UNIVERSITY OF JOHANNESBURG

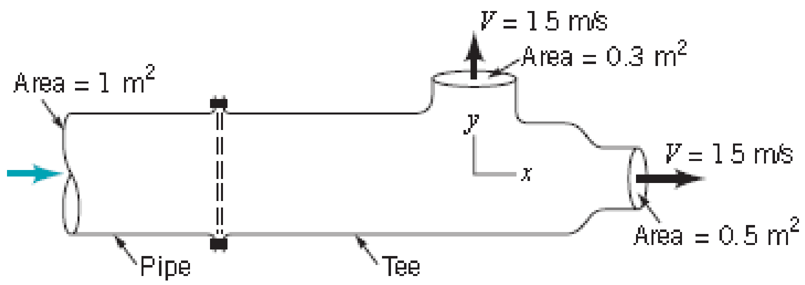
PROGRAM	:	BACCALAUREUS TECHNOLOGIAE *CHEMICAL ENGINEERING*
SUBJECT	:	**FLUID FLOW**
CODE	:	**WARA432**
DATE	:	WINTER EXAMINATION 22 MAY 2019
DURATION	:	(SESSION 2) 12:30 - 15:30
WEIGHT	:	40 : 60
TOTAL MARKS	:	100
EXAMINER(S)	:	DR T A MAMVURA
MODERATOR	:	DR I AMER
NUMBER OF PAGES	:	4 PAGES + 5 PAGES OF FORMULAE AND TABLES
REQUIREMENTS	:	Use of scientific (non-programmable) calculator is permitted (only one per candidate); graph paper

HINTS AND INSTRUCTIONS TO CANDIDATE(S):

- Purpose of assessment is to determine not only if you can write down an answer, but also to assess whether you understand the concepts, principles and expressions involved. Set out solutions in a logical and concise manner with justification for the steps followed.
- **ATTEMPT ALL QUESTIONS**. Please answer each question to the best of your ability.
- Write your details (module name and code, ID number, student number etc.) on script(s).
- Number each question clearly; questions may be answered in any order.
- Make sure that you read each question carefully before attempting to answer the question.
- Show all steps (and units) in calculations; this is a 'closed book' test.
- Ensure your responses are legible, clear and include relevant units (where appropriate).

Question One **[Total: 20 Marks]**

1.1. Water flows as two free jets from the tee attached to the pipe as shown in figure below. The exit speed is 15 m/s. If viscous effects and gravity are negligible, determine the x and y components of the force that the pipe exerts on the tee.



