UNIVERSITY OF JOHANNESBURG

PROGRAM	:	NATIONAL DIPLOMA *ENGINEERING: MECHANICAL*
SUBJECT	:	**FLUID MECHANICS III**
CODE	:	**IMF313**
DATE	:	29 MAY 2018
DURATION	:	12:30 – 15:30
EVALUATION	:	JUNE 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
2. ANSWERS WITHOUT UNITS WILL NOT BE CONSIDERED
3. NUMBER YOUR ANSWERS STRICTLY ACCORDING TO THE QUESTIONS
4. WHERE OMITTED, ASSUME THE NECESSARY CONSTANTS FOR YOUR SOLUTIONS

REQUIREMENTS: CALCULATORS

QUESTION 1

Using "Reynolds Transport Theorem", determine the linear velocity of the water jet caused by gravity (See Figure 1). The water exits the nozzle at 3 m/s. Make reasonable engineering assumptions where necessary.

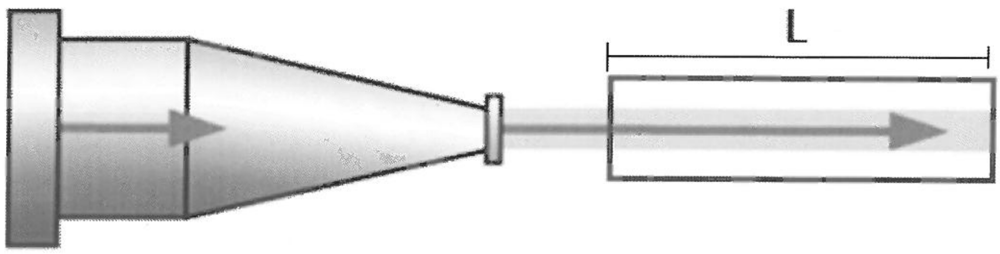


Figure 1

Properties

- The length "L" is 500mm
- Nozzle exit velocity "U" is 3 m/s

[15]

QUESTION 2

With the aid of a sketch (for marks). Derive an expression for calculating the time it takes to drain a tank. Use Torricelli's theorem for a tank. Assume the fluid is incompressible, inviscid, and follows a streamline. The fluid is from a tank with height "H" and Diameter "D". A pipe of diameter "d" is fitted at a distance "h" from the datum line.

[20]

QUESTION 3

The following tank of kerosene is 0.5m high. The tank has a 4mm diameter pipe with length of 1 meter at an incline of 30^0.

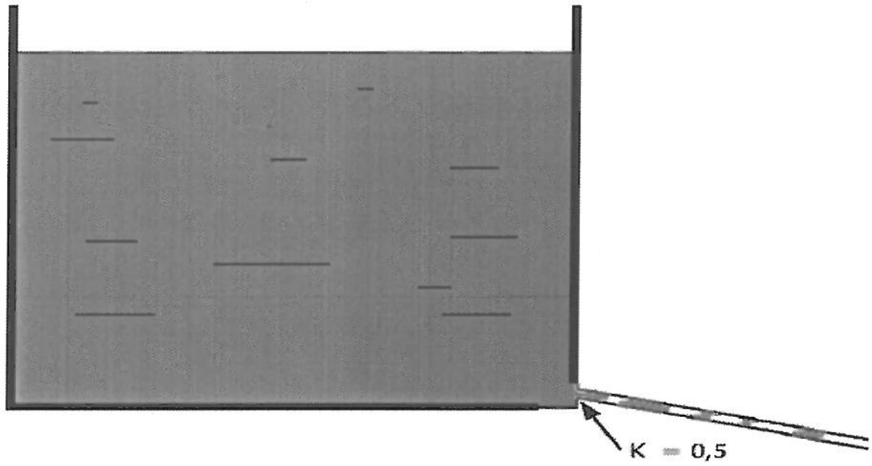


Figure 2

Properties

- Height of the tank 0.5 m
- The density of water is $\rho = 1000\ kg/m^3$
- The diameter pipe 4mm and Length 1 meter
- Kinematic Viscosity $3 \times 10^{-6} m^2/s$
- Specific gravity 0.8

a) Determine the total height the water will travel, taking the datum line at end of the 1-meter pipe [5]

b) Determine the density of kerosene [3]

c) Determine if the flow is turbulent or lamina [10]

