Al Imam Mohammad Ibn Saud Islamic University
College of Engineering
Department of Mechanical Engineering

MID TERM 2 (Solution)			
Course Code and Title:	**ME-413 Corrosion Engineering**		
Semester and Year:	**Fall 2020**		
Examination Date:	November 2, 2020	Maximum Time:	1 hour 30 minutes

Student Name:									
Student ID:									

Instructions to Students:

1. Show all steps of calculation clearly
2. ONLY use Black or Blue pen
3. Draw figures wherever necessary
4. Understanding a question is the part of question

For Official Use Only:

Question No.	1	2	3	4	5	**Total**
SO KPI Focused						**-**
CLO Focused:						**-**
Max. Points:	2.5	3	4.5	6	4	**20**
Points Obtained:						

Section- A: (Short answer type) ……. [2.5 x1 = 2.5 Marks]

1. **Write the limitations of EMF series? How these limitations are being eliminated? Write the limitations of Galvanic series** (1+0.5+1)

limitations of EMF series:

- The emf series lists only the electrode potentials of metals and not alloys. Alloys are not considered in the emf series.
- The emf series predicts the tendency to corrode but it cannot predict whether corrosion would actually take place.
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Overcoming the limitations of EMF series:

- The limitations imposed by emf series are overcome by another series called '*galvanic series*'. The galvanic series is an arrange-ment of metals and alloys in order of their corrosion potentials in the environment.
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Disadvantages of Galvanic series:

- Each environment requires a different galvanic series
- Galvanic corrosion also **depends on the extent of polarization** of the metals in alloys and not only on how close they are in the galvanic series

Section- B: (Design and selection) …… [3+4.5 = 7.5 Marks]

2. **Heavy galvanic corrosion took place (figure a) on the nut-bolt joint as shown in the figure due to a bad design (figure b). How do you modify the design to protect the joint from galvanic corrosion? (3)**

Figure a

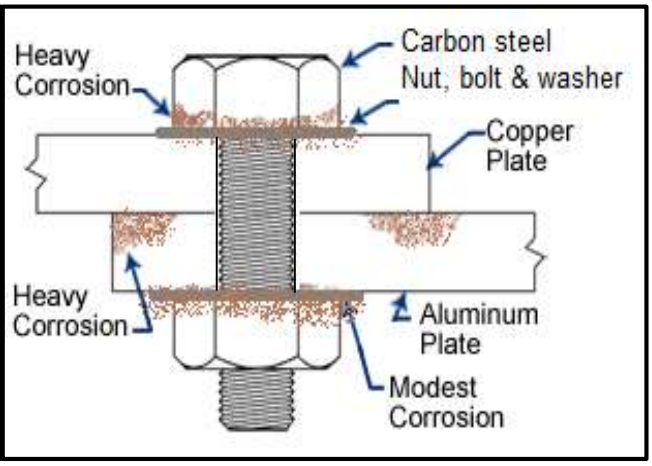
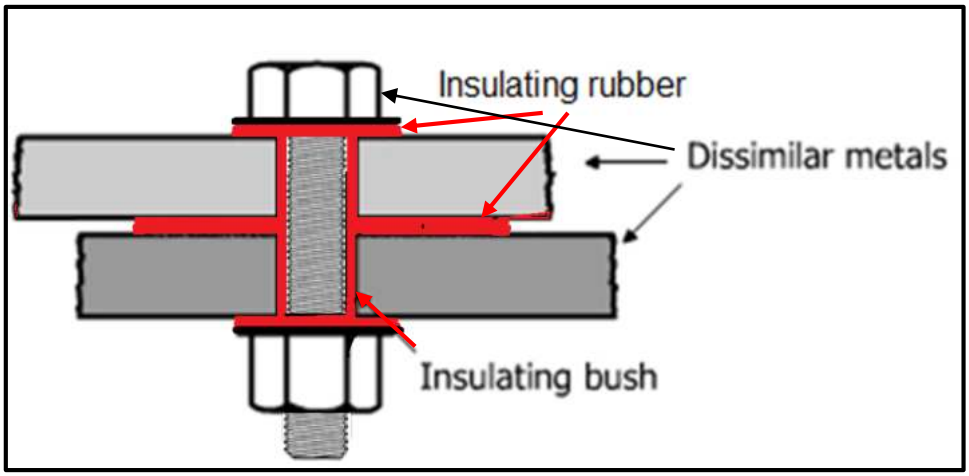


Figure b

The modified design of the joint to protect from galvanic corrosion is given below:



All the dissimilar metals are to be insulated so that it might not form/make any Galvanic cell. To avoid forming Galvanic cell, the followings steps are to be taken:

1. Insulating rubber is to be placed between the two plates.
2. Insulating bush is to be fitted in the hole to cover the bolt so that the bolt may not get contact with the metallic plates.
3. Insulating rubber washers are to be placed below the metallic washers of bolt head and the nut so that the nut and bolt head may not get contact with the metallic plates.