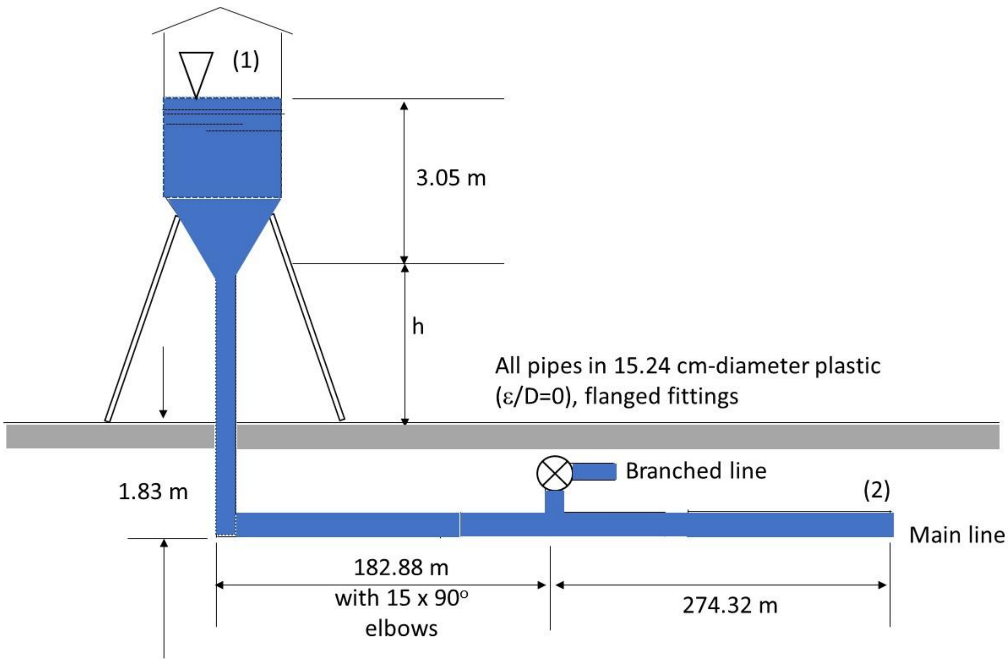
10 marks

1.2. Air under standard conditions flows through a 4.0-mm diameter drawn tubing with an average velocity of V = 50 m/s. For such conditions the flow would normally be turbulent. However, if precautions are taken to eliminate disturbances to the flow (the entrance to the tube is very smooth, the air is dust free, the tube does not vibrate, etc.), it may be possible to maintain laminar flow. (a) Determine the pressure drop in a 0.1-m section of the tube if the flow is laminar. (b) Repeat the calculations if the flow is turbulent.
Under standard temperature and pressure conditions, density of air = 1.23 kg/m^3 and viscosity of air = 1.79 x 10^{-5} Pa·s. Roughness, ε = 0.0015 mm.

10 marks

Question Two **[Total: 20 Marks]**

The pressure at section (2) shown in figure below is not to fall below 413685.44 Pa when the flowrate from the tank varies from 0 to 28.3 L/s and the branch line is shut off. Determine the minimum height, h, of the water tank under the assumption that minor losses are negligible. Properties for water: density = 1000 kg/m^3; viscosity = 1.002 x 10^{-3} Pa·s.



Question Three **[Total: 15 Marks]**

How much more power is required to pedal a bicycle at 6.71 m/s into a 8.94 m/s head-wind than at 6.71 m/s through still air? Assume a frontal area of 0.36 m^2 and a drag coefficient C_D = 0.88. Assume density of the wind is 1.23 kg/m^3.

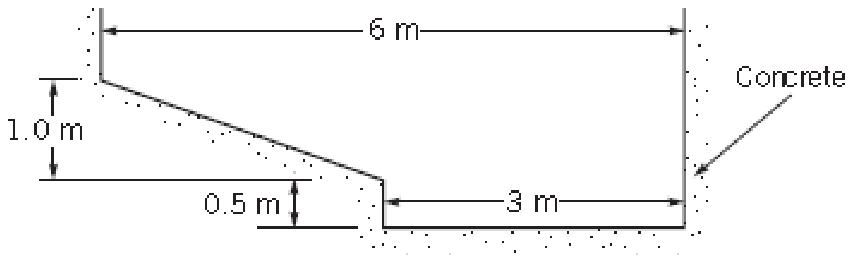
Question Four **[Total: 20 Marks]**

A velocity field is given by $V = xi + x(x-1)(y+1)j$, where u and v are in m/s and x and y are in metres.

4.1. Determine the streamline equation that passes through the origin. (6)
4.2. Plot the streamline that passes through the origin. Use $-1 \le x \le 3$. (8)
4.3. Determine if the flow is steady state at the origin. (1)
4.4. Determine if the flow is uniform at the origin. (2)
4.5. Determine the acceleration field. (3)

Question Five **[Total: 25 Marks]**

5.1. The smooth concrete-lined channel shown in the figure below is built on a slope of 2 m/km (S_o). Determine the flowrate if the depth is y = 1.5 m.



15 marks

5.2. A flat-blade turbine with six blades (curve 1 on Re vs N_p graph) is installed centrally in a vertical tank. The tank is 1.83 m in diameter, the turbine is 0.61 m in diameter and is positioned 0.61 m from the bottom of the tank. The turbine blades are 127 mm wide. The tank is filled to a depth of 1.83 m with a solution of 50% caustic soda, at 65.5°C, which has a viscosity of 12 cP (12 x 10^{-3} Pa·s) and a density of 1498 kg/m^3. The turbine is operated at 90 rpm. The tank is baffled. What power is required to operate the mixer?