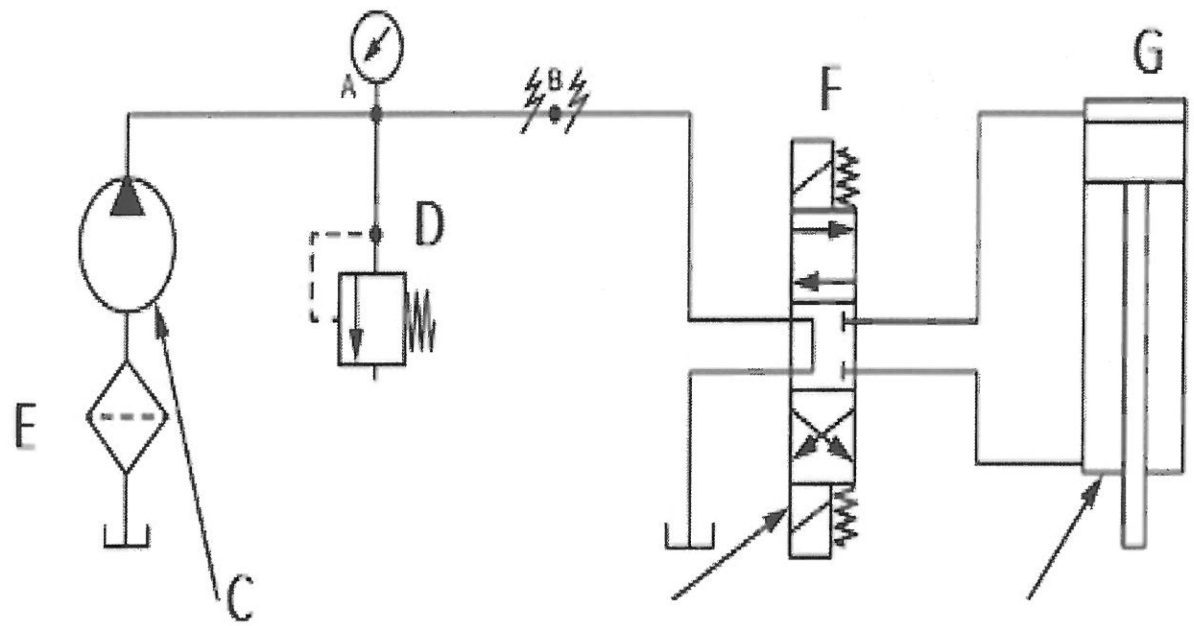
d) Determine the flowrate within the pipe [5]

[23]

QUESTION 5

The hydraulic circuit below has the following components.

- Gauge pressure point
- Relief Valve
- Hydraulic Pump
- Inlet to container
- 4 way valve
- Cylinder



a) Identify the components labelled A, C, D, E, F and G also give a brief description of each.

[12]

End

Fluid Mechanics 3: Formula and Datasheet 1

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

Liquid	Density (ρ) kg/m^3	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

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

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

Laminar Flow

Parallel Surfaces (Stationary)

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

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

Parallel Surfaces (One moving)

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

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

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

Pipes

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

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

Turbulent Flow in Pipes

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

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

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

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

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

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

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

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

Anchored Thick Walled Elastic Pipes

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

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

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

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

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

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

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

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

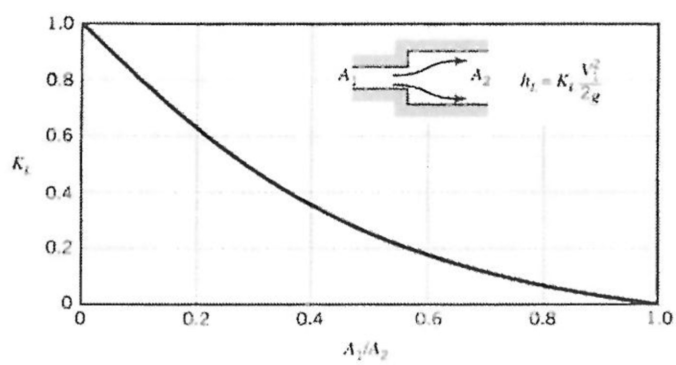
Loss Coefficients for of Pipe Fittings

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

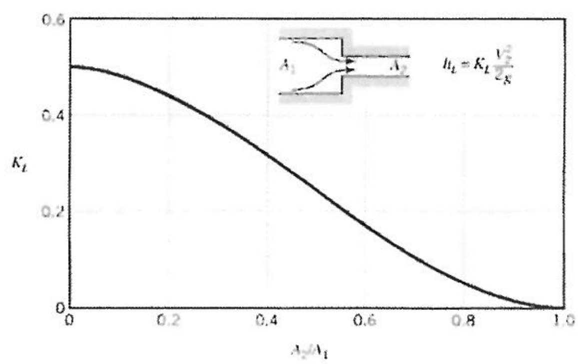
Pipe Roughness (mm)

