Name:

Student Id. #

Question 1: *{5 marks}*

(a) Steady-state creep rate data are given in the following table for a nickel alloy at 538°C

$\dot{\epsilon}_s\ (h^{-1})$	$\sigma(MPa)$
10^{-7}	22.0
10^{-6}	36.1

Compute the stress at which the steady-state creep is $10^{-5}\ h^{-1}$ also at 538°C.

(b) Name three metallurgical techniques by which creep resistance of metals alloys is enhanced

Solution:

(a) Given steady state creep rates for a nickel alloy exposed to different stresses but at the same temperature of 538°C. Therefore, we can use the following equation:

$$\dot{\varepsilon}_s = K_1\sigma^n$$

Applying logarithm on both sides of equation

$$\mathrm{Log}(\dot{\varepsilon}_s) = \mathrm{Log}(K_1) + n.\,\mathrm{Log}(\sigma)$$

At σ = 22.0 MPa, $\dot{\varepsilon}_s = 10^{-7}\ h^{-1}$ and at σ = 36.1 MPa, $\dot{\varepsilon}_s = 10^{-6}\ h^{-1}$

We now have two equations with two unknowns K_1 and n. Solving these two equations gives us n = 4.65 and $K_1 = 5.725 \times 10^{-14}$ à $\mathrm{Log}\ K_1 = -13.242$.

Therefore, we have

$$\mathrm{Log}(\dot{\varepsilon}_s) = -13.242 + 4.65 \times \mathrm{Log}(\sigma)$$

At $\dot{\varepsilon}_s = 10^{-5}\ h^{-1}$, we get σ = 59.22 MPa.

(b) Creep resistance of metal alloys can be enhanced by using techniques like

1) Solid Solution alloying
2) Dispersion strengthening
3) Increasing the grain size.

Question 2: *{5 marks}*

(a) An electrochemical cell is composed of pure copper and pure lead electrodes immersed in solutions of their respective divalent ions. For a 0.6 M concentration of Cu^{2+}, the lead electrode is oxidized yielding a cell potential of 0.507 V. Calculate the concentration of Pb^{2+} ions if the temperature is 25°C. Refer to Table 17.1 shown below for Standard electrode potential values.

(b) A municipal steel water pipe needs to be connected to a copper pipe. Which of the two pipes do you expect to corrode? What measures you would take to prevent or minimize corrosion?

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
↑ Increasingly inert (cathodic)	$Pt^{2+} + 2e^- \longrightarrow Pt$	~+1.2
	$Ag^+ + e^- \longrightarrow Ag$	+0.800
	$Fe^{3+} + e^- \longrightarrow Fe^{2+}$	+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
	$Cr^{3+} + 3e^- \longrightarrow Cr$	−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

Solution

(a) The electrochemical reaction that occurs within this cell is:

$$Pb + Cu^{2+} \rightarrow Pb^{2+} + Cu$$

We have ΔV = 0.507 V and [Cu2+] = 0.6 M

$$\Delta V = \left(V_{Cu}^{\circ} - V_{Pb}^{\circ}\right) - \frac{0.0592}{2}\log\frac{[Pb^{2+}]}{[Cu^{2+}]}$$

Substituting standard potentials from Table 17.1 that are $V_{Cu}^{\circ} = +0.340\ V$ and $V_{Pb}^{\circ} = -0.126\ V$

$$0.507 = \left(0.340 - (-0.126)\right) - \frac{0.0592}{2}\log\frac{[Pb^{2+}]}{0.6}$$

Solving this equation for $[Pb^{2+}]$ yields: $[Pb^{2+}] = 0.0247$ M

(b) Steel and copper being dissimilar metals, form a galvanic couple. Steel being more anodic to copper is expected to corrode. To minimize the corrosion, it must be ensured that the surface area of anode (Steel pipe) has to be as high as possible when compared to that of copper pipe. Also, cathodic protection can be provided by connecting a third metal, which is more anodic relative to steel, with both the pipes. If possible, the connection between steel and copper pipes must be electrically insulated to avoid the flow electrons thereby stopping corrosion.