UNIVERSITY OF JOHANNESBURG

PROGRAM	:	BACCALAUREUS INGENERIAE *CIVIL ENGINEERING*
SUBJECT	:	**FLUID MECHANICS 2A**
CODE	:	**STR2A11**
DATE	:	WINTER EXAMINATION 06 JUNE 2016
DURATION	:	(SESSION 2) 12:30 - 15:30
WEIGHT	:	50 : 50
TOTAL MARKS	:	100

ASSESSOR	:	Mr TT Mafokoane Dr MO Dinka	
MODERATOR	:	Dr S Nyende-Byakika	FILE NO: STR2A 2016
NUMBER OF PAGES	:	3 PAGES AND 3 ANNEXURES	

INSTRUCTIONS	:	ONLY ONE POCKET CALCULATOR PER CANDIDATE MAY BE USED. QUESTION PAPERS MUST BE HANDED IN.
REQUIREMENTS	:	2 ANSWER BOOKLETS

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SHOW ALL THE STEPS FOR CALCULATIONS CLEARLY.

QUESTION 1 [40]

a) Differentiate between the following: **(10)**

i. Fluids and solids
ii. Mass density and weight density
iii. Gage pressure and absolute pressure
iv. Dynamic viscosity and kinematic viscosity
v. Fluid dynamics and fluid kinematics

b) State the Pascal`s laws. **(4)**

c) Define the following: **(10)**

i. Compressibility
ii. Rheology
iii. Metacenter
iv. Viscosity index
v. Metacentric height

d) State the condition of stability for i) submerged bodies, and ii) floating bodies **(4)**

e) Describe the principle of operation of the following devices: **(12)**

i. Barometer
ii. Standard Calibrated Glass Capillary Viscometer
iii. Turbine flowmeter
iv. Ultrasonic flowmeter
v. Pilot tube
vi. Hot-wire anemometer

QUESTION 2 [10]

a) The pressure of water flowing through a pipe is measured by the arrangement shown in *Fig. 1*. For the values given, calculate the pressure in the pipe. **(5)**

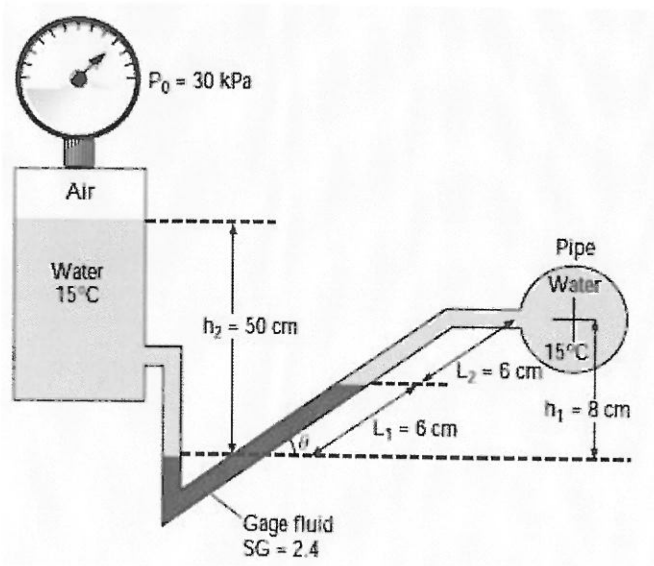


Fig. 1: Questions 2

b) A circular plate 3.0 m diameter is immersed in water in such a way that its greatest and least depth below the free surface are 4 m and 1.5 m respectively. Determine the magnitude of the resultant force on one face of the plate and position of the center of pressure. **(5)**

QUESTION 3 [15]

The speed of propagation C of a capillary wave in deep water is known to be a function only of density ρ, wavelength λ, and surface tension σ. Determine the functional relationship between the propagation speed, and the independent variables using a) the first principle, and b) the Buckingham π Theorem. c) For a given density and wavelength, how does the propagation speed change (in percentage) if the surface tension is doubled?

QUESTION 4 [15]

Assuming frictionless, incompressible, one-dimensional flow of water through the horizontal tee connection sketched in *Fig. 2*, estimate values of the x and y components of the force exerted by the tee on the water. Each pipe has an inside diameter of 1 m.