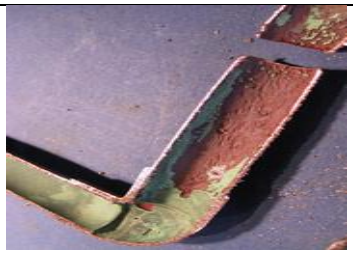
3. Identify the type of corrosion in the figures and write the correct matching in the table (4.5)

Sl. No.	*Type of corrosion*	*Matching with figure no.*
1	**Uniform corrosion**	**b**
2	**Galvanic or two-metals corrosion**	**g**
3	**Pitting corrosion**	**a**
4	**Crevice corrosion**	**c**
5	**Intergranular corrosion**	**e**
6	**Selective leaching corrosion**	**f**
7	**Erosion corrosion**	**d**
8	**Stress corrosion cracking**	**i**
9	**Hydrogen-induced cracking**	**h**

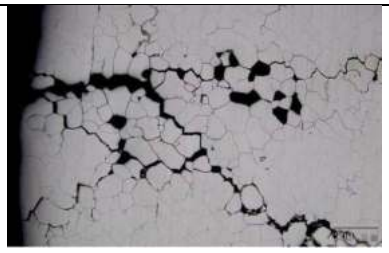
a

b

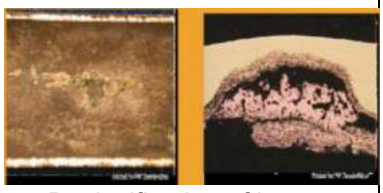
c



d

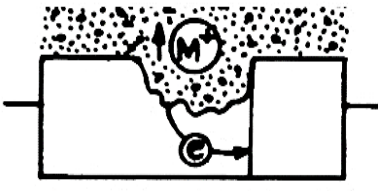


e



Dezincification of brass

f



g

Carbon steel

h

i

Section- C: (True/False and MCQ type) ……. [10Marks]

4. Tick on true or false: (0.75X8=6)

a) Add a suitable oil to the cooling water to protect from pitting corrosion of IC engine cylinder lining - **True/False -True**

b) Under localized tensile stress, and in a suitable environment, some metals and alloys get crack which is called intergranular cracking. - **True/False -False**

c) The Mixed-potential theory was developed to address the problem of several electromechanical reactions proceeding simultaneously at the same metal solution. - **True/False -True**

d) The presence of Cl^-, SO_x, NO_x in the environment have no effect on corrosion- - **True/False -False**

e) Sea water is not corrosive**.** - **True/False –False**

f) Fretting corrosion subjected to cyclic relative motion of extremely small amplitude of vibrations- **True/False -True**

g) Hydrogen enters the lattice of a metal, diffuses to voids, creates high internal stresses and causes hydrogen induced cracking - **True/False -True**

h) Stress corrosion cracking is not influence by temperature. **True/False –False**

5. Multiple choice questions: (1X4=4)

i) If the energy of a reversible process is negative, it implies that the cell reaction
   a) proceeds from right to left.
   b) is spontaneous.
   c) is not spontaneous.
   d) no reaction place at all **(b)**

ii) Factors important in Stress Corrosion Cracking (SSC)
   a) environmental composition, temperature;
   b) stress, metal composition and microstructure;
   c) all of the above
   d) none of the above **(c)**

iii) Which of the following pairs of metals would show the relatively highest rate of corrosion in seawater?
   a) Copper and Iron
   b) Copper and Zinc
   c) Copper and Aluminum
   d) Copper and Magnesium **(d)**

iv) In the following couples, which statement is correct?
   a) Copper anode; Iron cathode
   b) Copper cathode; Iron anode
   c) Both are anode
   d) Both are cathode **(b)**

Supplementary Tables:

Electromotive Force Series

Electrode Reaction	Standard Potential ϕ°(in volts) at 25°C
$Au^{3+} + 3e^- = Au$	1.50
$Pt^{2+} + 2e^- = Pt$	ca. 1.2
$Pd^{2+} + 2e^- = Pd$	0.987
$Hg^{2+} + 2e^- = Hg$	0.854
$Ag^{+} + e^- = Ag$	0.800
$Hg_2^{2+} + 2e^- = 2Hg$	0.789
$Cu^{+} + e^- = Cu$	0.521
$Cu^{2+} + 2e^- = Cu$	0.337
$2H^{+} + 2e^- = H_2$	0.000
$Pb^{2+} + 2e^- = Pb$	−0.126
$Sn^{2+} + 2e^- = Sn$	−0.136
$Mo^{3+} + 3e^- = Mo$	ca. −0.2
$Ni^{2+} + 2e^- = Ni$	−0.250
$Co^{2+} + 2e^- = Co$	−0.277
$Tl^{+} + e^- = Tl$	−0.336
$In^{3+} + 3e^- = In$	−0.342
$Cd^{2+} + 2e^- = Cd$	−0.403
$Fe^{2+} + 2e^- = Fe$	−0.440
$Ga^{3+} + 3e^- = Ga$	−0.53
$Cr^{3+} + 3e^- = Cr$	−0.74
$Cr^{2+} + 2e^- = Cr$	−0.91
$Zn^{2+} + 2e^- = Zn$	−0.763
$Nb^{3+} + 3e^- = Nb$	ca. −1.1
$Mn^{2+} + 2e^- = Mn$	−1.18
$Zr^{4+} + 4e^- = Zr$	−1.53
$Ti^{2+} + 2e^- = Ti$	−1.63
$Al^{3+} + 3e^- = Al$	−1.66
$Hf^{4+} + 4e^- = Hf$	−1.70
$U^{3+} + 3e^- = U$	−1.80
$Be^{2+} + 2e^- = Be$	−1.85
$Mg^{2+} + 2e^- = Mg$	−2.37
$Na^{+} + e^- = Na$	−2.71
$Ca^{2+} + 2e^- = Ca$	−2.87
$K^{+} + e^- = K$	−2.93
$Li^{+} + e^- = Li$	−3.05