UNIVERSITY OF JOHANNESBURG

PROGRAM : NATIONAL DIPLOMA
ENGINEERING: MECHANICAL

SUBJECT : **FLUID MECHANICS III**

CODE : **IMF313**

DATE : 18 July 2018

DURATION : 8:00 – 11:00

EVALUATION : SUPPLEMENTARY EXAMINATION

TOTAL MARKS : 100

EXAMINER : Mr. O.J KAELO

MODERATOR : Dr. L.K TARTIBU

NUMBER OF PAGES : 8 PAGES (including cover page)

INSTRUCTIONS :

1. ANSWER ALL QUESTIONS NEATLY.
2. SHOW ALL CALCULATIONS
3. ANSWERS WITHOUT UNITS WILL NOT BE CONSIDERED
4. NUMBER YOUR ANSWERS STRICTLY ACCORDING TO THE QUESTIONS
5. WHERE OMITTED, ASSUME THE NECESSARY CONSTANTS FOR YOUR SOLUTIONS

REQUIREMENTS: CALCULATORS

QUESTION 1

Using "Reynolds Transport Theorem", determine the force experienced by the bolts on the nozzle.

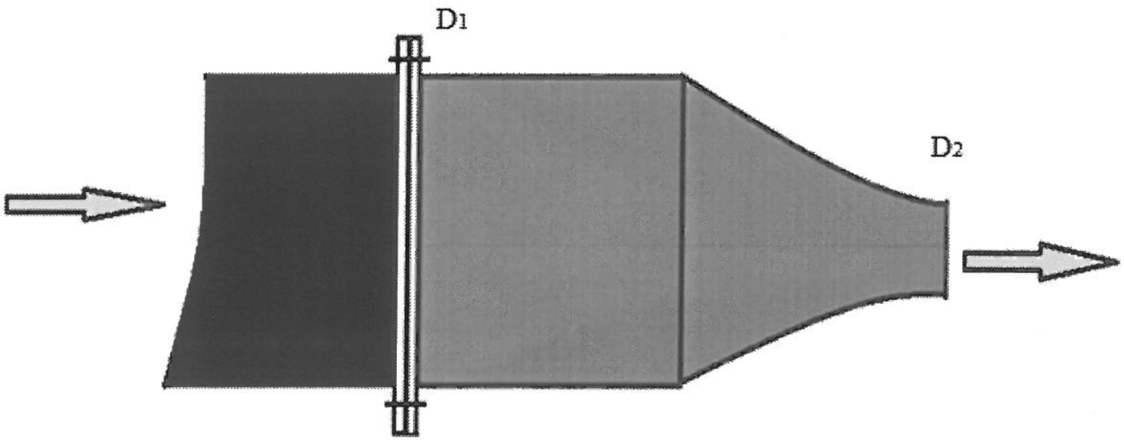


Figure 1

Assumptions

- The Flow is Steady
- The flow is Incompressible
- The Flow is Inviscid
- Neglect effects of Gravity

Properties

- The density is $\rho = 1000$ kg/m^3
- Flow rate Q_1=0.25 m^3/s
- The diameters are D_1=400mm and D_2=200mm
- Pressure at state 1 (entry) and 2 (exit) P_1=95Kpa and P_2= P_{atmos}=101Kpa

[30]

QUESTION 2

Two tanks with three throttle valves and a pump connected via a cast iron pipe with relative roughness of 0.2mm. $Z_S = 2m \text{ and } Z_D = 8m$

Properties

- The pipe diameter is 40 mm and the total Length is 150m
- The dynamic viscosity of the fluid is $2.1 \times 10^{-3} kg/m.s$ and Q_1=0.025 m^3/s
- Regular 90° elbow: $k - value = 0.4\ each$. Throttle valves $k - value = 0.25\ each$
- $and\ the\ K - values\ at\ inlet\ and\ outlet\ of\ the\ two\ tanks\ is\ 0.2\ each$