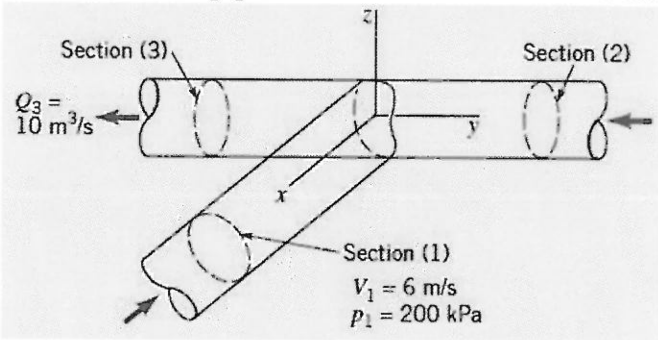


Fig. 2: Question 4

QUESTION 5 [20]

Refer to *Fig. 3*. Water at 80°C ($\gamma = 9.53 \times 10^3$, $\rho = 971$, and $\mu = 3.5 \times 10^{-4}$) is being pumped from the tank at the rate of 475 L/min. Compute the pressure at the inlet of the pump. For DN 65 Schedule 40 steel pipe, inside diameter = 62.7 mm and flow area = 3.09×10^{-3} m^2.

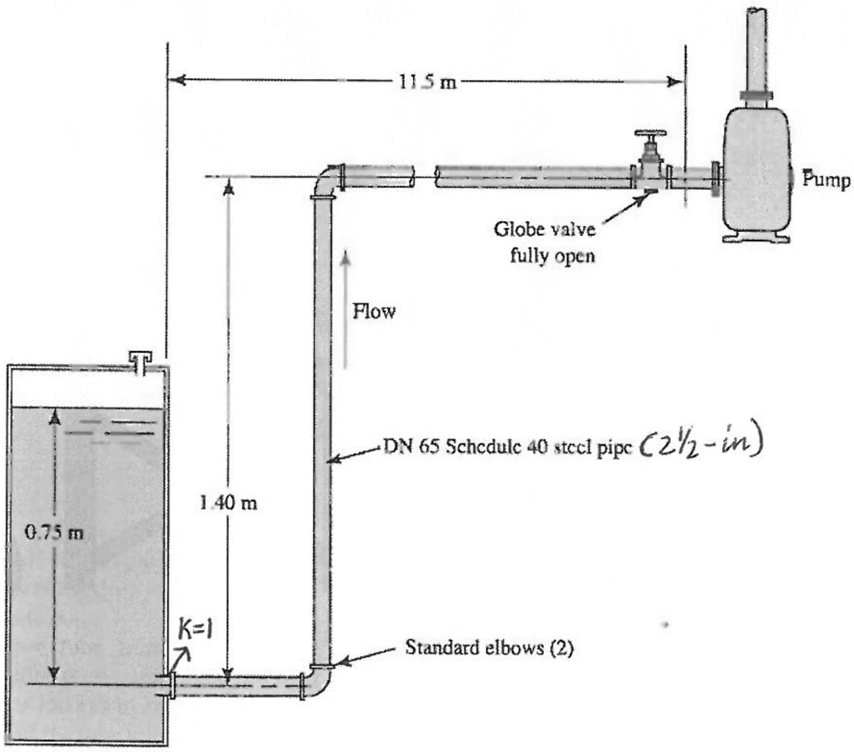
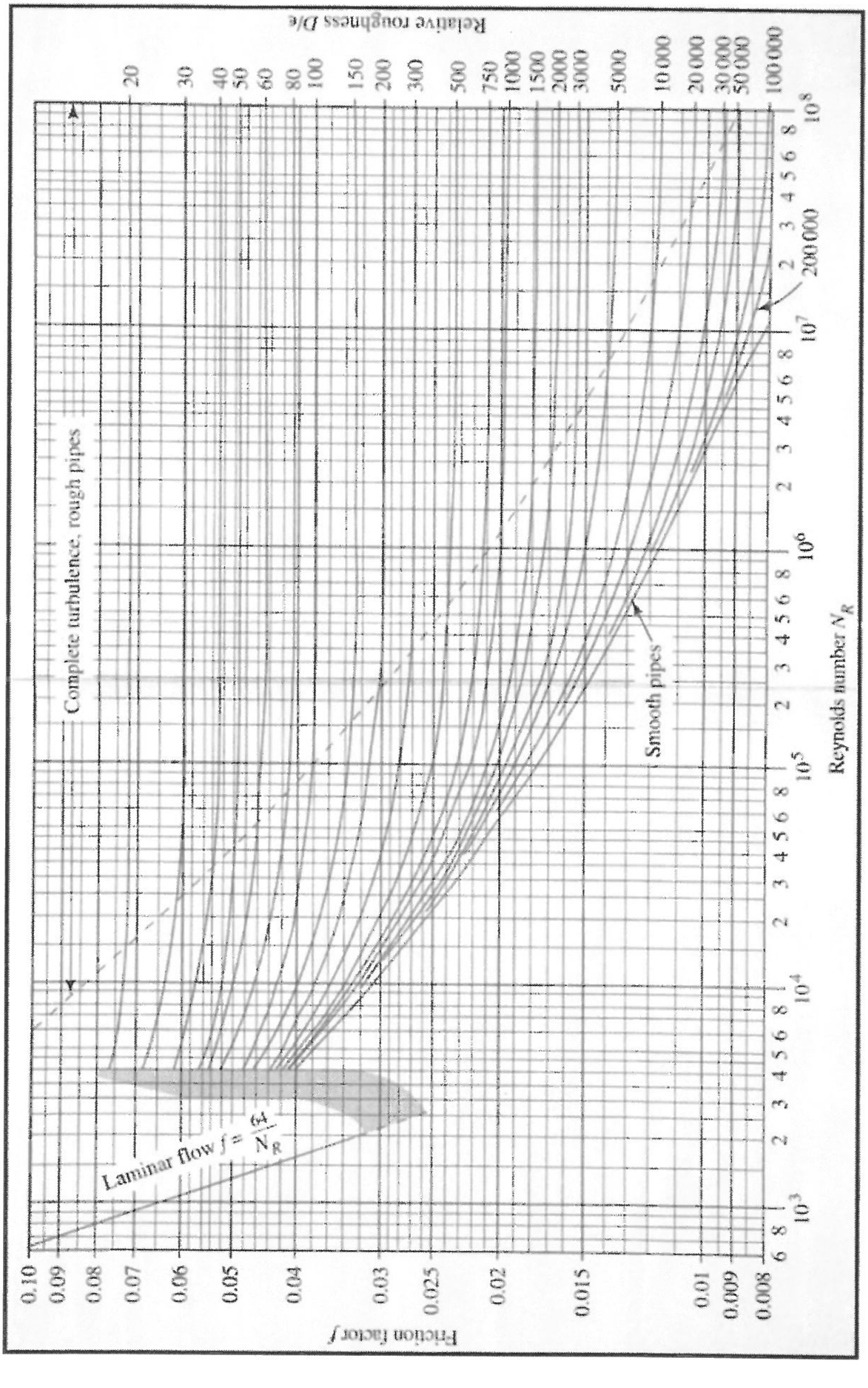


