a pipe of diameter 113 mm. The pipe transitions down to 55 mm diameter. What is the velocity in the smaller pipe?

From continuity

$\dot{V}_1 = \dot{V}_2$

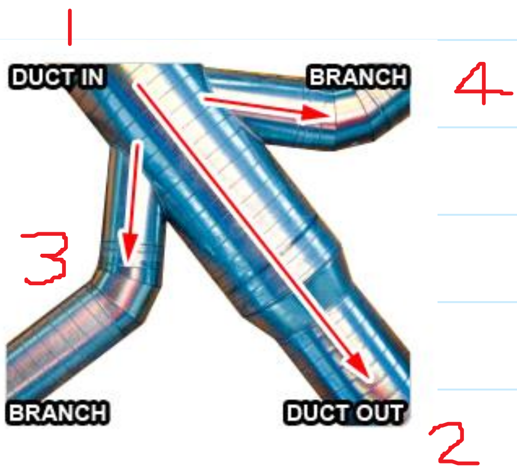
$v_1 A_1 = v_2 A_2$

$v_2 = v_1 A_1 / A_2$

$= 3.5 * (Pi*0.113\text{^}2/4) / (Pi*0.055\text{^}2/4)$

$= 14.7740$ m/s

A(0.113)



Q9: Air (Spec vol 0.89 m³/kg) flows at 7.1 m/s in a duct of 315 mm diam. After 2 branches of diam 142 mm the flow is now 5.8 m/s and the duct reduces to 268 mm diam. (a) Find total mass flow rate.

2

Spec Vol = $1 / \rho$

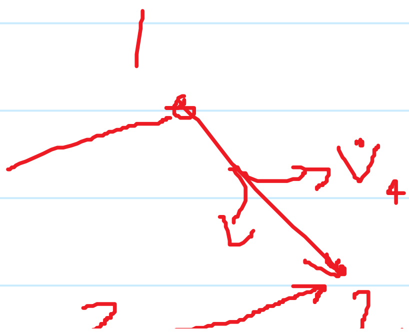
$\rho = 1 / 0.89 = 1.1236$ kg/m^3

$\dot{V}_1 = v\,A = 7.1 * Pi * 0.315\text{^}2/4 = 0.55331$ m^3/s

$\dot{m} = \rho * \dot{V} = 1.1236 * 0.55331 = 0.6217$ kg/s

Velocity in branches?

$\dot{V}_2 = v\,A = 5.8 * Pi * 0.268\text{^}2/4 = 0.32718$ m^3/s



m = ρ * V = 1.1236 * 0.55331 = 0.6217 kg/s

Velocity in branches?

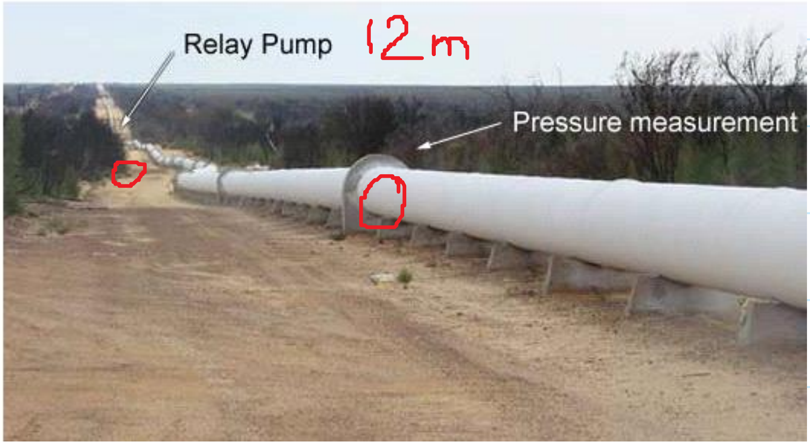
V_2 = v A = 5.8 * Pi * 0.268^2/4 = 0.32718 m^3/s

