UNIVERSITY OF JOHANNESBURG

PROGRAM	:	BACCALAUREUS TECHNOLOGIAE *CHEMICAL ENGINEERING*
SUBJECT	:	**FLUID FLOW**
CODE	:	**WARA432**
DATE	:	SSA WINTER EXAMINATION JULY 2019
DURATION	:	(SESSION X) 3 HOURS
WEIGHT	:	40 : 60
TOTAL MARKS	:	100
EXAMINER(S)	:	DR T A MAMVURA
MODERATOR	:	DR I AMER
NUMBER OF PAGES	:	3 PAGES + 5 PAGES FOR 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).

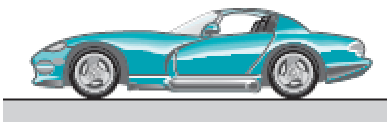
Question One **[Total: 20 Marks]**

The x- and y-components of a velocity field are given by $u = \frac{V_o}{l}x$ and $v = -\frac{V_o}{l}y$ where V_o and l are constants.

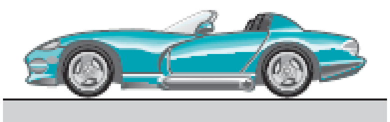
1.1 Plot the streamlines for this flow. Use constant = -2, -1, 1, and 2 for $-3 \leq x \leq 3$. (16)
1.2 Determine the acceleration field for this flow. (2)
1.3 Is the flow uniform? Justify your answer. (2)

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

The aerodynamic drag on a car depends on the "shape" of the car. For example, the car shown in figure below has a drag coefficient of 0.36 with the windows and roof are closed. With the windows and roof are open, the drag coefficient increases to 0.45.



Windows and roof closed: $C_D = 0.35$



Windows open; roof open: $C_D = 0.45$

2.1 Calculate the power required to overcome the drag if the windows and roof are closed and the car is moving at a speed of 29.06 m/s. Take the density of the air to be 1.23 kg/m^3 and the frontal area to be 10 m^2. (5)
2.2 With the windows and roof are open, at what speed is the amount of power needed to overcome aerodynamic drag the same as it is at 29.06 m/s with the windows and roof are closed? Assume the frontal area remains the same. Comment on your answer. (10)

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

A flat-blade turbine agitator with disk having six blades (curve 1 on Re vs N_p graph) is installed in a tank. The tank diameter D_T is 1.83 m, the turbine diameter d is 0.61 m, H = D_T and the width w is 0.122 m. The tank contains four baffles, each having a width J of 0.15 m. The turbine is operated at 90 rpm and the liquid in the tank has a viscosity of 10 cP (10 x 10^{-3} Pa·s) and a density of 929 kg/m^3.

3.1 Calculate the required power (in kW) of the mixer. (10)
3.2 For the same conditions, except for the solution having viscosity of 100000 cP, calculate the required power (kW). (10)

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

4.1 According to fire regulations in a town, the pressure drop in a commercial steel horizontal pipe must not exceed 6894.76 Pa per 45.72 m of pipe for flowrates up to 31.55 L/s. If the water temperature is above 10^{o}C, can a 15.24-cm-diameter pipe be used?

For commercial steel pipe, ε = 0.004572 cm. Properties for water are: density = 1000 kg/m^3 and viscosity = 1.002 x 10^{-3} Pa·s.
NB: Determine pressure drop for the diameter and comment on your answer.

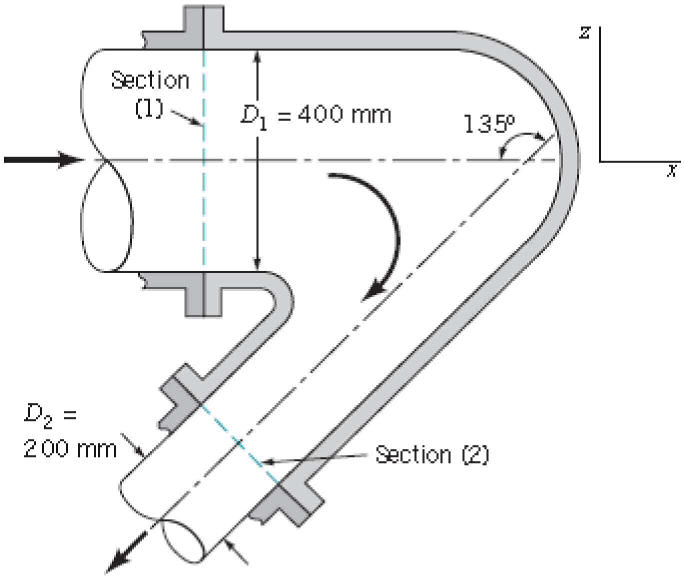
10 marks

4.2 A trapezoidal channel with a bottom width of 3.0 m and sides with a slope of 2:1 (horizontal:vertical) is lined with fine gravel (n = 0.020) and is to carry 10 m^3/s. Can this channel be built with a slope of S_o = 0.00010 if it is necessary to keep the velocity below 0.75 m/s to prevent scouring of the bottom? Explain.