Fig. 3: Question 5

FORMULA SHEET



FORMULA SHEET

Pipe Roughness – design values:

Material	Roughness ε (m)
Glass	smooth
Plastic	3.0×10^{-7}
Drawn tubing; copper, brass , steel	1.5×10^{-6}
Steel, commercial or welded	4.6×10^{-5}
Galvanized iron	1.5×10^{-4}
Cast iron – coated	1.2×10^{-4}
Cast iron – uncoated	2.4×10^{-4}
Concrete, well made	1.2×10^{-4}
Riveted steel	1.8×10^{-3}

Friction factor in zone of complete turbulence for new, clean, commercial *steel* pipes:

Nominal pipe size (in)	Friction factor f_T	Nominal pipe size (in)	Friction factor f_T
½	0.027	3½ 4	0.017
¾	0.025	5	0.016
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2½ 3	0.018		

Resistance in valves and fittings expressed as equivalent length in pipe diameter :

Type	Equivalent Length in Pipe Diameters (L_e/D)
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Butterfly valve – fully open (10 - 14 in)	35
Butterfly valve – fully open (16 - 24 in)	25
Foot valve – poppet disc type	420
Foot valve – hinged disc type	75
90° standard elbow	30
90° long radius elbow	20
90° street elbow	50
45° standard elbow	16
45° street elbow	26
Close return bend	50
Standard tee – flow through run	20
Standard tee – flow through branch	60

*Source: Cane Valves, Signal Hill, CA

Friction factor in zone of complete turbulence for new, clean, commercial *cast iron* pipes: $f_T = 0.014$

Sphere: $V = \frac{\pi D^3}{6}$, $\bar{y} = D/2$	Cylinder: $V = \frac{\pi D^2 H}{4}$, $\bar{y} = H/2$
Cube: $V = H^3$, $\bar{y} = H/2$	Pyramid: $V = \frac{H.B.G}{3}$, $\bar{y} = H/4$
Rectangular prism: $V = H.B.G$, $\bar{y} = H/2$	Cone: $V = \frac{\pi D^2 H}{12}$, $\bar{y} = H/4$
Square: $I_c = H^4/12$	Circle: $I_c = \pi D^4/64$
Rectangle: $I_c = BH^3/12$	Semicircle: $I_c = (6.86 \times 10^{-3}) D^4$
Triangle: $I_c = BH^3/36$	Trapezoid: $I_c = \frac{H^3(G^2 + 4GB + B^2)}{36(G+B)}$