V3+V4 = V1 - V2 = 0.55331-0.32718 = 0.22613 m^3/s

V3 = 0.22613 / 2 = 0.11307 m^3/s

v = V3/A3 = 0.11307 / (Pi * 0.142^2/4) = 7.13971 m/s

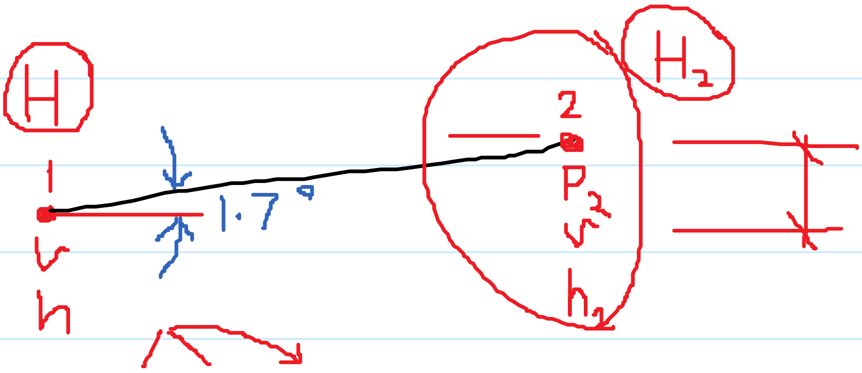
Head (p240)



$$P = \rho g h$$

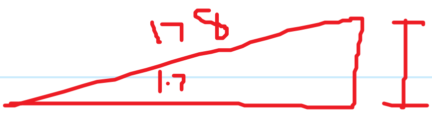
$$h = \frac{P}{\rho g}$$

Q14: A 539mm diameter pipeline carries water at 4.8 m/s up a hill sloping at 1.7 degs. After a distance of 178 m the pressure is 54 kPa. (a) What is the total head?



$$h = \frac{P}{\rho g}$$

$$h_v = \frac{v^2}{2g}$$



$H = h_p + h_v + h$

$H_1 = H_2$

Find H at point 2

(since we know the pressure there)

$H_2 = h_{p2} + h_{v2} + h_2$

$h_{p2} = 54000/(1000*9.81) = 5.5046$ m

$h_{v2} = 4.8^2 / (2*9.81) = 1.1743$ m

$h = 178*\sin(1.7) = 5.2806$ m

$H_2 = 5.5046 + 1.1743 + 5.2806 = 11.9595$ m

Bernoulli

BERNOULLI EXAMPLES

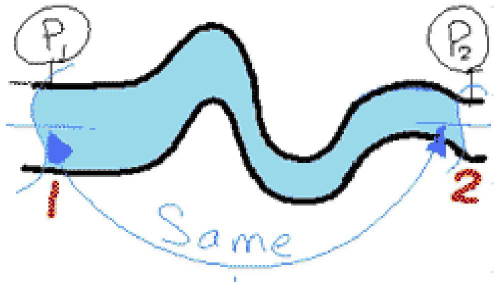
$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + h_2$$

NO FRICTION
NO HEAT LOSS

Same Height

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + \cancel{h_1} = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + \cancel{h_2}$$

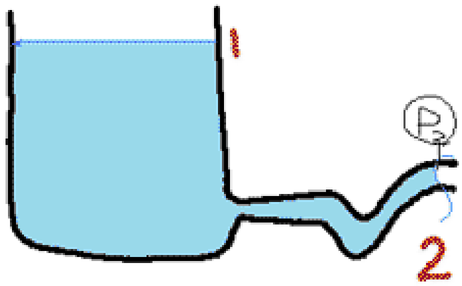
CANCEL



Surface at Atmosphere (Gauge p=0)

$$\cancel{\frac{P_1}{\rho g}} + \frac{v_1^2}{2g} + h_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + h$$

If large tank velocity = 0



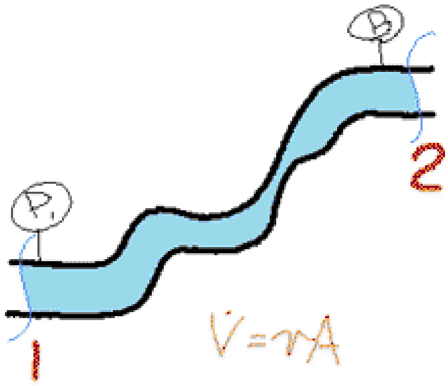
Now add nozzle to atmosphere…

$$\cancel{\frac{P_1}{\rho g}} + \cancel{\frac{v_1^2}{2g}} + h_1 = \cancel{\frac{P_2}{\rho g}} + \frac{v_2^2}{2g} + h_2$$

atm   large   atm

$$\frac{v^2}{2g} = h_1 - h_2 = \Delta h$$

$$v = \sqrt{2g\Delta h}$$



Same diameter (or parallel pipe)

