UNIVERSITY OF JOHANNESBURG

PROGRAM	:	BACHELOR OF TECHNOLOGY *CHEMICAL ENGINEERING*
SUBJECT	:	**CHEMICAL ENGINEERING TECHNOLOGY 4A - FLUID FLOW**
CODE	:	**WARA432**
DATE	:	SSA EXAMINATION 15 July 2014
DURATION	:	(SESSION 2) 11:30 – 14:30
WEIGHT	:	40: 60
TOTAL MARKS	:	119.

EXAMINER	:	PROF F. NTULI
MODERATOR	:	PROF M. ONYANGO
NUMBER OF PAGES	:	5 PAGES AND 4 ANNEXURES

REQUIREMENTS	:	GRAPH PAPER (ONE PER STUDENT)

INSTRUCTIONS TO CANDIDATES:

1. NUMBER ALL QUESTIONS CORRECTLY.
2. ANSWER ALL THE FIVE QUESTIONS.
3. THE MARKS ALLOCATED TO EACH QUESTION ARE INDICATED AFTER THE QUESTION AND THE TOTAL MARKS AT THE END.

QUESTION 1

A pressure drop of 100 kPa is desired in 80 m of a horizontal smooth pipe transporting water at a temperature of 20°C at a flow rate of 0.0016 m^3/s. Calculate the diameter of the pipe required? Changes in kinetic energy of the fluid may be neglected.

Density of water = 998.21 $kg.m^{-3}$, viscosity = 1.002×10^{-3} $kg\ m^{-1}\ s^{-1}$, $g = 9.81\ m\ s^{-2}$

[20]

QUESTION 2

A variable-speed pump is required to raise water from a sump to an upper channel, the difference in water levels being 12 m. The suction and delivery pipes have a common diameter of 80 mm and a combined length of 30 m. The friction factor (Moody friction factor) in these pipes is $f = 0.16$, whilst minor losses can be accommodated by a loss coefficient $K = 10$. The dynamic head in sump and delivery channel may be neglected.

Q ($L.s^{-1}$)	0	2.5	5	7.5	10	12.5	15	17.5
H (m)	19.1	19.0	18.4	17.1	15.1	12.4	9.0	4.9
η (%)	-	25.6	48.7	67.0	77.9	79.2	68.2	42.6

2.1 Derive the system characteristic (i.e. head as a function of discharge, stating carefully the units for head and discharge). (8)

2.2 In a bid to increase the total discharge two of the variable-speed pumps are connected is series. Assuming that the pumps are run at the same operational speed and that the system is unchanged, find the total discharge and power consumption. (20)

3/...

Density of water = 1000 kg.m^{-3}, viscosity = 1.109×10^{-3} kg m^{-1} s^{-1}, g = 9.81 m s^{-2} .

[28]

QUESTION 3

A nozzle is attached to a 6 cm diameter hose but the horizontal nozzle turns the water through an angle of 90° as shown in Fig. 1. The nozzle exit is 3 cm in diameter and the flow rate is 500 L/min. Determine the force components of the water on the nozzle and the magnitude and direction of the resultant force. The volume of the fluid in the nozzle is 200 ml and the water exits to the atmosphere. (20)
Density of water = 1000 kg.m^{-3}. Atmospheric pressure = 100 kPa

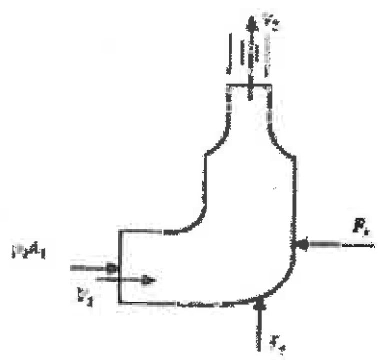


Fig. 1

[20]

QUESTION 4

4.1 What pressure gradient along a streamline is required to accelerate water in a horizontal pipe at a rate of 30 m/s^2? (6)

4.2 A particle of equivalent volume diameter 0.3 mm, density 2000 kg/m^3 and sphericity 0.6 falls freely under gravity in a fluid of density 1.2 kg/m^3 and viscosity 2×10^{-5} Pa.s. (20)