Sudden Enlargement:

D_2/D_1	Velocity v_1						
	0.6 m/s	1.2 m/s	3 m/s	4.5 m/s	6 m/s	9 m/s	12 m/s
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.2	0.11	0.10	0.09	0.09	0.09	0.09	0.08
1.4	0.26	0.25	0.23	0.22	0.22	0.21	0.20
1.6	0.40	0.38	0.35	0.34	0.33	0.32	0.32
1.8	0.51	0.48	0.45	0.43	0.42	0.41	0.40
2.0	0.60	0.56	0.52	0.51	0.50	0.48	0.47
2.5	0.74	070	0.65	0.63	0.62	0.60	0.58
3.0	0.83	0.78	0.73	0.70	0.69	0.67	0.65
4.0	0.92	0.87	0.80	0.78	0.76	0.74	0.72
5.0	0.96	0.91	0.84	0.82	0.80	0.77	0.75
10.0	1.00	0.96	0.89	0.86	0.84	0.82	0.80
∞	1.00	0.98	0.91	0.88	0.86	0.83	0.81

Entrance loss:

r/D_2	K
0	0.50
0.02	0.28
0.04	0.24
0.06	0.15
0.10	0.09
>0.15	0.04 (well rounded)

FORMULA SHEET

$\gamma = \rho.g$	$p = \frac{F}{A} = \mu.\frac{\Delta v}{\Delta y}$	$\frac{d(mv)}{dt} = F = \dot{m}.V$
$Q = v.A$	$P = \gamma.h = \rho.g.h$	$E = \frac{-\Delta P}{\Delta V/V}$
$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + h_A - h_R - h_L = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$		$P = \rho.g.Q.H$
$I = \frac{B.H^3}{12}$	$L_p = L_c + \frac{I_c}{L_c.A}$	$\mu = \rho.\nu$
$\tau = \mu\left(\frac{\Delta v}{\Delta y}\right)$	$\mu = \frac{(P_A - P_B).D^2}{32.v.L}$	$\mu = \frac{(\gamma_s - \gamma_f)D^2}{18.v}$
$P_{abs} = P_{gage} + P_{atm}$	$T_C = \frac{(T_F - 32)}{1.8}$	$F = \rho.Q.\Delta\nu$
$v = C_D.\sqrt{2gh}$	$t_2 - t_1 = \frac{2.\left(A_t/A_j\right)}{\sqrt{2.g}}.\left(\sqrt{h_1} - \sqrt{h_2}\right)$	$h_p = h_c + \frac{I_c.\sin^2\theta}{h_c.A}$

$Re = \frac{\rho.v.D}{\mu}$	$h_L = K.\left(\frac{v^2}{2.g}\right)$	$h_f = f.\frac{L}{D}.\frac{v^2}{2.g}$
$v = v_{max}.\left(\frac{y}{R}\right)^{1/n}$	$\frac{L_e}{D} = 4.4\,Re^{1/6}$	$\frac{L_e}{D} = 0.06\,Re$
$h_L = \frac{32.\mu.L.v}{\gamma.D^2}$	$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{Re^{0.9}}\right)\right]^2}$	$h = \frac{8.(1 - C^2\beta^4)}{\pi^2.g.D^4.C^2.\beta^4}.Q^2$
$f = \frac{64}{Re}$	$\frac{1}{\sqrt{f}} = -2.0\log\left[\frac{\varepsilon}{3.7D} + \frac{2.51}{Re.\sqrt{f}}\right]$	$v = \frac{p}{4.L.\mu}.\left[\frac{D^2}{4} - r^2\right]$
$U = 2.v.[1 - (\frac{r}{r_o})^2]$	$\frac{1}{\sqrt{f}} = -1.8\log\left[\left(\frac{\varepsilon}{3.7D}\right)^{1.11} + \frac{6.9}{Re}\right]$	$R = \frac{A}{P}$
$v = 0.85C_h R^{0.63} S^{0.54}$	$U = v[1 + 1.43\sqrt{f} + 2.15\sqrt{f}\log_{10}(\frac{y}{r_0})]$	$U_{max} = v[1 + 1.43\sqrt{f}]$
$Q = -2.22D^2\sqrt{\frac{gDh_L}{L}}\log\left(\frac{1}{3.7D/\varepsilon} + \frac{1.784\upsilon}{D\sqrt{gDh_L/L}}\right)$		$D = 0.66\left[\varepsilon^{1.25}\left(\frac{L.Q^2}{g.h_L}\right)^{4.75} + v.Q^{9.4}\left(\frac{L}{g.h_L}\right)^{5.2}\right]^{0.04}$