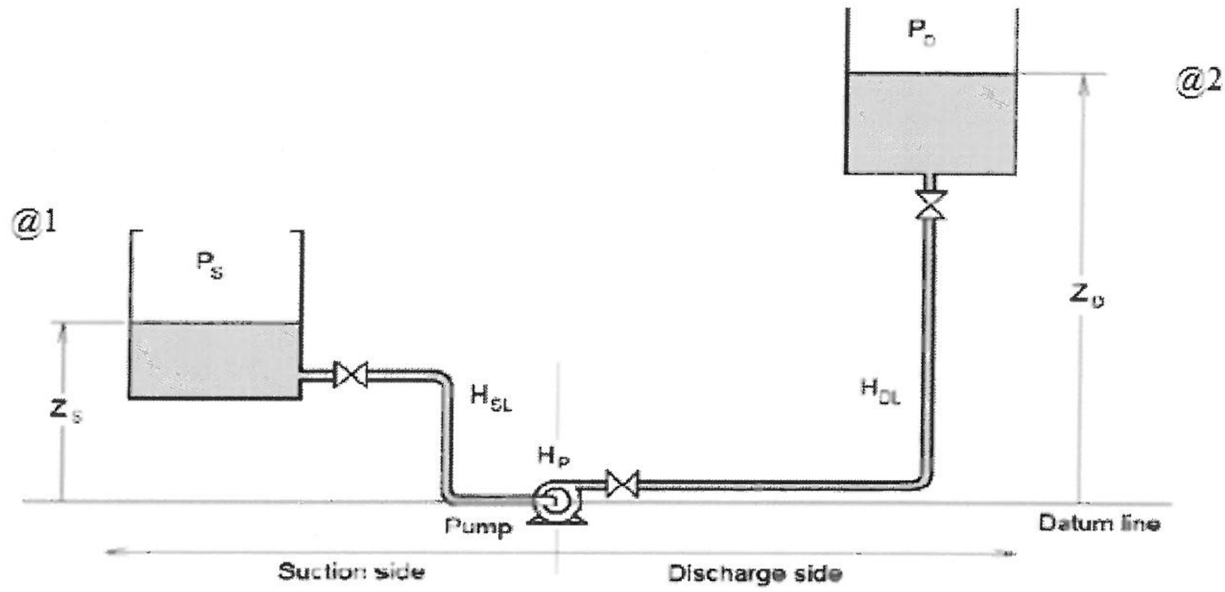


Figure 2

- The density of water is ρ = 1000 kg/m³

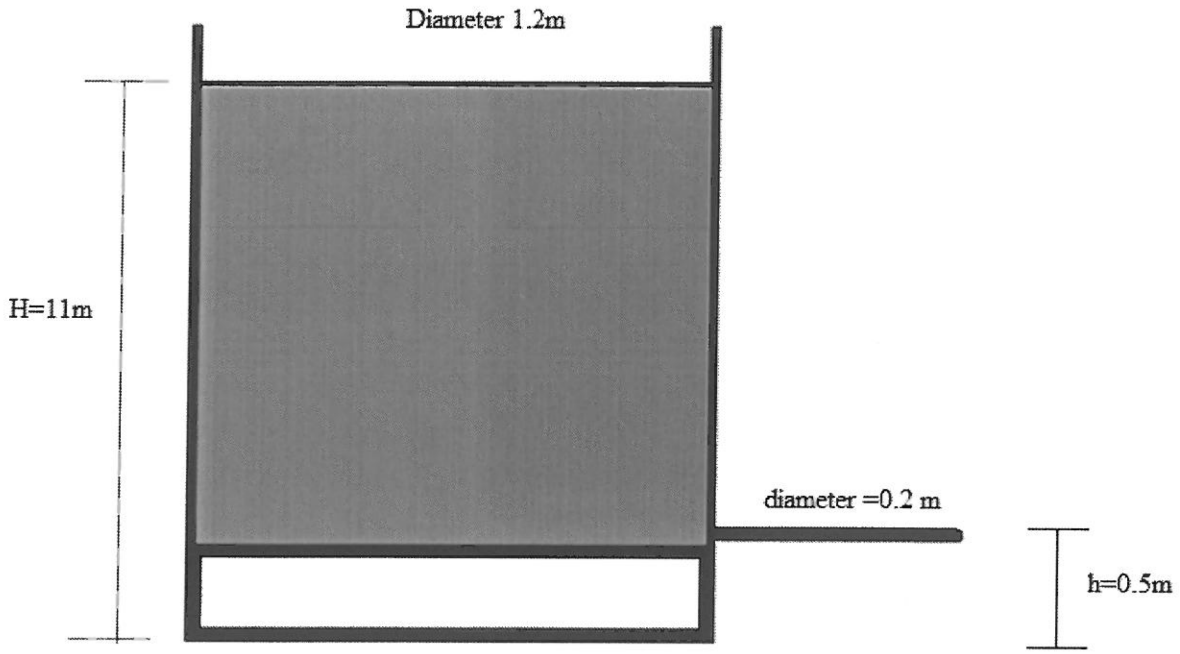
Determine:

a. The nature of the flow
b. The friction factor
c. The pump head

[20]

QUESTION 3

A container is fitted with a pipe and allowed to drain out. Determine the time it will take to empty the tank



Assumptions

- Flow is Inviscid
- Flow follow a streamline
- Incompressible

Properties

- Diameter of container is 1.2 meter and Height of the water in the container is 11 meters
- Diameter of pipe is 0.2 meters and Height of pipe from datum is 0.5 meters

[20]

QUESTION 4

In line with the growing need for clean energy, a wind turbine is used to supplement a community library. They require a power coefficient of 35%. The combine efficiency of the gearbox and generator is 90%. The HAWT wind turbine has a diameter disc of 13m. On a windy day, the wind speed is 9 m/s. Air density is 1.2 kg/m^3 at 20°C.

a) Calculate the electrical power generated. [10]

Hydraulic transient (water hammer) may cause disasters in pressurized liquid systems:

b) List three problems caused by water hammer. [6]

c) List two causes of "water hammer" [4]

[20]

QUESTION 5

Define the following.

a) Pump

b) Fan

c) Blower

d) Compressor

e) Turbo Machines

[10]

Fluid Power

$$Power = pQ = \rho g h Q$$

Momentum Equation

$$F_x = \rho Q(v_{2x} - v_{1x}) \quad F_y = \rho Q(v_{2y} - v_{1y})$$

Vortex Motion and Radial Flow

$$\frac{dH}{dr} = \frac{v^2}{g\,r} + \frac{v}{g}\frac{dv}{dr}$$

$$Forced\ Vortex: \quad v = \omega\, r \qquad H = \frac{p}{\rho g} + \frac{\omega^2 r^2}{2g} + z \qquad p_2 - p_1 = \frac{\rho\,\omega^2\left(r_2^{\,2} - r_1^{\,2}\right)}{2} \qquad Surface: \ z = \frac{\omega^2 r^2}{2g} + C$$

$$Free\ Vortex: \quad v = \frac{C}{r} \qquad \frac{p_1 - p_2}{\rho g} = \frac{C^2}{2g}\left(\frac{1}{r_2^2} - \frac{1}{r_1^2}\right) \qquad Surface: \ H - z = \frac{C^2}{2 g r^2}$$

$$Compound\ Vortex: \quad Total\ Depression\ z + d = \frac{\omega^2 r^2}{g}$$

$$Spiral\ Vortex: \quad v_A\, r_A = v_B\, r_B$$

$$Radial\ Flow: \quad Q = 2\pi R t v \qquad \frac{p_1 - p_2}{\rho g} = \frac{Q^2}{8\pi^2 t^2 g}\left(\frac{1}{r_2^2} - \frac{1}{r_1^2}\right)$$