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + h_2$$

EQUAL

$\dot{V} = vA$

HEAD LOSS — h (not changed) — h_v (not changed – continuity)

HEAD LOSS

- h (not changed)
- h_v (not changed – continuity)
- h_p

$\Delta p = \rho g H_L$

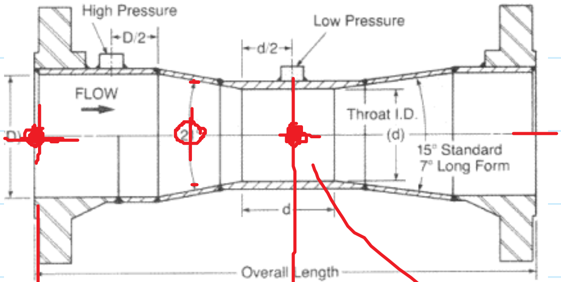
$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

Head loss

Bernoulli Eg (p241)

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

Q16: A horizontal venturi in a pipe of ID = 81 mm has a throat ID = 54 mm. Upstream the water pressure is 52 kPa and velocity is 4.2 m/s. (a) Find water velocity in the throat.



$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

Continuity:

V1 = vA = 4.2 * (Pi*0.081^2/4)

= 0.021643 m^3/s

v2 = V / A = 0.021643 / (Pi*0.054^2/4)

= 9.45018 m/s

Find Pressure at 2

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

h_{p1} = 52000 / 9810 = 5.3007 m

h_{v1} = 4.2^2/(2*9.81) = 0.8991 m

~~h_1 = ignore~~

h_{p2} =?

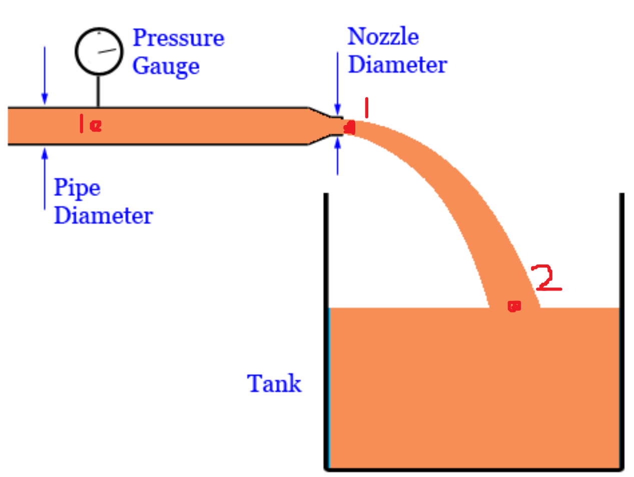
h_{v2} = 9.45018^2/(2*9.81) = 4.55178 m

~~h_2 = ignore~~

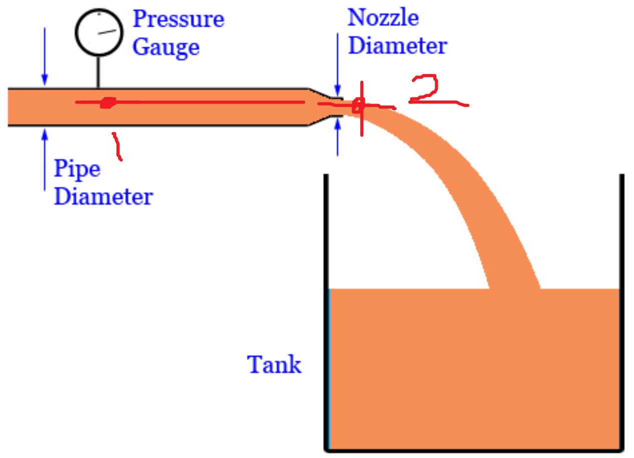
p2 / ρg = 5.3007 + 0.8991 - 4.55178 = 1.64802 m

p2 = 1.64802 * 9810 = 16167 Pa = 16.167 kPa

Q18: A 164mm diam pipe discharges 70 kg/s oil (RD=0.85) through a nozzle into a tank at atmospheric pressure. Pressure in the pipe is 128 kPa. (a) Find velocity of oil through the nozzle.