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QUESTION 1 [40]

a) Define the following phrases: **(8)**

i. Steady uniform flow
ii. Steady non-uniform flow
iii. Unsteady uniform flow
iv. Unsteady non-uniform flow

b) Write the following equations: **(10)**

i. Continuity equation
ii. Bernoulli's equation
iii. General energy equation
iv. Impulse-Momentum equation
v. Force equation

c) Name and describe three common types of velocity probes. **(6)**

d) Describe the basic principle on which variable-head meters are based, and give four examples of such meters. **(6)**

e) State the application of the follow flowmeters. **(10)**

i. Rotameter
ii. Turbine flowmeter
iii. Ultrasonic flowmeter
iv. Positive-displacement meter
v. Magnetic flowmeter

QUESTION 2 [10]

Fig. 1 shows a gate hinged at its bottom and held by a simple support at its top. The gate separates two fluids. Compute the net force and locate the center of pressure on the gate due to the fluid on each side. Then compute the force on the hinge and on the support.

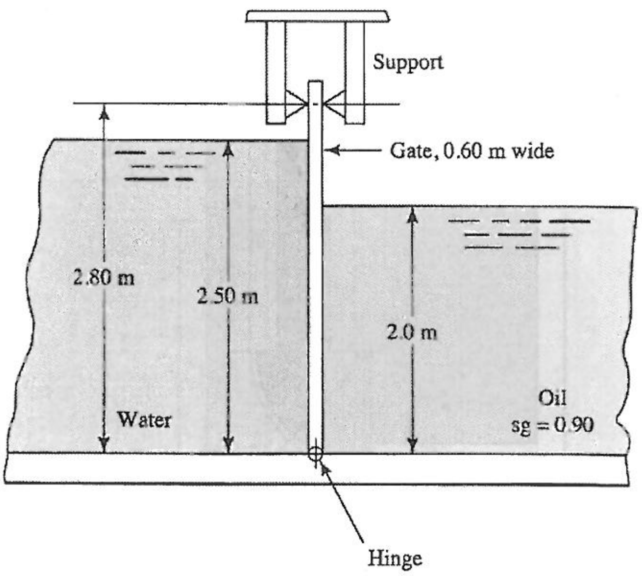


Fig. 1: Question 2

QUESTION 3 [20]

Refer to *Fig. 2.* All the surfaces are copper and the duct is horizontal.

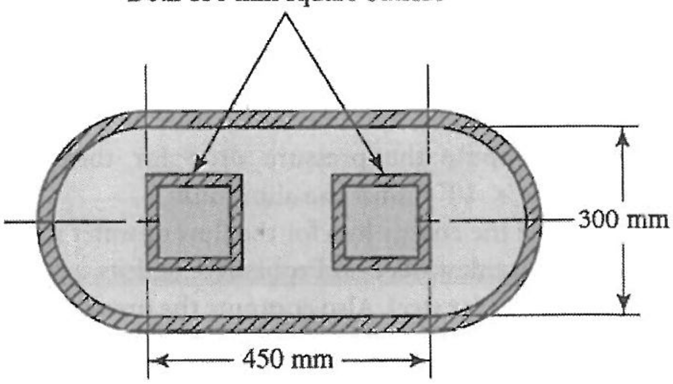


Fig. 2: Question 3

a) If each of the square tubes shown carries 0.75 m^3/s of water at 90°C ($\gamma = 9.47\times10^3$, $\rho = 965$, and $\mu = 3.11\times10^{-4}$) and the thickness of the walls of the tubes is 2.77 mm. Compute:
   i. The Reynolds number of the flow of water,
   ii. The pressure drop over the length of 22.6 m.