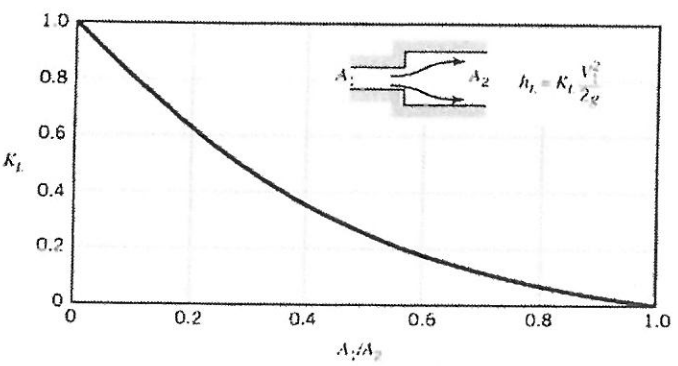
Loss Coefficients for of Pipe Fittings

Bends		**Valves**	
Regular 90° Flanged	0,3	Check/Non-Return Valve (ball)	3,5
Regular 90° Threaded	1,5	Check/Non-Return Valve (swing)	2,5
Long Radius 90° Flanged	0,2	Globe Valve (Fully Open)	8
Long Radius 90° Threaded	0,7	Gate Valve Fully Open	0,2
Regular 45° Threaded	0,4	Gate Valve Fully ¾ open	1,2
Long Radius 45° Flanged	0,2	Gate Valve Fully ½ Open	6
Long Radius 45° Threaded	0,4	Gate Valve Fully ¼ Open	24
Various		Butterfly Valve Fully Open 90°	0,9
Pipe Union/Coupling	0,08	Butterfly Valve 60°	4,6
Tee – straight through	0,05	Butterfly Valve 45°	10
Tee – branch flow	1,8	Butterfly Valve 30°	90

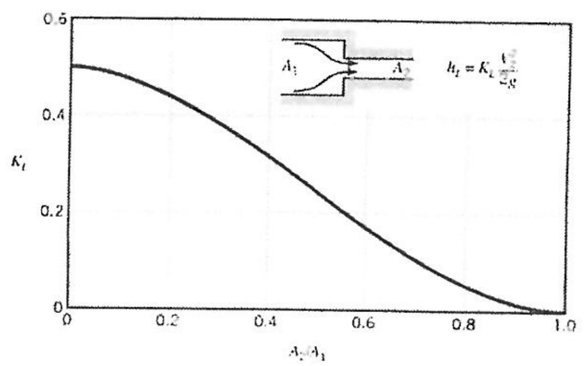
Pipe Roughness (mm)

Cast Iron	0.25
Concrete	3
Copper	0.12
Drawn Tubing	0.0015
Epoxy Coated Steel	0.065
HDPE (High Density Polyethylene)	0.007
PVC	0.0057
Glass	smooth
Galvanized Iron	0.15
Welded Steel	0.046
Riveted Steel	4

Sudden Expansion



Sudden Contraction



Fluid Mechanics 3: Formula and Datasheet 1

Physical Properties of Common Liquids at 20°C and 1 atmosphere

Liquid	Density (ρ) kg/m³	Dynamic Viscosity (μ) kg/ms	Bulk Modulus (K) GPa
Water (20°C)	998.2	1,005 x 10^{-3}	2.2 GPa
Sea Water	1025	Same as Fresh water	Same as Fresh water
Oil (SAE10) at 38°C	915	29,0 x 10^{-3}	
Mercury	13546	1,55 x 10^{-3}	26,2 GPa
Petrol	510	0,51 x 10^{-3}	
Benzene	879	0,647 x 10^{-3}	1,10 GPa
Alcohol, ethyl	789	1.197 x 10^{-3}	1.32 GPa
Air	1.205	0.018 x 10^{-3}	

