UNIVERSITY OF JOHANNESBURG

PROGRAM	:	BACHELOR OF ENGINEERING TECHNOLOGY *CHEMICAL ENGINEERING*
SUBJECT	:	**CHEMICAL PROCESS TECHNOLOGY 1B**
CODE	:	**CPTCHB1**
DATE	:	SUMMER EXAMINATION 25 NOVEMBER 2019
DURATION	:	(SESSION 1) 08:30 - 11:30
WEIGHT	:	40 : 60
TOTAL MARKS	:	120

EXAMINER(S)	:	MR P KHANGALE
MODERATOR	:	DR L MEKUTO
NUMBER OF PAGES	:	8 PAGES

REQUIREMENTS (only one per candidate)	:	Use of scientific (non-programmable) calculator is permitted

HINTS AND INSTRUCTIONS TO CANDIDATE(S):

- The purpose of this 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.

QUESTION 1

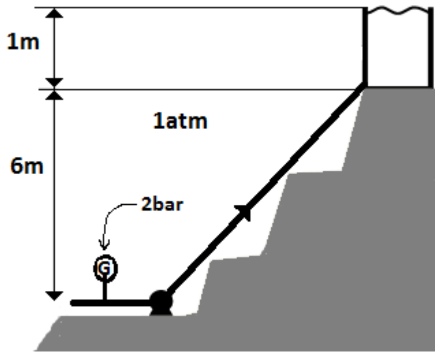
1.1. List three instruments used to measure Temperature (3)

1.2. Explain briefly the importance of pressure in a chemical process. (10)

1.3. Explain briefly what is meant by gauge pressure (5)

[18]

QUESTION 2



2.1. Derive the Bernoulli equation from first principles. (22)

2.2. Water is pumped at $0.001 m^3 s^{-1}$ to a tank through a 0.04m internal and 0.05m external diameter pipe as shown in the diagram. The frictional loss from the beginning of the system to the end, Δh_f, is 15m. The viscosity, heat capacity, thermal conductivity and the density of water is 1cP, $4200 Jkg^{-1}K^{-1}$, $0.6 Wm^{-1}K^{-1}$ and $1000 kgm^{-3}$ respectively. What is Δh_p, the head of the pump (m)? (15)

[37]

QUESTION 3

A shell and tube heat exchanger heats 2.52 kgs^{-1} of water from 21.1 to 54.4 °C by using hot water under pressure entering at 115.6 and leaving at 48.9 °C. The outside surface area of the tubes in the exchanger is $A_0 = 9.30\ m^2$. If this is a counter current operation, calculate:

a) The mean temperature difference ΔTm in the exchanger. (5)

b) The overall heat-transfer coefficient U_0. (15)

Cp of water is 4.187 $kJkg^{-1}K^{-1}$

[20]

QUESTION 4

A gas of pure A at 830 kPa (8.2 atm) enters a reactor with a volumetric flow rate of 2 $dm^3.s^{-1}$ at 500 K.

1.1 Calculate the entering concentration of A, C_{A0}, and the entering molar flow rate, F_{A0}. Assume that the gas behave as an ideal gas with PV = nRT. (10)

1.2 Calculate the volume of a CSTR reactor necessary to consume 65% of A if the rate of reaction $-r_A = 0.05\ mol.h^{-1}.dm^{-3}$. (10)

1.3 If this was a batch reactor with the same volume as CSTR, determine the time necessary to achieve the same conversion in 1.2. (5)

R=8.314 $dm^3.kPa.mol^{-1}.K^{-1}$

[25]

QUESTION 5

A hazard and operability study (**HAZOP**) is a structured and systematic examination of a complex planned or existing process or operation in order to identify and evaluate problems that may represent risks to personnel or equipment. Explain briefly why is important to conduct HAZOP study for a chemical process

[20]

TOTAL MARKS =120

FULL MARKS =120

DATA:

Quantity	Equivalent Values
Mass	1 kg = 1000 g = 0.001 metric ton = 2.20462 lb_m = 35.27392 oz 1 lb_m = 16 oz = 5×10^{-4} ton = 453.593 g = 0.453593 kg
Length	1 m = 100 cm = 1000 mm = 10^6 microns (μm) = 10^{10} angstroms (Å) = 39.37 in. = 3.2808 ft = 1.0936 yd = 0.0006214 mile 1 ft = 12 in. = 1/3 yd = 0.3048 m = 30.48 cm
Volume	1 m^3 = 1000 L = 10^6 cm^3 = 10^6 mL = 35.3145 ft^3 = 220.83 imperial gallons = 264.17 gal = 1056.68 qt 1 ft^3 = 1728 $in.^3$ = 7.4805 gal = 0.028317 m^3 = 28.317 L = 28,317 cm^3
Force	1 N = 1 kg·m/s^2 = 10^5 dynes = 10^5 g·cm/s^2 = 0.22481 lb_f 1 lb_f = 32.174 lb_m·ft/s^2 = 4.4482 N = 4.4482×10^5 dynes
Pressure	1 atm = 1.01325×10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bar = 1.01325×10^6 dynes/cm^2 = 760 mm Hg at 0°C (torr) = 10.333 m H_2O at 4°C = 14.696 lb_f/$in.^2$ (psi) = 33.9 ft H_2O at 4°C = 29.921 in. Hg at 0°C
Energy	1 J = 1 N·m = 10^7 ergs = 10^7 dyne·cm = 2.778×10^{-7} kW·h = 0.23901 cal = 0.7376 ft-lb_f = 9.486×10^{-4} Btu
Power	1 W = 1 J/s = 0.23901 cal/s = 0.7376 ft·lb_f/s = 9.486×10^{-4} Btu/s = 1.341×10^{-3} hp

Material	Coeff. per degree Celsius	Material	Coeff. per degree Celsius
Iron	0.006	Tungsten	0.0045
Nickel	0.005	Platinum	0.00385

TABLE 5.1
Loss coefficients for standard threaded pipe fittings[9b]

Fitting	K_f
Elbow, standard	
45°	0.35
90°	0.75
Tee	
Straight through	0.4
Used as elbow	1.0
Return bend, 180°	1.5
Gate valve	
Half open	4.5
Wide open	0.17
Angle valve, wide open	2.0
Globe valve, wide open	6.0

Selected Equivalent Lengths

Fitting	L_e/d
Elbow, 90° standard	35
Tee, flow straight through	20
Tee, flow through bend	60
Globe valve, fully open	340
Gate Valve, fully open	25

$$\Delta h_{fe} = \frac{(u_s - u_l)^2}{2g}$$

$$\Delta h_{fc} = K \frac{u_s^{\,2}}{2g}$$

$$K = 0.4\left(1.25 - \left(\frac{d_s}{d_l}\right)^2\right) \qquad \text{When} \qquad \frac{d_s^2}{d_l^2} \prec 0.715$$

$$K = 0.75\left(1.0 - \left(\frac{d_s}{d_l}\right)^2\right) \qquad \text{When} \qquad \frac{d_s^2}{d_l^2} \succ 0.715$$