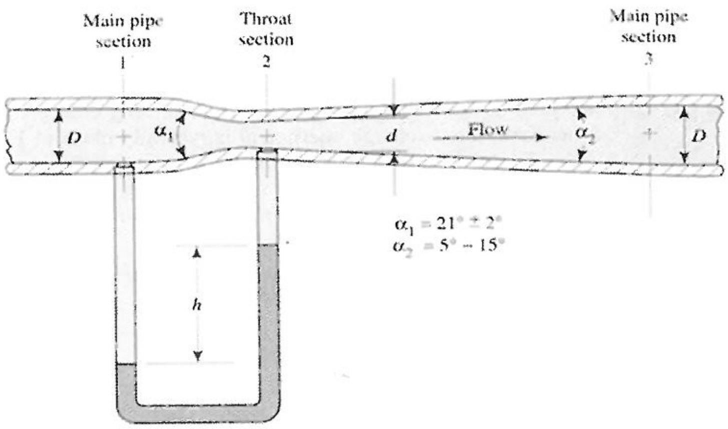
b) Suppose glycerine at 40°C (sg = 1.26, and $\mu = 3.0 \times 10^{-1}$) flows in the portion of the duct outside the square tubes as shown in the figure. Compute
   i. The Reynolds number for a flow rate of 0.10 m^3/s,
   ii. The pressure drop over the length of 22.6 m.

QUESTION 4 [10]

A venture tube shown in *Fig. 3* is being used to measure the volume flow rate at 5°C (specific weight = 9.81×10^3, density = 1000, & dynamic viscosity = 1.52×10^{-3}). The flow enter from the left in a 120 mm diameter steel pipe. The throat diameter is 60 mm. The venture is rough cast. The manometer fluid is mercury (sg = 13.54) and the deflection is 180 mm. Compute:

a) The velocity,
b) The volume flow rate,
c) The mass flow rate in the pipe.

Hint: Use Fig. 4 to estimate the discharge coefficient.



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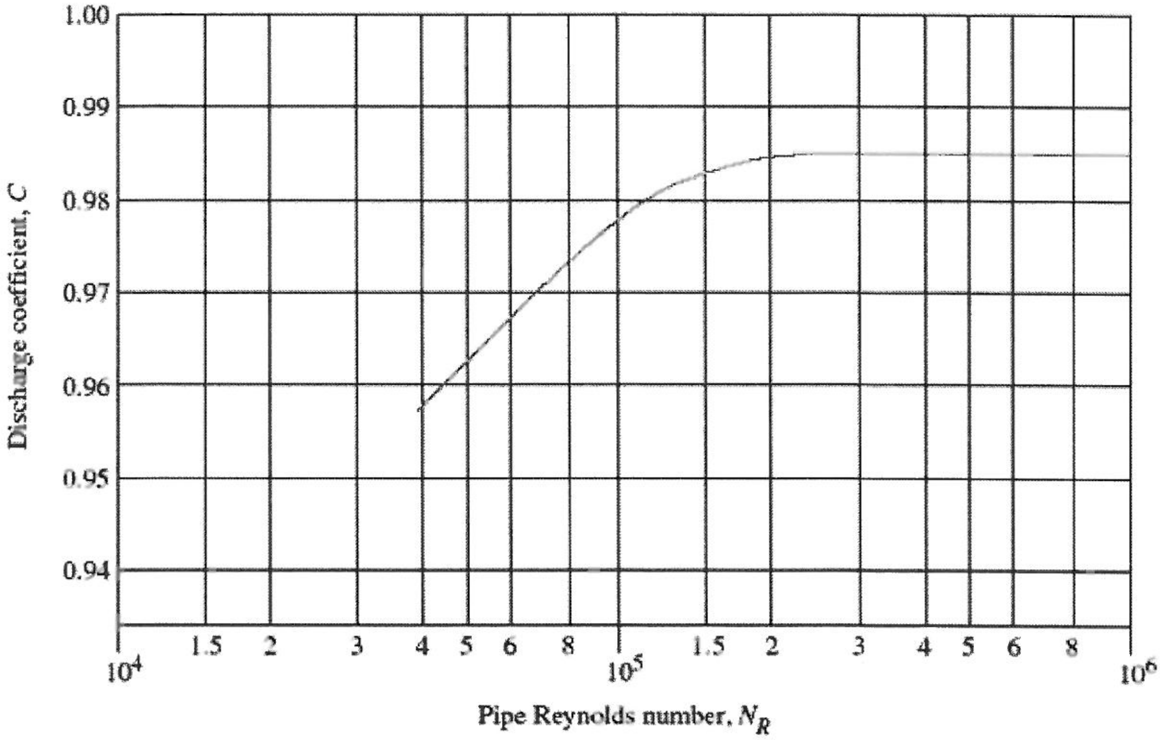

Fig. 4: Question 4

QUESTION 5 [20]

Linseed oil with a specific gravity of 0.93 enters the reducing bend shown in *Fig. 5* with a velocity of 3 m/s and a pressure of 275 kPa. The bend is in a horizontal plane. Calculate the x and y forces required to hold the bend in place. Also calculate the total resultant force and the direction in which it acts. Neglect energy losses in the bend.