4.2.1 Estimate the terminal velocity reached by the particle. (10)
4.2.2 What will be the terminal velocity if the particle were a cube? (10)

[26]

QUESTION 5

5.1 The channel shown in Fig. 2 has a channel bed inclination angle θ=0.0802. The sides are on a slope of 45°. The channel is made up of finished concrete and the Manning *n* is 0.012 $m^{-1/3}$ s. Calculate: (a) The flow rate in the channel (10); (b) The critical depth, and indicate if the flow is subcritical or supercritical (5) (15)

Fig. 2

5.2 A six blade flat turbine agitator is installed in a tank conforming to the configuration given in curve 1 on the Power curve. The impeller diameter $D_A = 2$ m and is running at a speed N = 0.3 rev/s. The liquid in the tank has a dynamic viscosity $\mu = 1.2$ Pa s and a density of 1000 kg/m^3. Calculate the theoretical power in kW required for the mixer. (10)

(10)

[25]

TOTAL MARKS [119]

Formulas

$$-\frac{dp}{ds}-\gamma\, Sin\theta = \rho\, a_s$$

$$-\frac{dp}{dn}-\gamma\, Cos\theta = \rho\, a_n$$

$$\frac{d}{dt}B_{sys} = \frac{d}{dt}\int_{cv} b\rho d\forall + \sum_{cs} b\rho\vec{V}.\vec{A}$$

$$B = mB$$

$$f = \left(\frac{\Delta p}{1/2\,\rho V^2}\right)/\left(\frac{L}{D}\right)$$

$$K_L = \left(\frac{\Delta p}{1/2\,\rho V^2}\right)$$

$$\tau = \mu\frac{dV}{dy}$$

$$C = \frac{1}{n}R_h^{1/6}$$

$$\mathrm{Fr} = V/(g\,l)^{1/2}$$

$$\gamma = K'8^{n'-1}$$

$$(\mu_a)_p = K_p'\left(\frac{8}{d_i}\right)^{n-1}$$

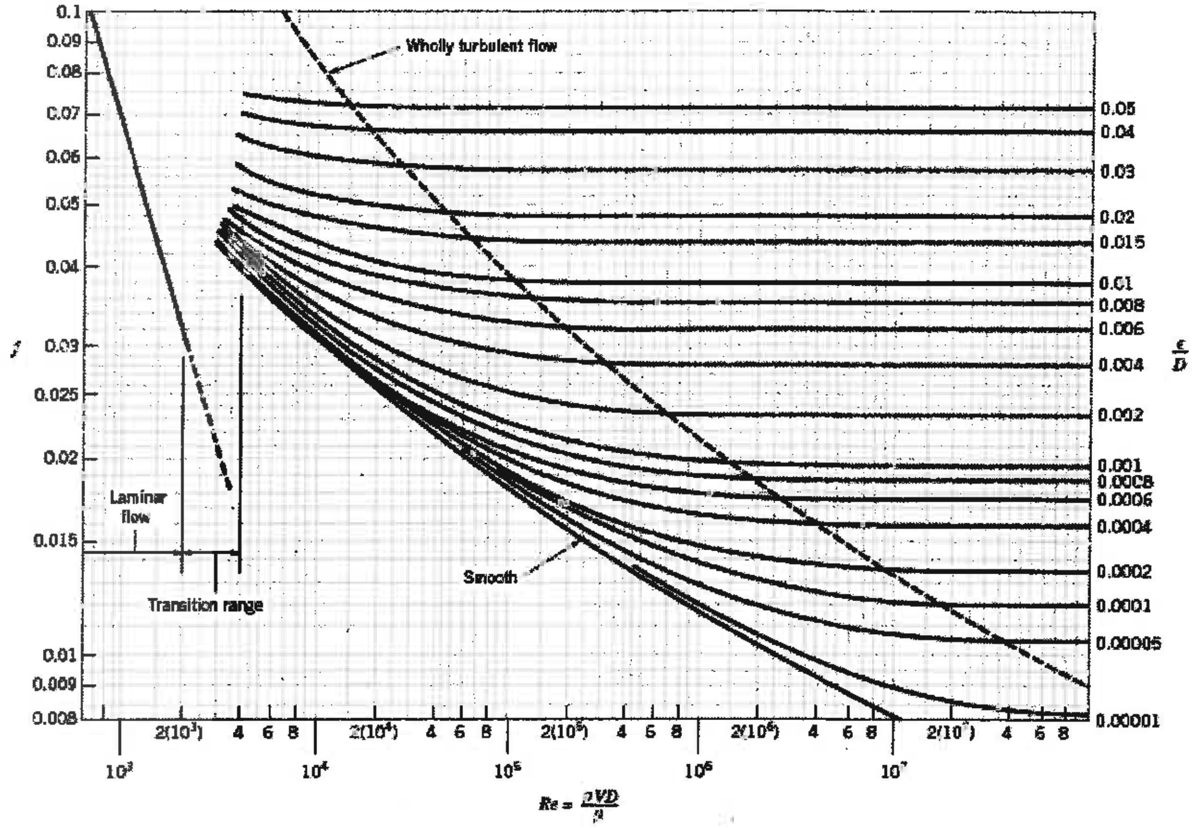
$$C_D\,\mathrm{Re}_p^2 = \frac{4}{3}\frac{x^3\rho_f(\rho_p-\rho_f)g}{\mu^2}$$

