UNIVERSITI
TEKNOLOGI
PETRONAS

FINAL EXAMINATION
MAY 2024 SEMESTER

COURSE	**:**	**AAB3033 - CORROSION AND DEGRADATION OF MATERIALS**
DATE	**:**	**9 AUGUST 2024 (FRIDAY)**
TIME	**:**	**9.00 AM - 12.00 NOON (3 HOURS)**

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **SIX (6)** pages in this Question Booklet including the cover page and appendix.

ii. **DOUBLE-SIDED** Question Booklet.

1. a. A desalination plant frequently experiences failures in its stainless steel piping system, which is exposed to a saline environment. Inspection reveals numerous small holes on both the external and internal surfaces of the pipes, as shown in **FIGURE Q1**. Analyze the principles underlying this type of corrosion.

[8 marks]

FIGURE Q1: STAINLESS STEEL PIPE WITH CORROSION

b. Explain the process of erosion-corrosion and the types of metallic and non-metallic that can be affected in the industry applications.

[6 marks]

c. Explain corrosion in ceramic materials using an example.

[5 marks]

d. A standard galvanic cell has electrodes of iron (Fe) and lead (Pb). Calculate the electromotive force (emf) of the cell. Justify which electrodes will be corroded.

[6 marks]

2. a. Thermal shock can lead to the degradation of ceramics in high-temperature environments. Discuss the mechanism of thermal shock in the application of ceramic used in turbine blades.

[6 marks]

b. Explain the role of environmental factors in the degradation of polymers used in automotive applications.

[8 marks]

c. Polymer-based products under the influence of one or more environmental factors such as heat, light, or chemicals like acids, alkalis, and some salts. These changes are usually undesirable, such as cracking and chemical disintegration of products or more rarely, desirable, in biodegradable plastic bags. Explain the degradation process of the biodegradable polymer material by giving an example.

[11 marks]

3. A crude oil storage tank was found leaking because of underside corrosion, which developed due to extended exposure to a corrosive environment. Following the removal of the corrosion product, a microscopic examination of the metal surface was performed, as depicted in **FIGURE Q3**.

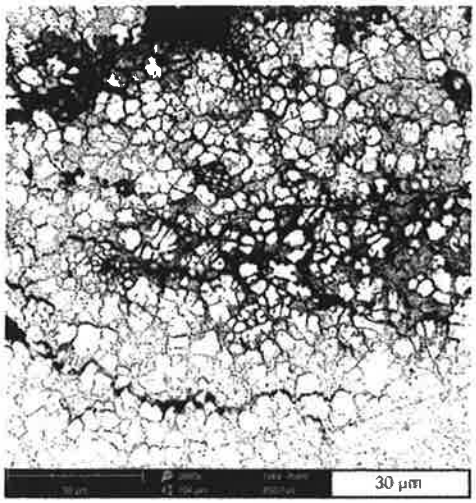

FIGURE Q3: MICROSCOPIC VIEW OF A METAL SURFACE

a. Evaluate the type and mechanism of corrosion on the bottom plate by examining the potential environmental factors that led to the corroded surface, as illustrated in the micrograph.

[10 marks]

b. Explain mitigation and monitoring techniques to protect the tank bottom plate from underside corrosion.

[9 marks]

c. Based on the investigation, a steel plate attached to the storage tank has been exposed to a corrosive environment for 6 years. Upon retrieval, it was determined that the initial mass of the steel plate was 510 g, and its final mass is 495 g. Assuming a density of steel as 7.85 g/cm^3 and an exposed surface area of 100 cm^2, calculate the corrosion rate of the steel plate in millimeters per year (mm/year).

[6 marks]

4. As a corrosion engineer, your responsibility is to safeguard long-distance underground pipelines, aiming to ensure a minimum lifespan of 20 years, as illustrated in **FIGURE Q4**.

FIGURE Q4: UNDERGROUND PIPELINE

a. Propose a corrosion prevention method to protect the long-distance underground pipelines. Provide justification for the principle mechanisms, supported by sketches.