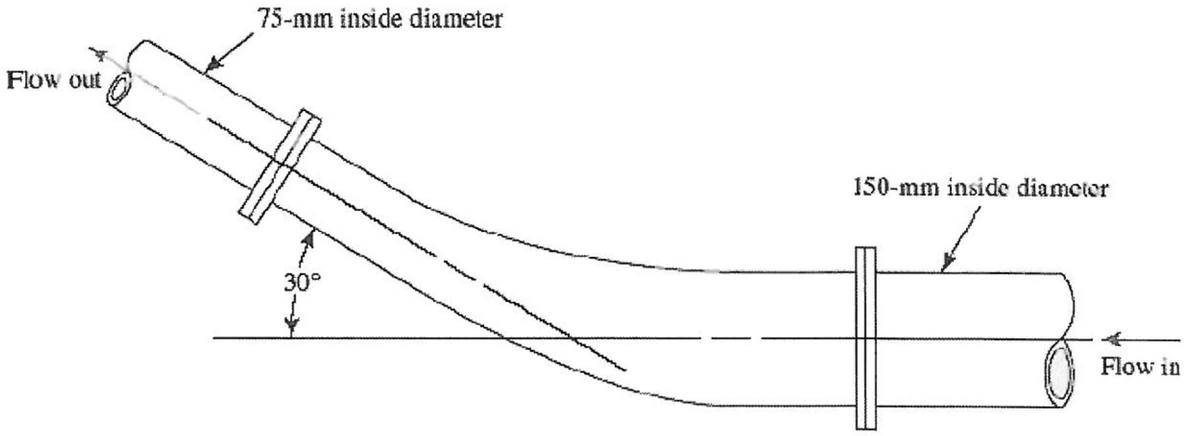

Fig. 5: Question 5

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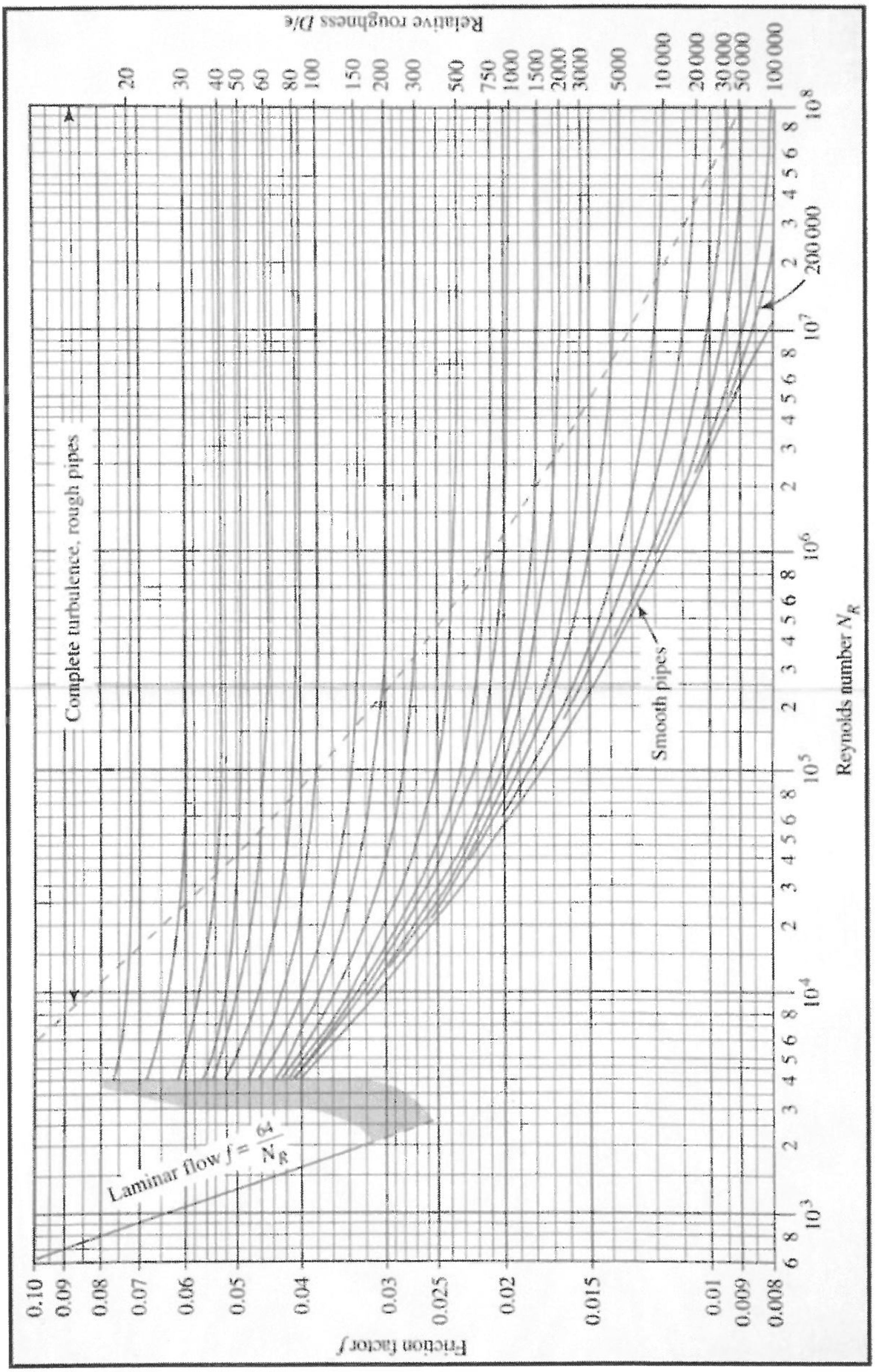

