Part B – Answer all questions. Put the working for your solution in the space below the question and if indicated, put your final answer in the box provided.

4 marks

51 (a). An electrochemical cell is constructed such that on one side a pure Zn electrode is in contact with a solution containing Zn^{2+} ions at a concentration of 10^{-2} *M.*
The other cell half consists of a pure Pb electrode immersed in a solution of Pb^{2+} ions that has a concentration of 10^{-4} *M.*

At what temperature will the potential between the two electrodes be +0.568 V?

Table 17.1 The Standard emf Series

	Electrode Reaction	Standard Electrode Potential, V^0(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
Increasingly inert (cathodic)	$Fe^{3+} + e^- \longrightarrow Fe^{2+}$	+0.771
	$O_2 + 2H_2O + 4e^- \longrightarrow 4(OH^-)$	+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
Increasingly active (anodic)	$Cr^{3+} + 3e^- \longrightarrow Cr$	−0.744
	$Zn^{2+} + 2e^- \longrightarrow Zn$	−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

Temperature (°C):

51 (b). Briefly describe the phenomenon of passivity. Name two common types of alloys that passivate.

4 marks

Passivating alloy A:	Passivating alloy B:

52 (a). Give 2 examples of metallurgical/processing techniques that are used to increase resistance to creep in metal alloys and explain briefly how they work.

4 marks

Technique 1:

Technique 2:

52 (b) Steady-state creep rate data are given here for some alloy taken at 200°C:

4 marks

$\dot{\varepsilon}_s$ (h^{-1})	σ (MPa)
2.5 x 10 $^{-3}$	55
2.4 x 10 $^{-2}$	69

If it is known that the activation energy for creep is 140,000 J/mol, compute the steady-state creep rate at a temperature of 250°C and a stress level of 48 MPa.

Steady-state creep rate:

53 (a). Briefly describe 3 methods for increasing the resistance to fatigue in metallic components.

3 marks

Technique 1:

Technique 2:

Technique 3:

2 marks

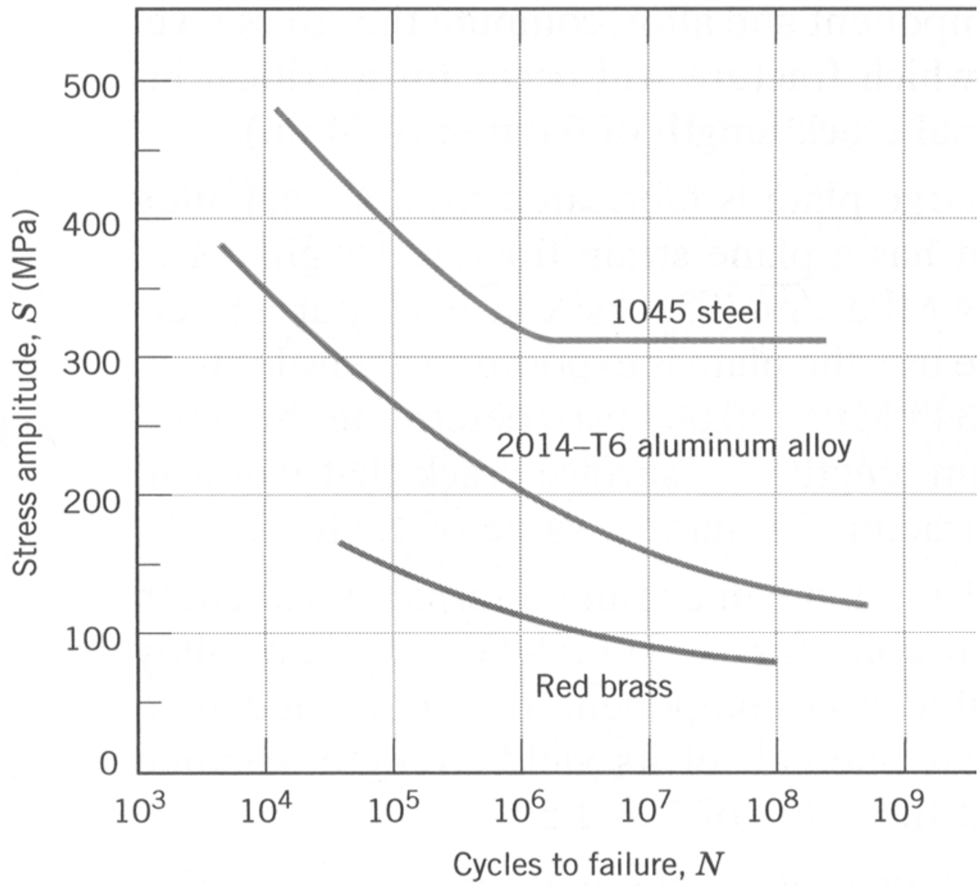
53 (b). Using the Fatigue data given on the S-N Figure answer the following.

The Fatigue limit for 1045 steel is:

The Fatigue limit for 2014 T6 aluminum is:

4 marks

(c). Determine the fatigue lifetimes for cylindrical specimens (15 mm diameter) of these two materials that are dynamically loaded from 0 to + 61,850 N in uniaxial tension.



Fatigue life 1045 steel:

Fatigue life 2014 aluminum:

54. Fill in the missing words in the following statements with the best word from the list of words given at the end of the text.

