CRANFIELD UNIVERSITY

Examination

SCHOOL OF WATER, ENERGY AND ENVIRONMENT
WATER AND WASTEWATER ENGINEERING
STREAM

PROCESS SCIENCE AND ENGINEERING

Wednesday 4 January 2017: 13.00 – 15.30 (2hrs 30m)

Open Book

INSTRUCTIONS TO CANDIDATES:

Answer **ALL** questions.

Start each answer on a separate page.

Candidates are allowed a non-programmable calculator and Watermaths text and annotations in the book only.

EXAM MATERIALS:
This paper is provided with **GRAPH PAPER**.

You are expected to answer all questions

Provide the results and the process through which you obtained the results (equations, assumptions ...)

#	Question	Mk
1	Water at 10°C flowing at 15000 m^3/d contains 280 mg/L hardness as $CaCO_3$, 140 mg/l chloride, 200 mg/L alkalinity as $CaCO_3$, 55 mg/L nitrate and 5 mg/L phosphate. It flows along a 30 m-long cast iron pipe which is 200 mm in diameter and contains four long-radius 90° bends and a gate valve fully open.	**28**
	a) What is the concentration of sodium in mg/L assuming we have a charge balanced system?	9
	b) What is the velocity of the water in the pipe in m/s?	3
	c) What is the Reynolds number?	3
	d) What is the friction factor?	3
	e) What is the total headloss along the length of the pipe in m of water?	6
	f) If the water is to be blended with a second stream containing 15 mg/L nitrate to produce a stream containing less than 40 mg/L nitrate, what is the minimum flow rate of the second stream in m^3/d?	4
2	Carbon dioxide is dissolved in water at a temperature of 20°C	**10**
	a) What is the Schmidt number?	4
	b) If mass transfer is defined by a Sherwood number of 2400 and if turbulent flow is assumed, what is the Reynolds number?	3
	c) To what crossflow velocity in m/s does this relate for a pipe diameter of 100 mm?	3
3	A CSTR of volume 8 m^3 treats water flowing at 45 m^3/hr	**9**
	a) What is the removal efficiency attained at a reaction rate of 0.25 per minute?	5
	b) What would be the removal efficiency of a PFR having half this tank volume?	4
4	A tank containing water at 15°C is installed at a height of 5.5 m above ground level. The water is fed to a treatment unit through pipe with the outlet at 1.0 m above ground level.	**8**
	a) What is the velocity in the pipe knowing that both the tank and pipe outlet are open to the atmosphere?	6
	b) How much pressure (in bar) is required to fill the tank if the outlet of the previous stage of the treatment train is located 2.5 m below ground level?	2
5	A wastewater is being treated in a CSTR following a first order reaction kinetics with a reaction rate constant equal to 0.15 day^{-1}. For a reactor volume of 50 m^3, what should be the flow rate to achieve 96% removal efficiency?	**4**
6	Determine the reaction order for reagent A removal process with the given data below:	**7**

Concentration reagent A	235	150	100	55	30	20
Time (min)	0	7	15	25	35	40

7	What is the new pH of a solution, initially at pH 6.6 and containing a bicarbonate concentration of 65 mM after adding 0.03 M of OH^-?	6
8	The Henry's law constant for H_2S is 0.1 mol/(L*atm), and H_2S (aq) $\leftrightarrow$ HS^- + H^+ where $K_a = 10^{-7}$. If you bubble pure H_2S into a beaker of water, what is the concentration of HS^- at pH 5 in mol/L? Since H_2S is a pure gas, assume a partial pressure of 1 atm.	7
9	What should be the particle size (diameter in microns) of flocs with a density of 1600 kg/m³ to settle in water at 10°C at a velocity of 6.5 mm/s?	4
	Total	83