Classification of Flow

$$\tau = \mu \frac{dv}{dy} \qquad \upsilon = \frac{\mu}{\rho}$$

$$R_e = \frac{\rho v d}{\mu} = \frac{v d}{\upsilon} \qquad HR = \frac{A}{WP}$$

Laminar Flow

Parallel Surfaces (Stationary)

$$v = \frac{p}{2\mu L}\left(\frac{h^2}{4} - y^2\right) \quad Q = \frac{pbh^3}{12\mu L}$$

$$\textit{Viscous Shear at Walls } \tau = \frac{6\mu v_m}{h}$$

Parallel Surfaces (One moving)

$$v = -\frac{p}{2\mu L}\left(y^2 - hy\right) + \frac{u}{h}(h - y)$$

$$Q = b\left(\frac{uh}{2} + \frac{h^3}{12\mu}\frac{p}{L}\right)$$

$$\textit{Viscous Shear at Walls } \tau = \frac{\mu u}{h} \pm \frac{h}{2}\frac{p}{L}$$

Pipes

$$v = \frac{p}{4\mu L}\left(\frac{d^2}{4} - r^2\right) \quad Q = \frac{\pi p d^4}{128\mu L}$$

$$f = \frac{16}{R_e}$$

Turbulent Flow in Pipes

$$v = v_m\left[1 + 1{,}43\sqrt{f} + 2{,}15\sqrt{f}\,\log_{10}\left(1 - \frac{r}{d/2}\right)\right]$$

$$v_{\max} = v_m\left(1 + 1{,}43\sqrt{f}\right)$$

$$h_f = \frac{4fl}{d}\frac{v_m^2}{2g} \approx \frac{fl}{3d^5}Q^2$$

$$f = 0{,}0079\,R_e^{-1/4} \quad \textit{Blasius} \quad 3000 < R_e < 10^5$$

$$\frac{1}{\sqrt{4f}} = 2\log_{10}\left(\frac{R_e}{\sqrt{f}}\right) - 0{,}8 \quad \textit{Prandtl von Karmen} \quad R_e > 3\times10^6$$

$$f = 0{,}001375\left[1 + \sqrt[3]{20000\frac{k}{d} + \frac{1\times10^6}{R_e}}\right] \quad \textit{Moody} \quad 4000 < R_e < 10^7$$

Water hammer

$$c = \sqrt{\frac{K_e}{\rho}} \qquad t_{wave} = \frac{l}{c}$$

$$\Delta P = v\sqrt{\rho K_e} = \rho v c$$

$$\frac{1}{K_g} = \frac{1}{K_f} + \left[\frac{V_{air}}{V_{fluid}} x \frac{1}{d_p}\right] \quad \text{Air in the fluid}$$

Anchored Thin Walled Elastic Pipes

$$K_e = \frac{1}{\left(\frac{d}{tE} + \frac{1}{K}\right)} \qquad \varepsilon_1 = 0$$