10 marks

END **[Total: 100 Marks]**

Formula Sheet

1. Equation of a streamline: $\frac{dx}{u} = \frac{dy}{v} = \frac{dz}{w}$
2. Acceleration in velocity field: $a = a_x i + a_y j + a_z k = \frac{\partial V}{\partial t} + u\frac{\partial V}{\partial x} + v\frac{\partial V}{\partial y} + w\frac{\partial V}{\partial z}$
3. Reynolds number: $Re = \frac{\rho V D}{\mu}$
4. Bernoulli's equation: $P_1 + \frac{1}{2}\rho V_1^2 + \gamma z_1 = constant$
5. Continuity equation: $Q_1 = A_1 V_1 = Q_2 = A_2 V_2$
6. Conservation of momentum: $\sum F = \frac{d}{dt}(mV) = \sum_{out} \dot{m}V - \sum_{in} \dot{m}V$
7. Conservation of momentum: $\sum F = V_{out}\rho V_{out}A_{out} - V_{in}\rho V_{in}A_{in}$
8. Momentum in x-axis: $\sum F = V_{out}\rho V_{out}A_{out}\cos\theta - V_{in}\rho V_{in}A_{in}\cos\theta$
9. Momentum in y-axis: $\sum F = V_{out}\rho V_{out}A_{out}\sin\theta - V_{in}\rho V_{in}A_{in}\sin\theta$
10. Force: $\sum F = P_{out}A_{out} - P_{in}A_{in}$
11. Force in x-axis: $\sum F = P_{out}A_{out}\cos\theta - P_{in}A_{in}\cos\theta$
12. Force in y-axis: $\sum F = P_{out}A_{out}\sin\theta - P_{in}A_{in}\sin\theta$
13. Conservation of mass: $\frac{dm_{CV}}{dt} = \dot{m}_{in} - \dot{m}_{out}$
14. Energy Equation: $\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 + h_p = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_t + h_L$
15. Energy Equations: $h_L = \left(f\frac{L}{D} + \sum K_L\right)\frac{V^2}{2g}$
16. Pressure drop in flow: $\Delta P = f\frac{L}{D}\frac{1}{2}\rho V^2$
17. For laminar flow: $f = \frac{64}{Re}$
18. For turbulent flow: $f = fn\left(Re, \frac{\varepsilon}{D}\right)$ from Moody chart
19. Power: $P = \Delta P \times Q$

