Name: ____________________

Student #: ____________________

UNIVERSITY OF TORONTO

DEPARTMENT OF CIVIL ENGINEERING

SPRING EXAMINATION, APRIL 2001

CIV 238S - CHEMISTRY, MATERIALS & THE ENVIRONMENT

Examiners:

Prof. R.D. Hooton

1. Non-programmable calculators may be used. No other aids are allowed.
2. Answer all questions in the space provided or on the backs of adjacent pages. Additional space is provided at the end of the paper.
3. Answer all questions.
4. Time: 2.5 hours

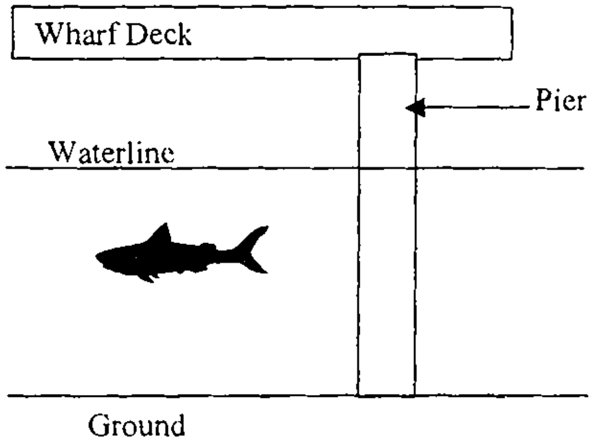
Question	Total Mark	Student Mark
1	12	
2	11	
3	11	
4	10	
5	16	
Total	60	

Name: ______________________

Question 1 (12 Marks)

a. List the four things that must be present for corrosion to occur. (2 marks)

b. Where would you expect the greatest amount of corrosion to occur on a pier in a salt water harbour, and explain why? (4 marks)



Name: ____________________

Question 1 (continued)

c. Describe the process of cathodic protection with a sacrificial anode, using diagrams if desired. Also state two drawbacks of this system. (6 marks)

Name: ____________________

Question 2 (**11 Marks**)

You have been hired as a consulting engineer to evaluate a concrete foundation wall supporting a cottage in Northern Ontario. After a thorough site inspection and laboratory testing of samples obtained from the site, you determine that the structure is suffering from an advanced form of alkali-aggregate reaction (AAR). The owner of the cottage has never heard of AAR. Briefly explain the following to her:

a) The two types of AAR recognized in the CSA standards. (2 marks)

b) The three necessary requirements for AAR to occur. (3 marks)

c) How does this reaction manifest itself physically? (ie: what symptoms or clues will be obvious on site to indicate that AAR is the potential cause of the deterioration?) (3 marks)

Name: ______________________

<u>Question 2</u> (continued)

d) You have determined that the structure is so extensively damaged that it is unsafe and must be replaced. The owner intends to do so and is also planning further concrete work on the property. What precaution would you advise your client to take to ensure that AAR does not cause further problems in the new concrete (list at least 3 approaches). (3 marks)

Name: ______________________

Question 3 **(11 marks)**

a) Explain with the aid of a diagram how sulphate salt crystallization can lead to surface damage in porous building materials. (4 marks)

b) List 3 ways in which the sulphate resistance of concrete can be improved. (3 marks)

Name: ____________________

Question 3 (continued)

c) Explain with the help of a diagram how sulphur bearing compounds in domestic sewage may lead to deterioration of concrete pipes. What is the role of bacteria in the process? (4 marks)

Name: ____________ ______________

Question 4 **(10 points)**

a) Using point form, describe how the hydraulic pressure theory can be used to explain the need for a system of entrained air bubbles in concrete that is exposed to freezing and thawing while saturated. (5 marks)

b) Will all non-air entrained concrete which is exposed to freezing and thawing eventually become damaged? Explain why? (3 marks)

c) The provision of an adequate entrained air system does not guarantee resistance to freezing and thawing. Explain 2 instances where damage could occur. (2 marks)