$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$



Q18: A 164mm diam pipe discharges 70 kg/s oil (RD=0.85) through a nozzle into a tank at atmospheric pressure. Pressure in the pipe is 128 kPa. (a) Find velocity of oil through the nozzle.

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

$v_1 = \dot{V}/A$ $\qquad$ $\dot{V} = vA$ $\qquad$ Area ?

Find v1 from $\dot{m} = \rho v A$

$v_1 = \dot{m}/\rho A$ = 70 / (850*Pi*0.164^2/4) = 3.8985 m/s

h_{p1} = 128000 / (9.81*850) = 15.3505 m

h_{v1} = 3.8985 ^2/(2*9.81) = 0.7746 m

h_1= ignore

Note:
Kinsky p 239 (b)

h_{p1} = 128000 / (9.81 * 850) = 15.3505 m
h_{v1} = 3.8985 ^2/(2*9.81) = 0.7746 m
~~h_1 = ignore~~
h_{p2} = 0 (atmosphere)
h_{v2} = ?
~~h_2 = ignore~~
From Bernoulli;
$v_2^2/2g = h_{p1} + h_{v1}$
= 15.3505 + 0.7746 = 16.1251 m
v_2^2 = 16.1251 * 2 * 9.81 = 316.3745 m
v_2 = 316.3745^0.5 = 17.7869 m/s

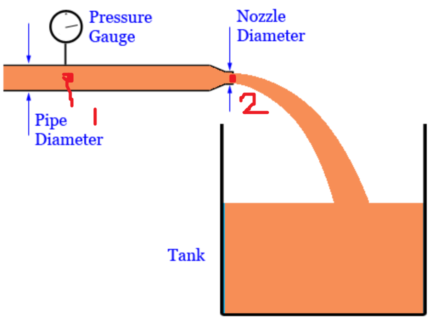
Note:
Kinsky p 239 (b)
A2 = A(0.02)
This means Area (0.02 diameter)

Q19: Find nozzle diameter;
$\dot{V}1 = \dot{V}2$
v1A1 = v2A2
A2 = v1A1/v2
= 3.8985 * (Pi*0.164^2/4) / 17.7869
= 0.00462993m^2
From $A = \pi R^2$ then $R = (A/\pi)$^0.5
Radius = (0.00462993 / Pi)^0.5 = 0.0383895m
So Diam = 2 * 0.0383895 = 0.076779 m 76.78mm

JUST FOR FUN…
What happens if we change nozzle diameter to 100mm?

Q18: A 164mm diam pipe discharges 70 kg/s oil (RD=0.85) through a nozzle into a tank at atmospheric pressure. Pressure in the pipe is ~~128 kPa~~. (a) Find velocity of oil through the nozzle.

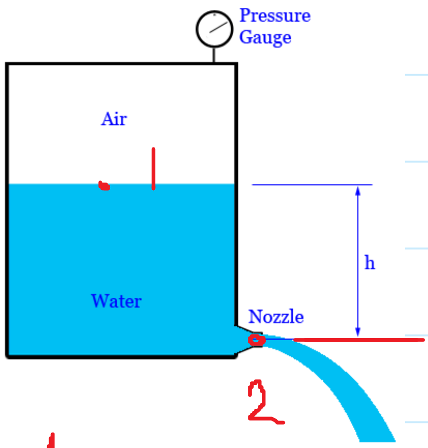
$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2 + H_L$$



v1 = 3.8985 m/s
h_{v1} = 3.8985 ^2/(2*9.81) = 0.7746 m
Continuity…v1A1 = v2A2
$\dot{V}$ = v1A1 = 3.8985*Pi*0.164^2/4 = 0.082352 m3/s
A2 = Pi*0.100^2/4 = 0.0078539 m2
v2 = $\dot{V}$/A2 = 0.082352/0.0078539 = 10.4854913 m/s
h_{v2} = 10.4854913 ^2/(2*9.81) = 5.6037476 m
From Bernoulli;
$h_{p1} + h_{v1} = h_{v2}$
h_{p1} = 5.6037476 - 0.7746 = 4.8291476 m
p1 / ρg = 4.8291476
p1 = 4.8291476 * ρg
= 4.8291476 * 850 * 9.81
= 40267.8 Pa (40kPa)

Bernoulli Eg2

Q19: A water tank is filled to h = 3.3 m above a nozzle discharging to atmospheric pressure. If the pressure gauge reads 69 kPa, find the velocity of water at the nozzle.