APPENDIX 3

Dimensions, Capacities, and Weights of Standard Steel Pipe†

Nominal pipe size, in.	Outside diameter, in.	Schedule no.	Wall thickness, in.	Inside diameter, in.	Cross-sectional area of metal, in.^{2}	Inside sectional area, ft^2	Circumference, ft or surface, ft^2/ft of length: Outside	Inside	Capacity at 1 ft/s velocity: U.S. gal/min	Water, lb/h	Pipe weight, lb/ft
1/8	0.405	40	0.068	0.269	0.072	0.00040	0.106	0.0705	0.179	89.5	0.24
		80	0.095	0.215	0.093	0.00025	0.106	0.0563	0.113	56.5	0.31
1/4	0.540	40	0.088	0.364	0.125	0.00072	0.141	0.095	0.323	161.5	0.42
		80	0.119	0.302	0.157	0.00050	0.141	0.079	0.224	112.0	0.54
3/8	0.675	40	0.091	0.493	0.167	0.00133	0.177	0.129	0.596	298.0	0.57
		80	0.126	0.423	0.217	0.00098	0.177	0.111	0.440	220.0	0.74
1/2	0.840	40	0.109	0.622	0.250	0.00211	0.220	0.163	0.945	472.0	0.85
		80	0.147	0.546	0.320	0.00163	0.220	0.143	0.730	365.0	1.09
3/4	1.050	40	0.113	0.824	0.333	0.00371	0.275	0.216	1.665	832.5	1.13
		80	0.154	0.742	0.433	0.00300	0.275	0.194	1.345	672.5	1.47
1	1.315	40	0.133	1.049	0.494	0.00600	0.344	0.275	2.690	1,345	1.68
		80	0.179	0.957	0.639	0.00499	0.344	0.250	2.240	1,120	2.17
1 1/4	1.660	40	0.140	1.380	0.668	0.01040	0.435	0.361	4.57	2,285	2.27
		80	0.191	1.278	0.881	0.00891	0.435	0.335	3.99	1,995	3.00
1 1/2	1.900	40	0.145	1.610	0.800	0.01414	0.497	0.421	6.34	3,170	2.72
		80	0.200	1.500	1.069	0.01225	0.497	0.393	5.49	2,745	3.63
2	2.375	40	0.154	2.067	1.075	0.02330	0.622	0.541	10.45	5,225	3.65
		80	0.218	1.939	1.477	0.02050	0.622	0.508	9.20	4,600	5.02
2 1/2	2.875	40	0.203	2.469	1.704	0.03322	0.753	0.647	14.92	7,460	5.79
		80	0.276	2.323	2.254	0.02942	0.753	0.608	13.20	6,600	7.66
3	3.500	40	0.216	3.068	2.228	0.05130	0.916	0.803	23.00	11,500	7.58
		80	0.300	2.900	3.016	0.04587	0.916	0.759	20.55	10,275	10.25
3 1/2	4.000	40	0.226	3.548	2.680	0.06870	1.047	0.929	30.80	15,400	9.11
		80	0.318	3.364	3.678	0.06170	1.047	0.881	27.70	13,850	12.51
4	4.500	40	0.237	4.026	3.17	0.08840	1.178	1.054	39.6	19,800	10.79
		80	0.337	3.826	4.41	0.07986	1.178	1.002	35.8	17,900	14.98
5	5.563	40	0.258	5.047	4.30	0.1390	1.456	1.321	62.3	31,150	14.62
		80	0.375	4.813	6.11	0.1263	1.456	1.260	57.7	28,850	20.78
6	6.625	40	0.280	6.065	5.58	0.2006	1.734	1.588	90.0	45,000	18.97
		80	0.432	5.761	8.40	0.1810	1.734	1.508	81.1	40,550	28.57
8	8.625	40	0.322	7.981	8.396	0.3474	2.258	2.089	155.7	77,850	28.55
		80	0.500	7.625	12.76	0.3171	2.258	1.996	142.3	71,150	43.39
10	10.75	40	0.365	10.020	11.91	0.5475	2.814	2.620	246.0	123,000	40.48
		80	0.594	9.562	18.95	0.4987	2.814	2.503	223.4	111,700	64.40
12	12.75	40	0.406	11.938	15.74	0.7773	3.338	3.13	349.0	174,500	53.56
		80	0.688	11.374	26.07	0.7056	3.338	2.98	316.7	158,350	88.57

† Based on ANSI B36.10-1959 by permission of ASME.