$$C_D/\mathrm{Re}_p = \frac{4}{3}\frac{g\mu(\rho_p-\rho_f)}{U_T^3\,\rho_f^2}$$

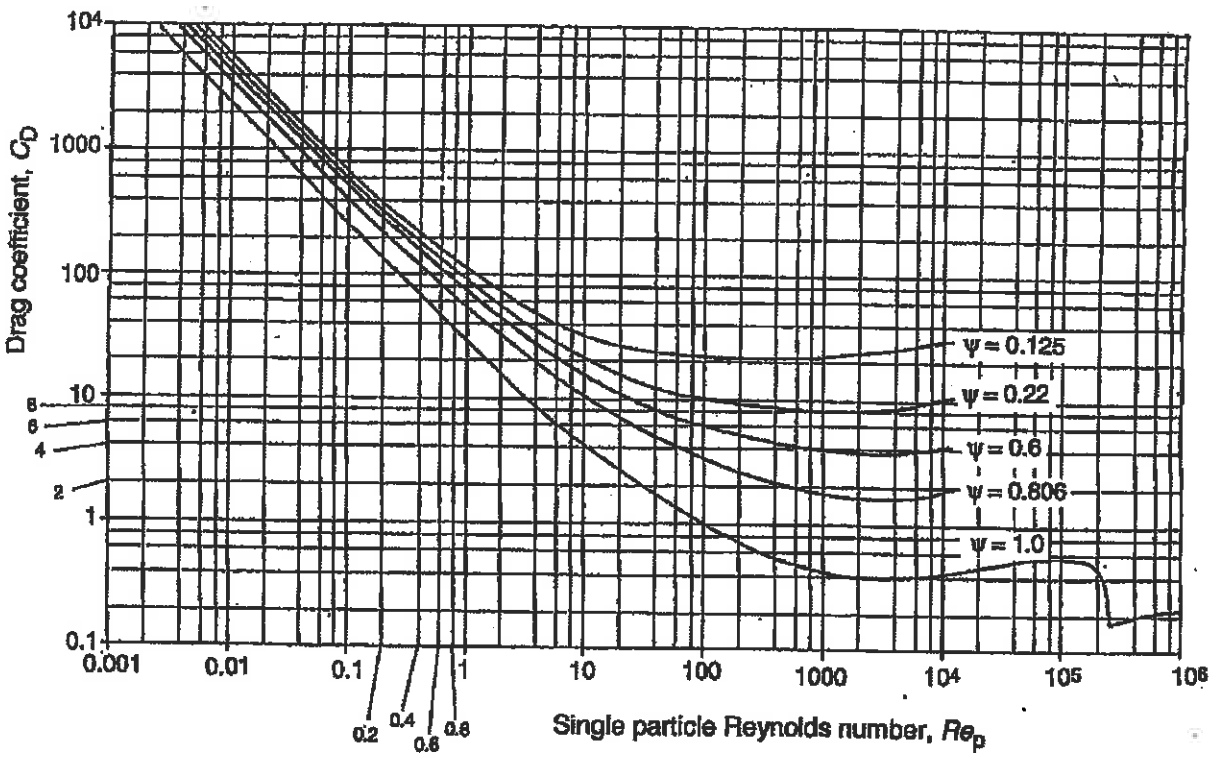
Volume of a sphere $= \dfrac{\pi d^3}{6}$