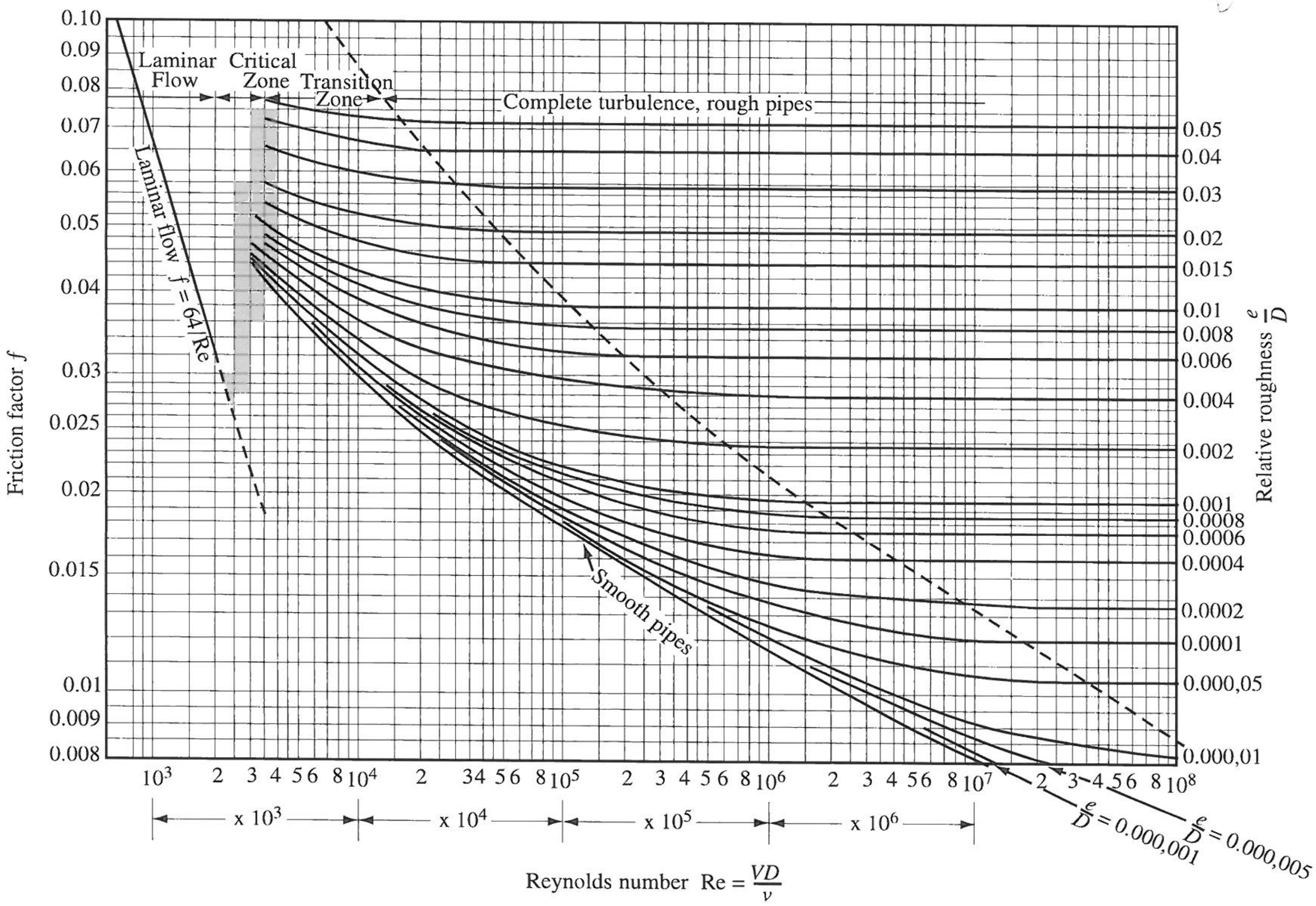
Cast Iron	0.25
Concrete	3
Copper	0.12
Drawn Tubing	0.0015
Epoxy Coated Steel	0.065
HDPE (High Density Polyethylene)	0.007
PVC	0.0057
Glass	smooth
Galvanized Iron	0.15
Welded Steel	0.046
Riveted Steel	4

Sudden Expansion



Sudden Contraction





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.