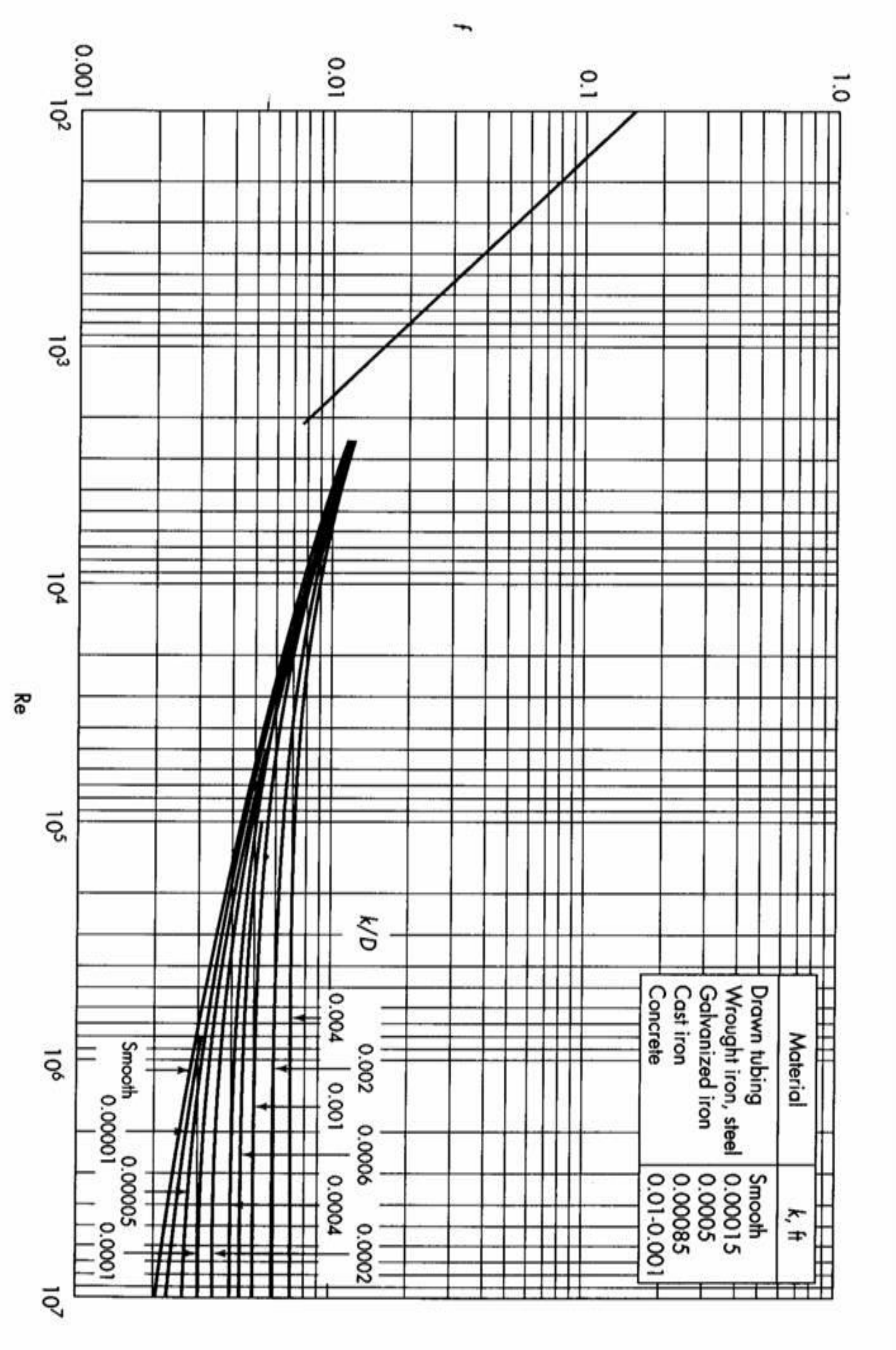


FIGURE 5.10
Friction factor chart.