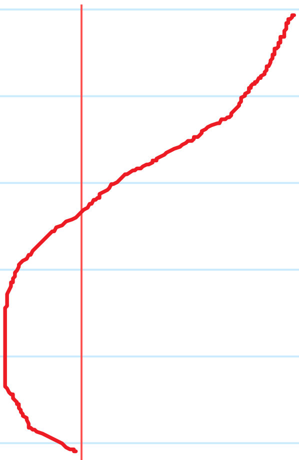
$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

7   3.3   atm

Compare points 1 & 2:

Look for surfaces, exit to atmosphere (nozzles), measured point (such as pressure gauge). Always use centreline of pipes, nozzles. Gases considered constant pressure (no height effect so ignore P = ρgh)

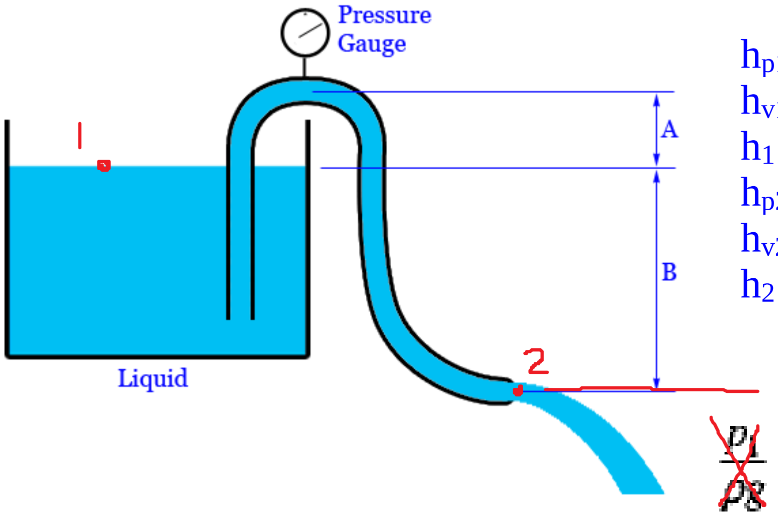
h_{p1} = 69000 / (9.81 * 1000) = 7.0336 m
*h_{p1} = 69000 / (9.81 * 1.2) = 5.8614 km (air!!!)*
h_{v1} = (ignore due to large diam tank)
h_1= 3.3m
h_{p2} = (ignore due to atmospheric pressure)
h_{v2} = 7.0336 + 3.3 = 10.3336 m
v_2 = (10.3336*(2*9.81))^0.5 = 14.2389 m/s



Bernoulli Eg3

Thursday, 18 August 2011
12:10 PM

Q21: A siphon drains petrol (RD 0.737) from a tank. Tube diam=14mm, nozzle diam=9.6mm. Dim A=1.6m and B=1.4m. (a) How long would it take to siphon 27 litres?



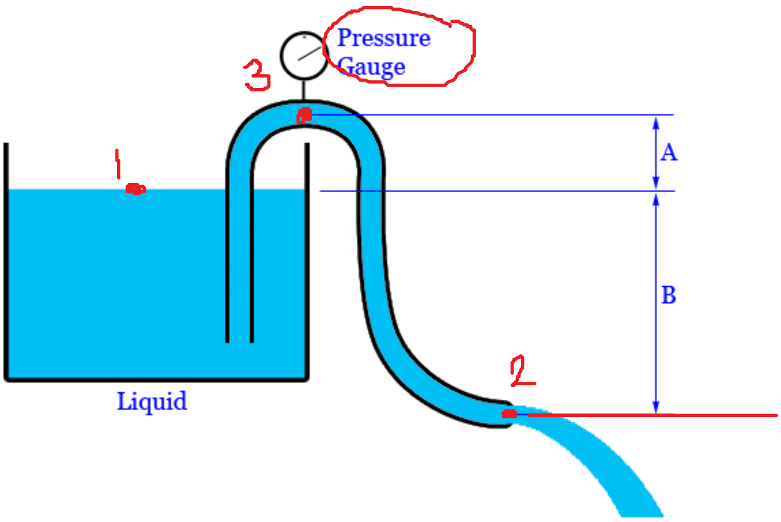
h_{p1} = 0 m
h_{v1} = 0 m
h_1 = 1.4 m
h_{p2} = 0 m
h_{v2} = ?
h_2 = 0 m