Non-Anchored Thin Walled Elastic Pipes

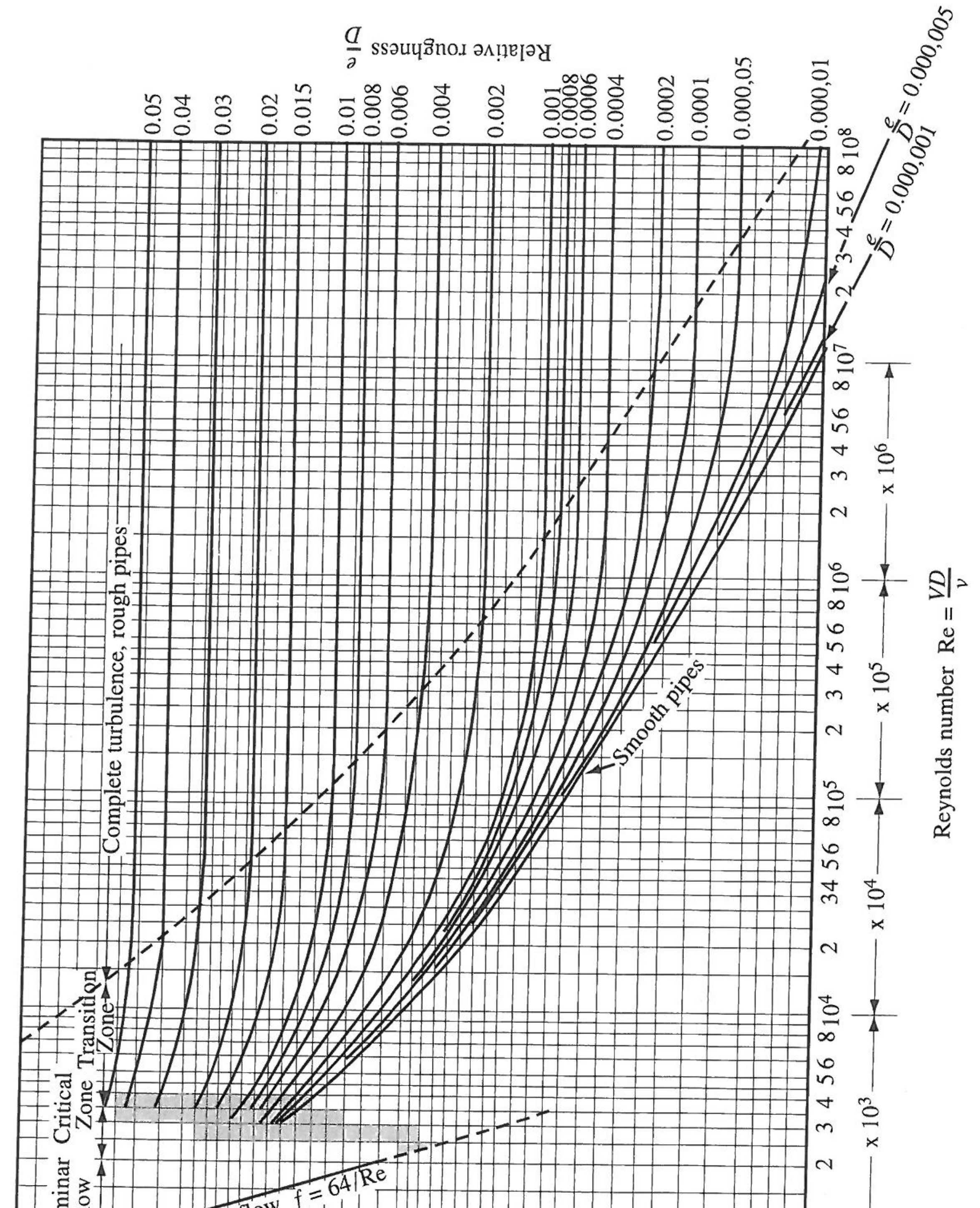
$$K_e = \frac{1}{\left(\frac{d(5 - 4\upsilon)}{4tE} + \frac{1}{K}\right)} \qquad \sigma_1 = 0$$

Anchored Thick Walled Elastic Pipes

$$K_e = \frac{d^2}{\left(\frac{d^2}{K} + \frac{(D + d)^3}{8tE}\right)}$$

$$\textit{Longitudinal Stress} = \sigma_1 = \sigma_L = \frac{\Delta P\, d}{4t} \qquad \textit{Hoop Stress} = \sigma_2 = \sigma_H = \frac{\Delta P\, d}{2t}$$

$$\textit{Longitudinal Strain} = \varepsilon_1 = \frac{1}{E}(\sigma_1 + \upsilon\,\sigma_2) \qquad \textit{Hoop Strain} = \varepsilon_2 = \frac{1}{E}(\sigma_2 + \upsilon\,\sigma_1)$$



From L. F. Moody, "Friction factors for Pipe Flow," *Trans.* A.S.M.E., Vol. 66, 1944, with permission.

Figure 2.2 The Moody diagram for the Darcy-Weisbach friction factor *f*.