

Part B – Answer all questions.

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?

4 marks

Table 17.1 The Standard emf Series

	Electrode Reaction	Standard Electrode Potential, $V^0(V)$
	$Au^{3+} + 3e^- \rightarrow Au$	+1.420
	$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	+1.229
	$Pt^{2+} + 2e^- \rightarrow Pt$	~+1.2
	$Ag^+ + e^- \rightarrow Ag$	+0.800
	$Fe^{3+} + e^- \rightarrow Fe^{2+}$	+0.771
	$O_2 + 2H_2O + 4e^- \rightarrow 4(OH^-)$	+0.401
	$Cu^{2+} + 2e^- \rightarrow Cu$	+0.340
	$2H^+ + 2e^- \rightarrow H_2$	0.000
	$Pb^{2+} + 2e^- \rightarrow Pb$	-0.126
	$Sn^{2+} + 2e^- \rightarrow Sn$	-0.136
	$Ni^{2+} + 2e^- \rightarrow Ni$	-0.250
	$Co^{2+} + 2e^- \rightarrow Co$	-0.277
	$Cd^{2+} + 2e^- \rightarrow Cd$	-0.403
	$Fe^{2+} + 2e^- \rightarrow Fe$	-0.440
	$Cr^{3+} + 3e^- \rightarrow Cr$	-0.744
	$Zn^{2+} + 2e^- \rightarrow Zn$	-0.763
	$Al^{3+} + 3e^- \rightarrow Al$	-1.662
	$Mg^{2+} + 2e^- \rightarrow Mg$	-2.363
	$Na^+ + e^- \rightarrow Na$	-2.714
	$K^+ + e^- \rightarrow K$	-2.924



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

4 marks

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

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

4 marks

$\dot{\epsilon}_s$ (h^{-1})	σ (MPa)
2.5×10^{-3}	55
2.4×10^{-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.

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

3 marks

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

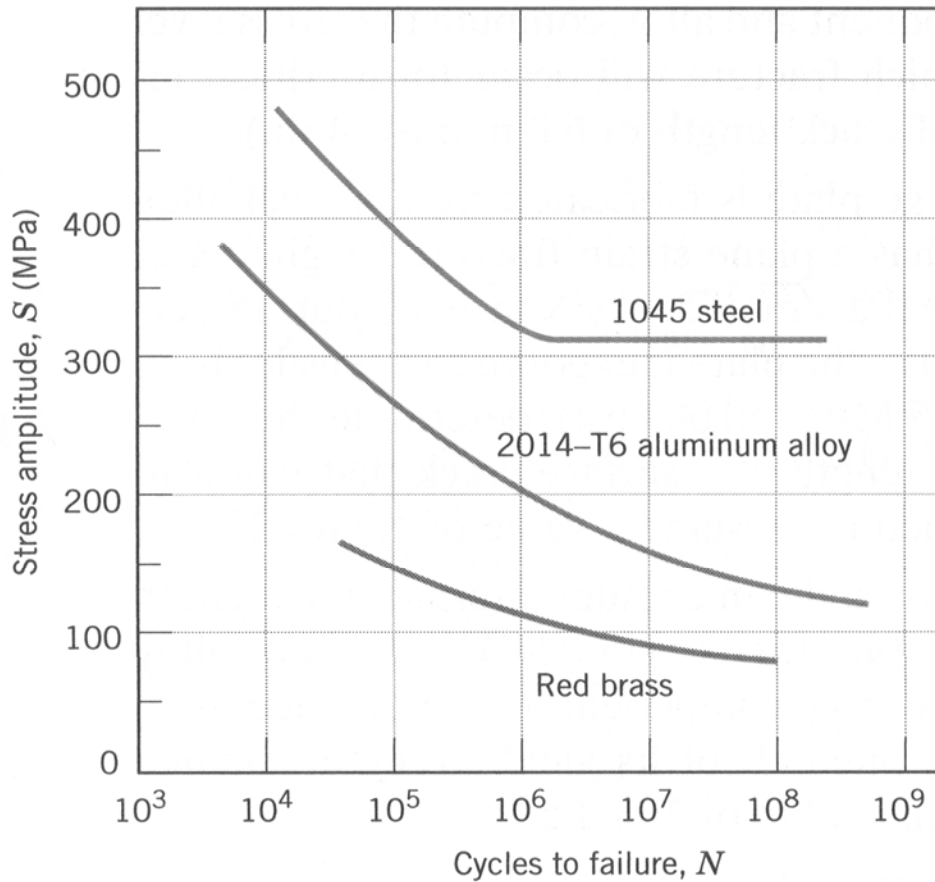
The Fatigue limit for 1045 steel is:

The Fatigue life for 2014 Aluminum is:

2 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.

4 marks



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

- The principal advantage of _____ is its very low density which gives its alloys a very good strength to weight ratio.
- Nickel and its alloys are commonly used at high _____ and also in _____ environments, such as being in contact with human skin.
- 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.
- From a mechanical property viewpoint, steels not only have excellent _____, they can also be produced with a wide range of _____ by varying heat treatments.
- Aluminum alloys can be either _____ or _____ depending on the alloy system. _____ may also be used as a strengthening method for wrought alloys.
- One of the best alloys for damping vibrations is _____. This is due to the microstructure which contains ferrite and/or pearlite and _____.
- _____ is used in large quantities for _____ steel to reduce _____. 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.

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

$$\sigma_y = \sigma_0 + kd^{-1/2} \quad \% \text{ Cold Work} = \left(\frac{A_o - A_d}{A_o}\right) \times 100 \quad \tau = \frac{M_T r}{J} \quad \gamma = \frac{r\theta}{L} \quad \tau_r = \sigma \cos \lambda \cos \phi$$

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

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

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

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

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

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

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

$$CPR = \frac{KW}{\rho A t} \quad r = \frac{i}{nF}$$

Constants

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

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

$$N_A = 6.023 \times 10^{23} \text{ molecules/mol}$$