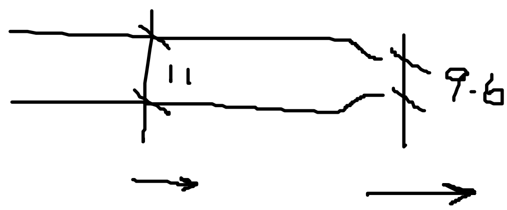
$$\frac{p_1}{\rho g}+\frac{v_1^2}{2g}+h_1=\frac{p_2}{\rho g}+\frac{v_2^2}{2g}+h_2+H_L$$

$$\frac{p_1}{\rho g}+\frac{v_1^2}{2g}+h_1=\frac{p_2}{\rho g}+\frac{v_2^2}{2g}+h_2+H_L$$

h_1 = 1.4 = v2^2 / 2g
v2 = (1.4*2*9.81) ^0.5 = 5.241 m/s
$\dot{V}$ = vA = 5.241 * Pi*0.0096^2/4 = 0.000379356 m3/s
= 0.000379356 * 1000 = 0.379356 L/s
Time = 27 / 0.379356 = 71.173252 s

Q22: (cont)A siphon drains petrol (RD 0.737) from a tank. Tube diam=14mm, nozzle diam=9.6mm. Dim A=1.6m and B=1.4m. (b) What is the pressure reading? (at the top of the tube)





$\dot{V}_3 = \dot{V}_2$

$v_3 A_3 = v_2 A_2$

Very common to use continuity before we can get

Very common to use continuity before we can get into the Bernoulli eqn.

$$\frac{p_3}{\rho g} + \frac{v_3^2}{2g} + h_3 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

3 2

Q22: (cont)A siphon drains petrol (RD 0.737) from a tank. Tube diam=14mm, nozzle diam=9.6mm. Dim A=1.6m and B=1.4m. (b) What is the pressure reading? (at the top of the tube)

$v2 = (1.4*2*9.81)$ ^0.5 = 5.241 m/s
$\dot{V}_2 = v_2A_2$ = 5.241 * Pi*0.0096^2/4 = 0.000379356 m^3/s
$\dot{V}_2 = \dot{V}_3 = v_3A_3$
$v_3 = \dot{V}_2/A_3$ = 0.000379356 / (Pi*0.014^2/4) = 2.4643 m/s

Now ready for Bernoulli!

$p_3/\rho g = v_2^2/2g - v_3^2/2g - h_3$
= 5.241^2/(2*9.81) - 2.4643^2/(2*9.81) - (1.4+1.6) = -1.9095 m

This shows that the pressure head has to make up for the negative height below the surface (above) of 1.6m PLUS there is 0.3m worth of velocity head!

p_3 = -1.9095 * 0.737 * 1000 * 9.81 = -13805.6 Pa (-13.806 kPa)

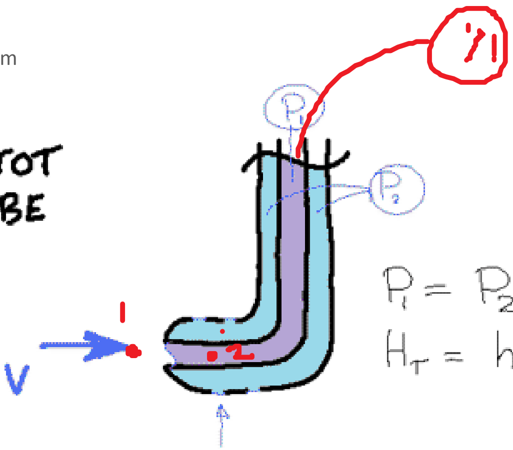
Toricelli Equation:
PE = KE
$mgh = 0.5mv^2$
$2gh = V^2$
V = sqrt(2gh)

And some more...