[12 marks]

b. Discuss the advantages and disadvantages of the proposed corrosion prevention method in **part (a)**.

[4 marks]

c. Compare the factors influence the design of your proposed protection system for offshore pipelines instead of buried pipelines.

[9 marks]

- END OF PAPER -

APPENDIX

$$CPR = \frac{KW}{\rho AT}$$

$$E_{cell} = (E^0_{cathode} - E^0_{anode}) - \frac{0.059}{n} log_{10} \frac{[\text{Products}]}{[\text{Reactants}]}$$

Galvanic Series

	Electrode Reaction	Standard Electrode Potential, V° (V)
	$Au^{3+} + 3e^- \longrightarrow Au$	+1.420
	$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$	+1.229
	$Pt^{2+} + 2e^- \longrightarrow Pt$	~+1.2
	$Ag^+ + e^- \longrightarrow Ag$	+0.800
	$Fe^{3+} + e^- \longrightarrow Fe^{2+}$	+0.771
Increasingly inert (cathodic)	$O_2 + 2H_2O + 4e^- \longrightarrow 4(OH^-)$	+0.401
	$Cu^{2+} + 2e^- \longrightarrow Cu$	+0.340
	$2H^+ + 2e^- \longrightarrow H_2$	0.000
	$Pb^{2+} + 2e^- \longrightarrow Pb$	−0.126
	$Sn^{2+} + 2e^- \longrightarrow Sn$	−0.136
	$Ni^{2+} + 2e^- \longrightarrow Ni$	−0.250
	$Co^{2+} + 2e^- \longrightarrow Co$	−0.277
	$Cd^{2+} + 2e^- \longrightarrow Cd$	−0.403
	$Fe^{2+} + 2e^- \longrightarrow Fe$	−0.440
	$Cr^{3+} + 3e^- \longrightarrow Cr$	−0.744
Increasingly active (anodic)	$Zn^{2+} + 2e^- \longrightarrow Zn$	−0.763
	$Al^{3+} + 3e^- \longrightarrow Al$	−1.662
	$Mg^{2+} + 2e^- \longrightarrow Mg$	−2.363
	$Na^+ + e^- \longrightarrow Na$	−2.714
	$K^+ + e^- \longrightarrow K$	−2.924

4. Reinforced concrete is crucial in modern construction for its strength and durability, especially in bridges. However, it degrades over time due to corrosion, swelling, and cracking, as shown in **FIGURE Q4**.

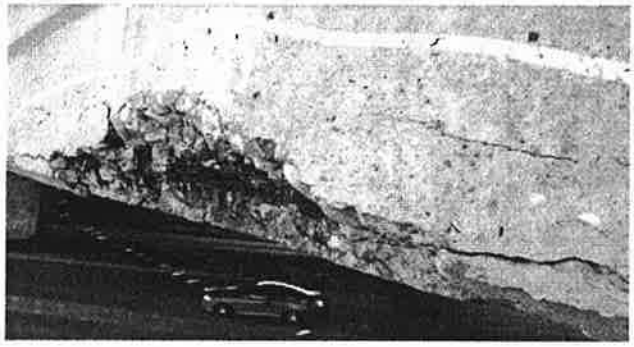

FIGURE Q4: DEGRADED CONCRETE

a. Explain **TWO (2)** primary causes for swelling damage in bridge structures.

[6 marks]

b. Discuss the carbonation process towards the corrosion damage in the reinforced concrete Justify the answer.

[6 marks]

c. Steel bars embedded in reinforced concrete are subject to corrosion. Explain the underlying mechanism and provide a sketch to support your answer.

[8 marks]

d. A 2-meter-long with 0.02-meter diameter steel bar in reinforced concrete was exposed to corrosion for 10 years. Its weight decreased from 3000 grams to 2950 grams. With a steel density of 7.85 g/cm^3 and an exposed surface area of 200 cm^2, calculate the corrosion rate in mm/year.

[5 marks]

- END OF PAPER -

FORMULAE

$$CPR = \frac{KW}{\rho AT}$$