15 marks

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

A converging elbow (figure below) turns water through an angle of 135^{o} in a vertical plane. The flow cross section diameter is 400 mm at the elbow inlet, section (1), and 200 mm at the elbow outlet, section (2). The elbow flow passage volume is 0.2 m^3 between sections (1) and (2). The water volume flowrate is 0.4 m^3/s and the elbow inlet and outlet pressures are 150 kPa and 90 kPa. The elbow mass is 12 kg. Calculate the horizontal (x direction) and vertical (z direction) anchoring forces required to hold the elbow in place.



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: $P = N_p \rho N^3 d^5$

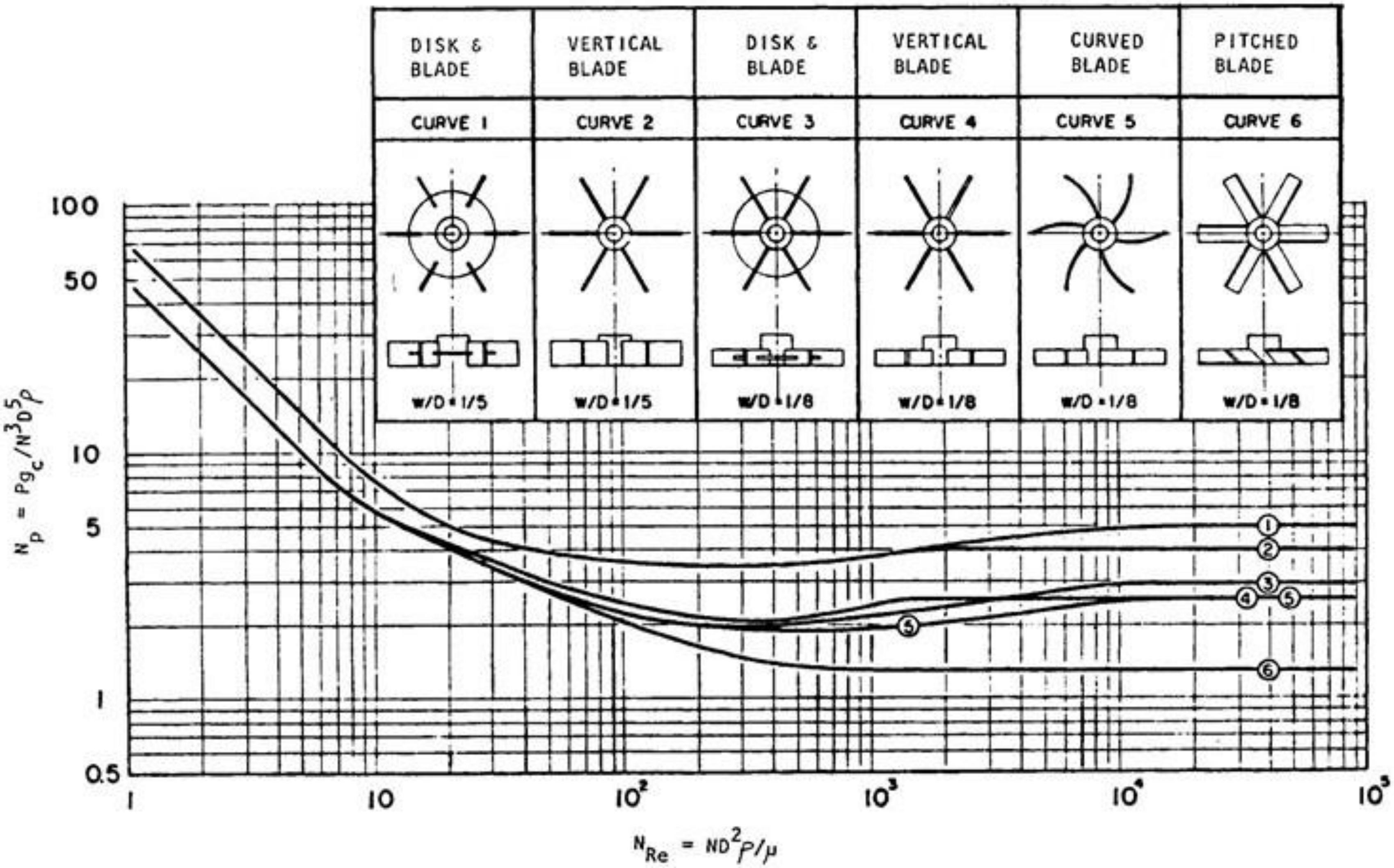
Tables and Figures

Values for Manning coefficients

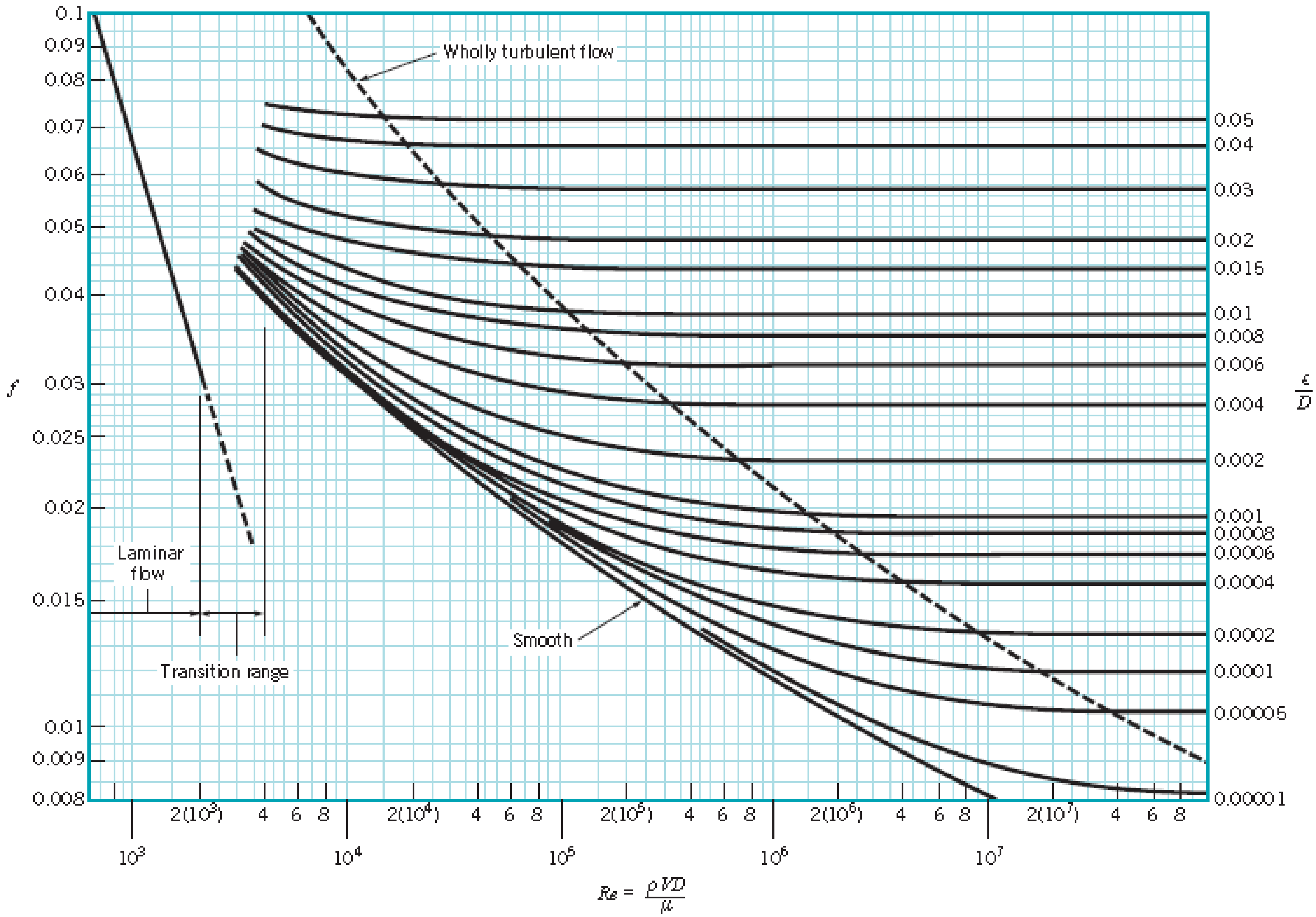
TABLE 10.1
Values of the Manning Coefficient, n (Ref. 6)

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



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
f
Wholly turbulent flow
Laminar flow
Transition range
Smooth
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(10³) 4 6 8 2(10⁴) 4 6 8 2(10⁵) 4 6 8 2(10⁶) 4 6 8 2(10⁷) 4 6 8
10³ 10⁴ 10⁵ 10⁶ 10⁷
$Re = \frac{\rho V D}{\mu}$

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

CENTRE NUMBER						CANDIDATE NUMBER				

QUESTION NUMBER