Tuesday, 23 August 2011
6:23 PM

Pasted from

PITOT TUBE



$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2 + h_L$$

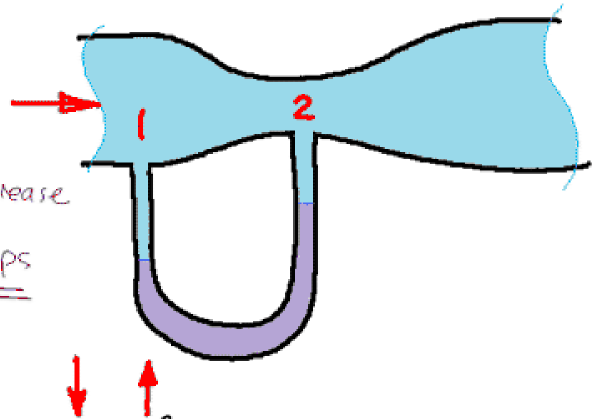
$P_1 = P_2 + P_{vel}$ (pressure)

$H_T = h_p + h_v$ (head)

$p_2 = \rho v_1^2 / 2$

$v_1 = (2p_2 / \rho)\text{^}0.5$

Venturi



Area decrease
→ Velocity increase
→ Pressure drops

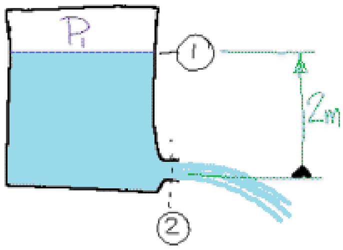
$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + h_2$$

Ex 11.3 p244

$P_1 = 50\ \text{kPa}$

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + h_2$$

big, atm, datum



$$\frac{50E3}{1000 \times 9.81} + 2 = \frac{v_2^2}{2 \times 9.81}$$

$$5.0968 + 2 = \frac{v_2^2}{2 \times 9.81}$$

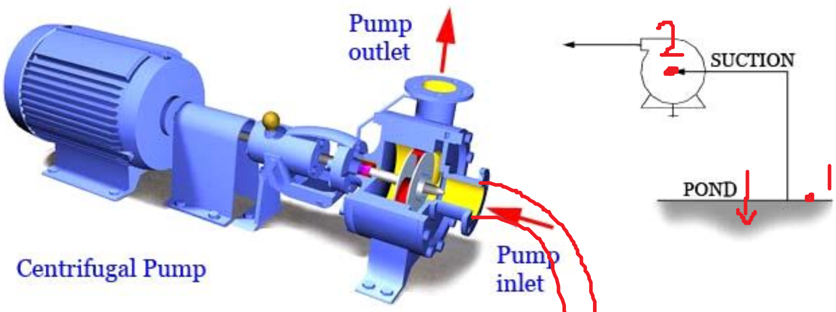
$$139.24 = v_2^2 \rightarrow V_2 = 11.8\ \text{m/s}$$

Head Loss

Tuesday, 6 August 2013
6:58 PM

Q20: Salt water (RD=1.04) is pumped at 28.1 L/s through a pipe (ID=80 mm) from a pond 2.7 m below the pump. Head loss in suction line is 1.6 m. Find gauge pressure at pump inlet.

H_L = 1.6m
h_2 = 2.7m



Centrifugal Pump

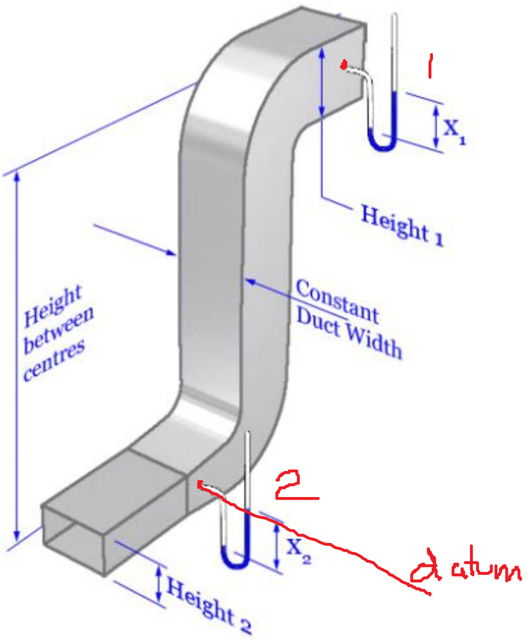
$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

V = vA
v2 = V/A

Duct

Tuesday, 23 August 2011
6:33 PM

Q23: Air in a 327mm square inlet flows at 14 m/s where a water manometer X1=214 mm. The duct reduces to 195mm tall at the outlet 13m below. (Air Spec Vol = 0.85m³/kg). (a) Find mass flow rate.