20. Drag force: $F_D = C_D \frac{1}{2} \rho V^2 A$

21. Manning Equation: $V = \frac{1}{n} R_h^{2/3} S_o^{1/2}$

22. Specific energy: $E = y + \frac{V^2}{2g} = y + \frac{1}{2g}\left(\frac{q}{y}\right)^2$

23. Froude number: $Fr = \frac{V}{\sqrt{gl}}$

24. Critical depth of flow: $y_c = \left(\frac{Q^2}{gb^2}\right)^{1/3} = \left(\frac{q}{g}\right)^{1/3}$

25. Reynolds for mixing: $Re = \frac{\rho N d^2}{\mu}$

26. Power for a mixer: $P = N_p \rho N^3 d^5$

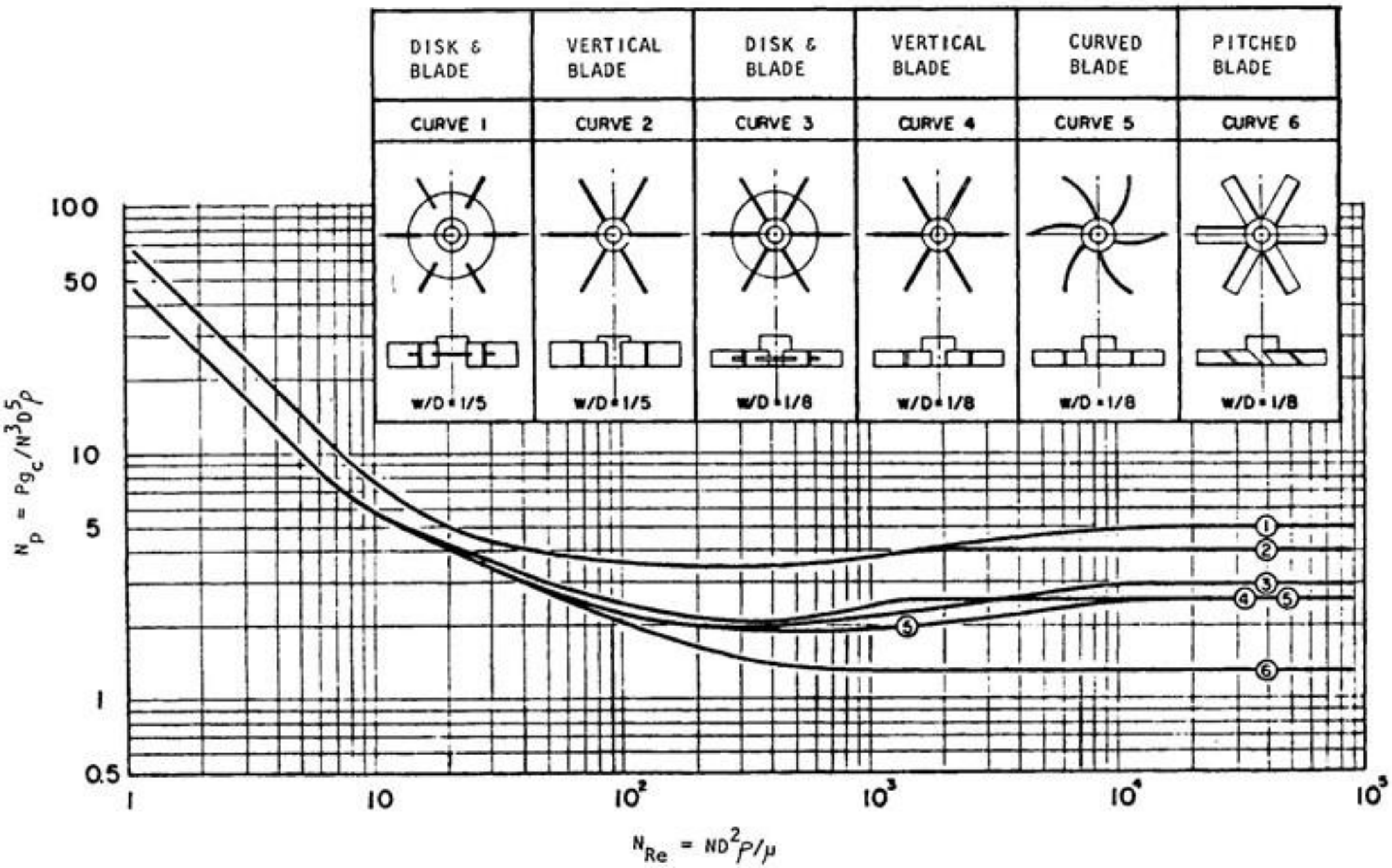
Tables and Figures

Values for Manning coefficients

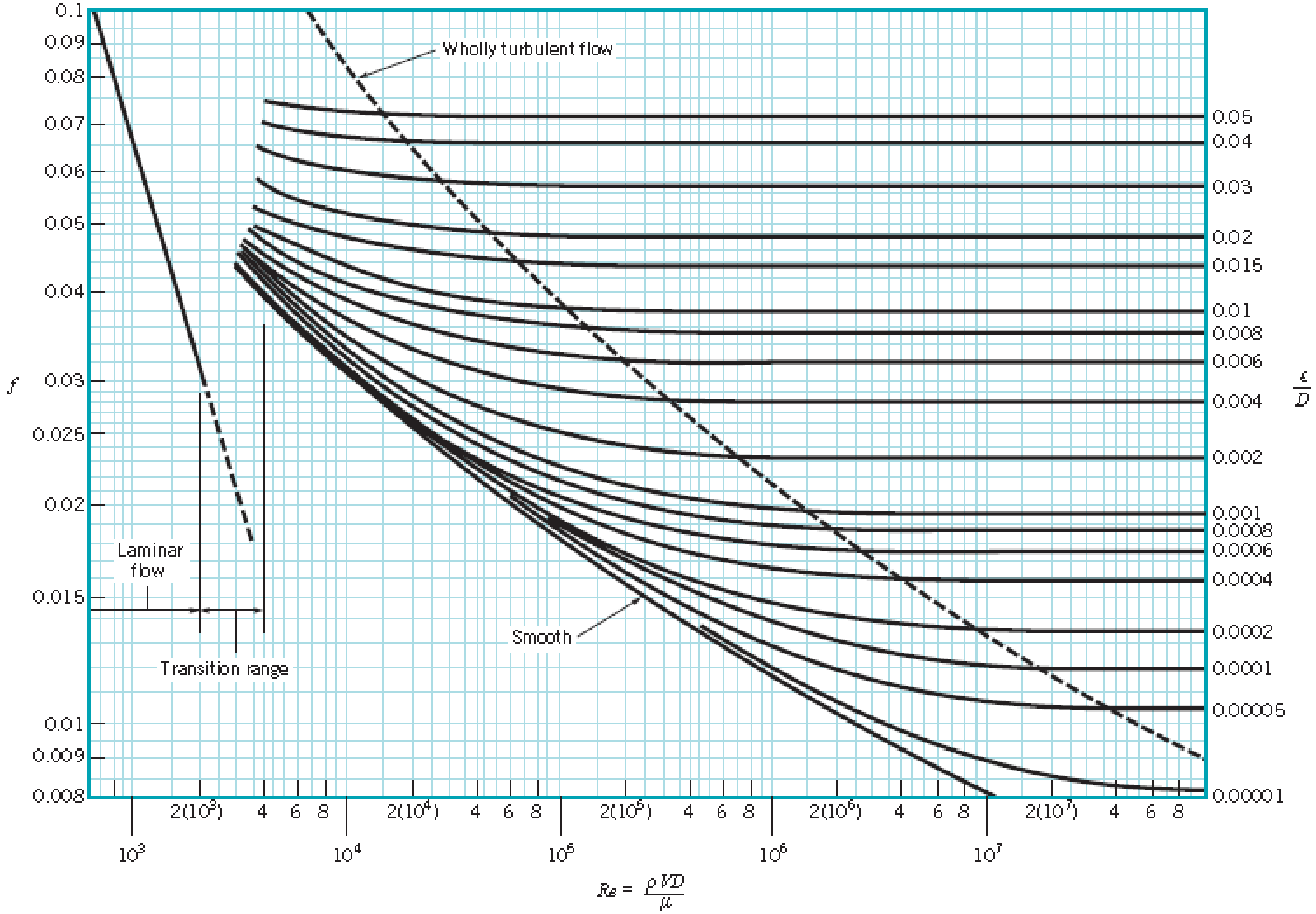
TABLE 10.1
Values of the Manning Coefficient, *n* (Ref. 6)

Wetted Perimeter	n	Wetted Perimeter	n
A. Natural channels		*D. Artificially lined channels*	
Clean and straight	0.030	Glass	0.010
Sluggish with deep pools	0.040	Brass	0.011
Major rivers	0.035	Steel, smooth	0.012
B. Floodplains		Steel, painted	0.014
Pasture, farmland	0.035	Steel, riveted	0.015
Light brush	0.050	Cast iron	0.013
Heavy brush	0.075	Concrete, finished	0.012
Trees	0.15	Concrete, unfinished	0.014
C. Excavated earth channels		Planed wood	0.012
Clean	0.022	Clay tile	0.014
Gravelly	0.025	Brickwork	0.015
Weedy	0.030	Asphalt	0.016
Stony, cobbles	0.035	Corrugated metal	0.022
		Rubble masonry	0.025

Power number against Reynolds number of some turbine impellers



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
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
$\frac{\varepsilon}{D}$
$2(10^3)$ 4 6 8 $2(10^4)$ 4 6 8 $2(10^5)$ 4 6 8 $2(10^6)$ 4 6 8 $2(10^7)$ 4 6 8
10^3
10^4
10^5
10^6
10^7
$Re = \frac{\rho V D}{\mu}$

SQUARED PAPER, METRIC; 2mm, 10mm, 20mm

CENTRE NUMBER						CANDIDATE NUMBER					

QUESTION NUMBER

Open Rubric