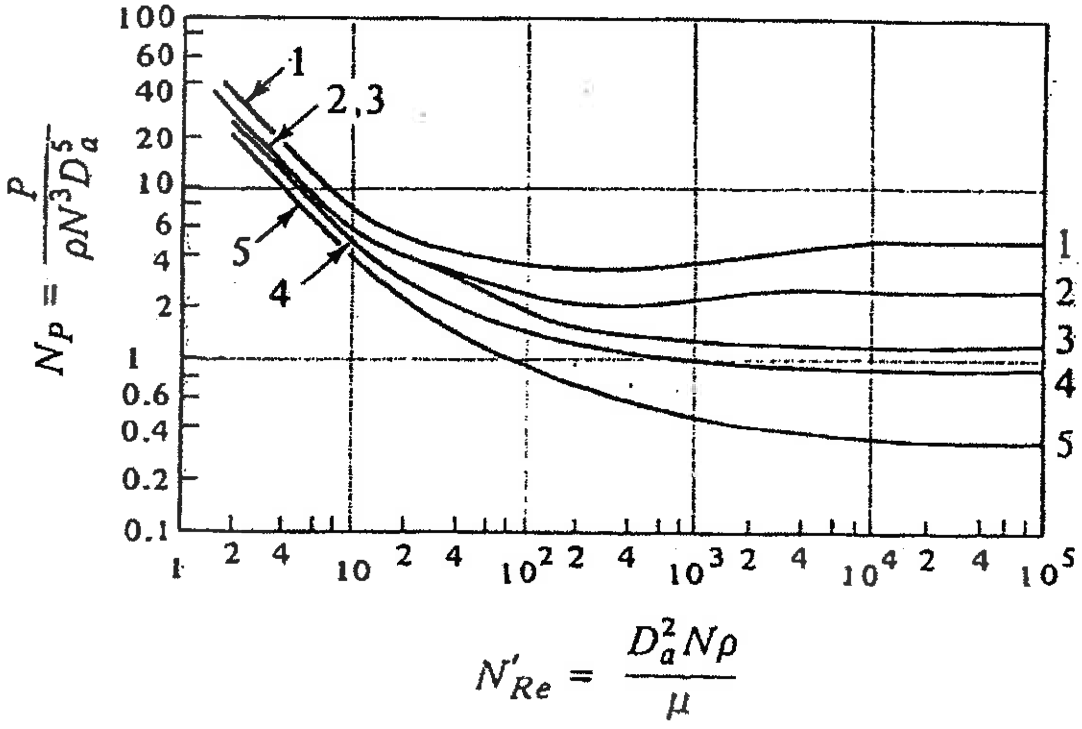
Surface area $= \pi d^2$

Moody Chart


Wholly turbulent flow
Laminar flow
Transition range
Smooth
f
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.025
0.02
0.015
0.01
0.009
0.008
ε/D
0.05
0.04
0.03
0.02
0.015
0.01
0.008
0.006
0.004
0.002
0.001
0.0008
0.0006
0.0004
0.0002
0.0001
0.00005
0.00001
10³
10⁴
10⁵
10⁶
10⁷
Re = ρVD/μ

Standard drag curve




100
60
40
20
10
6
4
2
1
0.6
0.4
0.2
0.1
1
2
4
10
2
4
10^2
2
4
10^3
2
4
10^4
2
4
10^5
1
2,3
5
4
1
2
3
4
5
$N_P = \frac{P}{\rho N^3 D_a^5}$
$N'_{Re} = \frac{D_a^2 N \rho}{\mu}$