$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

Mass flow rate... (kg/s)

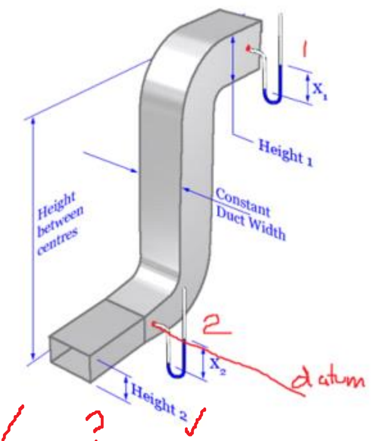
$\dot{V} = vA$

$\dot{m} = \rho\dot{V} = \rho vA$

Density = $1/\nu$, = 1/0.85 = 1.1765 kg/m³

$\dot{m}$ = 1.1765 * 14 * (0.327*0.327) = 1.7612 kg/s

Q24: (cont)Air in a 327mm square inlet flows at 14 m/s where a water manometer X1=214 mm. The duct reduces to 195mm tall at the outlet 13m below. (Air Spec Vol = 0.85m³/kg). (b) Find velocity at 2



Continuity: $v_1A_1=v_2A_2$

$v_2 = v_1A_1/A_2$

= 14*0.327^2/(0.327*0.195)

= 23.4769 m/s

Q25: (cont)Air in a 327mm square inlet flows at 14 m/s where a water manometer X1=214 mm. The duct reduces to 195mm tall at the outlet 13m below. (Air Spec Vol = 0.85m³/kg). (c) Manometer reading at 2

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

h_p (m) working fluid is AIR !

Handy Hints:

Manometer: P = ρgh

"Specific" = per kg

" " = per second

Manometer: (water)

P_1 = ρgh = 1000*9.81*0.214 = 2099.34 Pa

Air at point 1...

h_p = 2099.34/(1.1765*9.81) = 181.8955 m

h_v = 14^2/(2*9.81) = 9.9898 m

h = 13 m

Total Head H_1 = 181.8955 + 9.9898 + 13

= 204.8853 m

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + H_L$$

h_{v2} = (23.4769^2)/(2*9.81) = 28.092 m

Then re-arrange Bernoulli eqn...

h_{p2} = 181.8955 + 9.9898 + 13 -28.092 = 176.7933 m

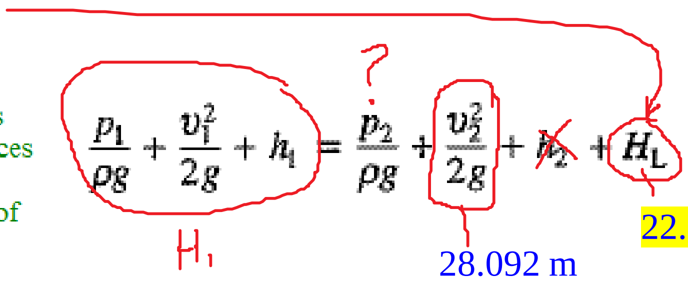
Convert pressure head to pressure...

$p_2 = h_{p2}*\rho g$ = 176.7933*(1.1765*9.81) = 2,040.5 Pa
Now convert to manometer reading…
$P_1 = \rho g h$ = 1000*9.81*??? = 2040.5 Pa
...

Head loss of 11% means 11% of the TOTAL HEAD. and Bernoulli's eqn (*as distinct from Bernanke's eqn*) must balance on both sides...
H1 = H2.
$H = h_p + h_v + h$
$= p/\rho g + v^2/2g + h$

At point 1...
h_p = 2099.34/(1.1765*9.81) = 181.8955 m
h_v = 14^2/(2*9.81) = 9.9898 m
h = 13 m
Total Head H_1 = 181.8955 + 9.9898 + 13
= 204.8853 m
11% of H = 204.8853 * 0.11 = 22.5374 m

Q27: (cont)Air in a 327mm square inlet flows at 14 m/s where a water manometer X1=214 mm. The duct reduces to 195mm tall at the outlet 13m below. (Air SV=0.85m³/kg). (e) Find manometer 2 with head loss of 11%



22.5374 m
28.092 m
204.8853