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4.0	0.92	0.87	0.80	0.78	0.76	0.74	0.72
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$I = B . H^3 / 12$	$L_p = L_c + I_c / L_c . A$	$\mu = \rho . \nu$
$\tau = \mu \left(\frac{\Delta v}{\Delta y} \right)$	$\mu = \frac{(P_A - P_B) . D^2}{32 . v . L}$	$\mu = \frac{(\gamma_s - \gamma_f) D^2}{18 . v}$
$P_{abs} = P_{gage} + P_{atm}$	$T_C = \frac{(T_F - 32)}{1.8}$	$F = \rho . Q . \Delta v$
$v = C_D . \sqrt{2gh}$	$t_2 - t_1 = \frac{2 . \left(A_t / A_j \right)}{\sqrt{2 . g}} . \left(\sqrt{h_1} - \sqrt{h_2} \right)$	$h_p = h_c + \frac{I_c . \sin^2 \theta}{h_c . A}$

$Re = \frac{\rho . v . D}{\mu}$	$h_L = K . \left(\frac{v^2}{2 . g} \right)$	$h_f = f . \frac{L}{D} . \frac{v^2}{2 . g}$
$v = v_{max} . \left(\frac{y}{R} \right)^{1/n}$	$\frac{L_e}{D} = 4.4 \, Re^{1/6}$	$\frac{L_e}{D} = 0.06 \, Re$
$h_L = \frac{32 . \mu . L . v}{\gamma . D^2}$	$f = \frac{0.25}{\left[\log \left(\frac{1}{3.7 (D/\varepsilon)} + \frac{5.74}{Re^{0.9}} \right) \right]^2}$	$h = \frac{8 . (1 - C^2 \beta^4)}{\pi^2 . g . D^4 . C^2 . \beta^4} . Q^2$
$f = \frac{64}{Re}$	$\frac{1}{\sqrt{f}} = -2.0 \log \left[\frac{\varepsilon}{3.7D} + \frac{2.51}{Re . \sqrt{f}} \right]$	$v = \frac{p}{4 . L . \mu} . \left[\frac{D^2}{4} - r^2 \right]$
$U = 2 . v . [1 - (\frac{r}{r_o})^2]$	$\frac{1}{\sqrt{f}} = -1.8 \log \left[\left(\frac{\varepsilon}{3.7 D} \right)^{1.11} + \frac{6.9}{Re} \right]$	$R = \frac{A}{P}$
$v = 0.85 C_h R^{0.63} s^{0.54}$	$U = v[1 + 1.43\sqrt{f} + 2.15\sqrt{f} \log_{10}(\frac{y}{r_0})]$	$U_{max} = v[1 + 1.43\sqrt{f}]$
$Q = -2.22 D^2 \sqrt{\frac{gDh_L}{L}} \log \left(\frac{1}{3,7 D/\varepsilon} + \frac{1,784 \upsilon}{D \sqrt{gDh_L / L}} \right)$	$D = 0.66 \left[\varepsilon^{1.25} \left(\frac{L . Q^2}{g . h_L} \right)^{4.75} + v . Q^{9.4} \left(\frac{L}{g . h_L} \right)^{5.2} \right]^{0.04}$	