Name: ______________________

Question 5 **(16 marks)**

a) List three different mechanisms which can result in moisture or ionic transport in porous materials and provide a single-sentence description to differentiate them. (6 marks)

b) One face of a 100 mm thick wall of a saturated concrete storage tank is exposed to a chloride solution under a hydraulic head of 40 m (above atmospheric). The opposite face is at atmospheric pressure. Disregarding ionic diffusion, what would be the depth of chloride penetration into the concrete after 120 days if its measured hydraulic conductivity, $k_w = 2 \times 10^{-13}$ m/s and its accessible porosity, $n = 8\%$. (5 marks)

Name: ____________________

Question 5 (continued)

c) A concrete tunnel is exposed to a chloride environment such that the chloride concentration at the surface is 1.1% (by mass of concrete). Using a corrosion threshold value of 1.2 kg/m^3 chloride (by mass of concrete), calculate the maximum allowable chloride diffusion coefficient if the steel is to be protected from corrosion for 50 years. The depth of cover to the steel is 60 mm. Assume diffusion is the only mechanism governing chloride transport. The density of the concrete is 2400 kg/m^3. (5 marks)

Name: ____________________

$$\frac{C_s}{C_x} = 1 - erf\left(\frac{x}{2\sqrt{D \cdot t}}\right)$$

$$Q = -k_w \cdot \frac{\Delta h}{l} \cdot A$$

$$\overline{v} = \frac{Q}{n \cdot A}$$

Values of the Error Function

	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.000	0.011	0.023	0.034	0.045	0.056	0.068	0.079	0.090	0.101
0.1	0.112	0.124	0.135	0.146	0.157	0.168	0.179	0.190	0.201	0.212
0.2	0.223	0.234	0.244	0.255	0.266	0.276	0.287	0.297	0.308	0.318
0.3	0.329	0.339	0.349	0.359	0.369	0.379	0.389	0.399	0.409	0.419
0.4	0.428	0.438	0.447	0.457	0.466	0.475	0.485	0.494	0.503	0.512
0.5	0.520	0.529	0.538	0.546	0.555	0.563	0.572	0.580	0.588	0.596
0.6	0.604	0.612	0.619	0.627	0.635	0.642	0.649	0.657	0.664	0.671
0.7	0.678	0.685	0.691	0.698	0.705	0.711	0.718	0.724	0.730	0.736
0.8	0.742	0.748	0.754	0.760	0.765	0.771	0.776	0.781	0.787	0.792
0.9	0.797	0.802	0.807	0.812	0.816	0.821	0.825	0.830	0.834	0.839
1.0	0.843	0.847	0.851	0.855	0.859	0.862	0.866	0.870	0.873	0.877
1.1	0.880	0.884	0.887	0.890	0.893	0.896	0.899	0.902	0.905	0.908
1.2	0.910	0.913	0.916	0.918	0.921	0.923	0.925	0.928	0.930	0.932
1.3	0.934	0.936	0.938	0.940	0.942	0.944	0.946	0.947	0.949	0.951
1.4	0.952	0.954	0.955	0.957	0.958	0.960	0.961	0.962	0.964	0.965
1.5	0.966	0.967	0.968	0.970	0.971	0.972	0.973	0.974	0.975	0.975
1.6	0.976	0.977	0.978	0.979	0.980	0.980	0.981	0.982	0.982	0.983
1.7	0.984	0.984	0.985	0.986	0.986	0.987	0.987	0.988	0.988	0.989
1.8	0.989	0.990	0.990	0.990	0.991	0.991	0.991	0.992	0.992	0.992
1.9	0.993	0.993	0.993	0.994	0.994	0.994	0.994	0.995	0.995	0.995
2.0	0.995	0.996	0.996	0.996	0.996	0.996	0.996	0.997	0.997	0.997
2.1	0.997	0.997	0.997	0.997	0.998	0.998	0.998	0.998	0.998	0.998
2.2	0.998	0.998	0.998	0.998	0.998	0.999	0.999	0.999	0.999	0.999
2.3	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
2.4	0.999	0.999	0.999	0.999	0.999	0.999	0.999	1.000	1.000	1.000
2.5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2.6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2.7	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2.8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2.9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
3.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000