12.5 marks

a) The principal advantage of ______________________________ is its very low density which gives its alloys a very good strength to weight ratio.

b) Nickel and its alloys are commonly used at high ___________________________ and also in ______________________________ environments, such as being in contact with human skin.

c) Although _________________________ and its alloys do not show fatigue limits, their good strength and stiffness to weight ratios have resulted in them being used extensively in aerospace applications.

d) From a mechanical property viewpoint, steels not only have excellent ______________________________ , they can also be produced with a wide range of _______________________________ by varying heat treatments.

e) Aluminum alloys can be either ___________________________________ or ______________________________ depending on the alloy system. ___________________________ may also be used as a strengthening method for wrought alloys.

f) One of the best alloys for damping vibrations is __________________________________ . This is due to the microstructure which contains ferrite and/or pearlite and __________________________________.

g) __________________________ is used in large quantities for ____________________________________ steel to reduce __________________________ and its alloys are also used for high pressure die castings for small machine components.

h) __________________________ and its alloys have a very good combination of mechanical properties but they also show excellent resistance to many ___________________________ . Their main disadvantage is their reactivity with air when molten which increases their processing costs.

i) _________________________________ is the hardest of the cast irons and is used primarily for its excellent wear resistance.

j) _________________________________ and _____________________________ alloy steels such as 4340 (steel with chromium, nickel, molybdenum additions), can be used for very demanding applications such as aircraft undercarriages because of their combination of high ______________________________ and high ________________________________ .

k) __________________________ and its alloys are useful in electrical systems because of their high ______________________________________ and ____________________________________ . However they are also used in __________________________ fixtures because of their good resistance to corrosion in water.

grey-cast-iron, copper, magnesium, white-cast-iron, titanium, aluminium, zinc, chemicals, corrosive, temperatures, plumbing, thermal-conductivity, stiffness, rusting, heat-treatable, graphite-flakes, strengths, quenched, strength, galvanising, toughness, non-heat-treatable, electrical-conductivity, cold-working, tempered.

MECH 321 **Equation Sheet**

$$U_r = \frac{\sigma_y^2}{2E} \qquad \varepsilon_T = \ln\left(\frac{l_i}{l_o}\right) \qquad \varepsilon_{eng} = \left(\frac{l_i - l_o}{l_o}\right) = \frac{\Delta l}{l_o} \qquad \sigma_T = k\varepsilon_T^n \text{ (uniform plastic)}$$

$$\sigma_y = \sigma_0 + kd^{-1/2} \qquad \%\text{ Cold Work} = \left(\frac{A_o - A_d}{A_o}\right)x100 \qquad \tau = \frac{M_T r}{J} \qquad \gamma = \frac{r\theta}{L} \qquad \tau_r = \sigma\cos\lambda\cos\phi$$

$$\rho_c = V_f\,\rho_f + (1-V_f)\rho_m \qquad L_c = \frac{\sigma_f d}{2\tau_c} \qquad E_{c1} = E_f v_f + E_m v_m \qquad E_{c2} = \frac{E_f E_m}{E_f(1-v_f) + E_m v_f}$$

$$\sigma_{cd}^* = \sigma_f^* V_f\left(1 - \frac{\ell_c}{2\ell}\right) + \sigma_m^{'}(1 - V_f) \qquad \sigma_{cd'}^* = \frac{\ell\tau_c}{d}V_f + \sigma_m^{'}(1 - V_f) \qquad \sigma_{cl}^* = \sigma_m^{'}(1 - V_f) + \sigma_f^* V_f$$

$$\sigma_{c2} \approx \frac{\sigma_m}{2} \qquad \sigma_{\max} = 2\sigma_o\left(\frac{a}{\rho}\right)^{1/2} \qquad k_t = \frac{\sigma_{\max}}{\sigma_o} \qquad \sigma_c = \sqrt{\frac{2E\gamma_s}{\pi a}} \text{ (brittle)} \qquad \sigma_c = \sqrt{\frac{2E(\gamma_s + \gamma_p)}{\pi a}} \text{ (plastic)}$$

$$G_c = \frac{K_{1c}^2}{E} \qquad K_{1c} = Y\sigma\sqrt{\pi a} \qquad B \geq 2.5\left(\frac{K_{1c}}{\sigma_y}\right)^2 \qquad \sigma_{amplitude} = \frac{\sigma_{range}}{2} = \frac{\sigma_{\max} - \sigma_{\min}}{2}$$

$$\sigma_{mean} = \frac{\sigma_{\max} + \sigma_{\min}}{2} \qquad \sigma_{range} = \sigma_{\max} - \sigma_{\min} \qquad \frac{da}{dN} = A(\Delta K)^m \text{ where } \left(\Delta K = Y(\sigma_{\max} - \sigma_{\min})\sqrt{\pi a}\right)$$

$$\sigma_{thermal} = \alpha E \Delta T \qquad \dot{\varepsilon} = Ae^{-Q/RT} = k\sigma^n e^{-Q/RT} \qquad P_{(Larson-Miller)} = T(C + \log t)$$

$$\Delta V = (V_2^o - V_1^o) - \frac{RT}{nF}\ln\frac{[M_1^{n+}]}{[M_2^{n+}]} \qquad \Delta V = (V_2^o - V_1^o) - \frac{0.0592}{n}\log\frac{[M_1^{n+}]}{[M_2^{n+}]}$$

$$CPR = \frac{KW}{\rho At} \qquad r = \frac{i}{nF}$$

Constants

R = 8.314 $J.mol^{-1}.K^{-1}$

F = 96,500 $C.mol^{-1}$

N_A = 6.023 x 10^{23} molecules/mol