Material Science
EXAM II

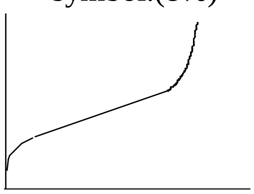
December 21, 201

I. Explain the following terms: (24%)

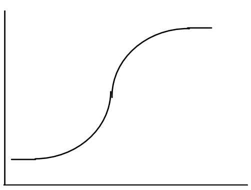
(1) Boltzmann's relationship
(2) Gas Carburizing
(3) Forming
(4) Engineering stress
(5) Deep drawing
(6) Hardness
(7) Twinning
(8) Recrystallization
(9) Brittle fracture
(10) Fracture toughness
(11) Endurance of fatigue limit
(12) Creep of metal

II. 目前所教到的，有那三種強化材料的方法？這三種方法為何可增加材料強度？ (9%)

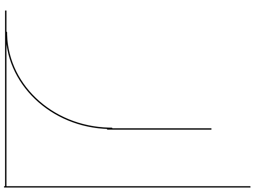
III. Below are shown four plots giving the result of laboratory tests that are used to assess the mechanical or failure characteristics of metals. For each, label both horizontal and vertical axes with the appropriate parameter; write out the parameter names rather than using its symbol.(8%)



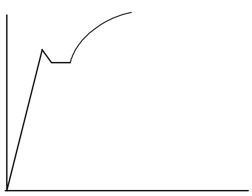
(a)



(c)



(a)



(d)

VI. Below are tabulated the tensile stress-strain data for several materials. (12%)

Mat-erial	Yielding Strength (MPa)	Tensile Strength (MPa)	Strain at Fracture	Fracture Strength (MPa)	Elastic Modulus (MPa $\times 10^3$)
A	310	340	0.23	265	210
B	100	120	0.40	105	150
C	415	550	0.15	500	310
D	700	850	0.14	720	210
E	Fractures before yielding			650	350

(a) Which of these materials is the hardest? Why?
(b) Which of these materials is the toughest? Why?
(c) Which of these materials is the strongest? Why?
(d) Which of these materials will experience the greatest percent area reduction? Why?

V. Consider the gas carburizing of a gear of 1018 steel (0.18 wt %) at 927°C (1700°F). Calculate the time necessary to increase the carbon content to 0.35 wt % at 0.40 mm below the surface of the gear. Assume the carbon content at the surface to be 1.15 wt % and that the nominal carbon content of the steel gear before carburizing is 0.18 wt %. D (C in γ iron) at 927°C = 1.28×10^{-11} m^2/s. (8%)

Hint:

$$\frac{C_s - C_x}{C_s - C_0} = \text{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

erf z	z	erf z	z
0.7969	0.90	0.8427	1.0
0.8209	0.95	0.9661	1.5

VI. The following engineering stress-strain data were obtained for a 0.2% C plain-carbon steel. (*a*) Plot the engineering stress-strain curve. (*b*) Determine the ultimate tensile strength of the alloy. (*c*) Determine the percent elongation at fracture. (9%)

Engineering Stress (in./in.)	Engineering stress (ksi)	Engineering strain (ksi)	Engineering strain (in. /in.)
0	0	76	0.08
30	0.001	75	0.10
55	0.002	73	0.12
60	0.005	69	0.14
68	0.01	65	0.16
72	0.02	56	0.18
74	0.04	51	(Fracture) 0.19
75	0.06		

VII. A stress of 75 MPa is applied in the [001] direction on an FCC single crystal. Calculate the resolved shear stress acting on the (111) $[\bar{1}01]$ slip system. (6%)

VIII. The following creep data were obtained for a titanium alloy at 50 ksi and 400°C. Plot the creep strain versus time (hours) and determine the steady-state creep rate for these test conditions. (5%)

Strain (in./in.)	**Time (h)**
0.010×10^{-2}	2
0.030×10^{-2}	18
0.050×10^{-2}	40
0.075×10^{-2}	80
0.090×10^{-2}	120
0.11×10^{-2}	160

IX. Short answer: (42%)

1. Why do many rotating or sliding steel parts need case hardening**?**
2. In a diffusion process, what are the two primary control factors?
3. 為何說一個材料是會脆性破壞（brittle fracture）或延性破壞（ductile fracture）不是絕對的？
4. What's the difference between the slip and the twinning mechanisms of plastic deformation of metals?
5. Why is deformation by twinning especially important for HCP metals?
6. The Arrhenius rate equation can be written as Rate of reaction $= Ce^{-Q/RT}$. In an experiment of measuring the data of the reaction rate and the corresponding temperature, if the behavior of the reaction rate follows the Arrhenius rate equation, how do you determine the constant C and the activation energy Q from the measuring data? (5%)
7. Why do people use the engineering stress and strain instead of the true stress and strain?
8. As the purity of metal is higher, the recrystallization temperature is lower. Why?
9. What are the differences between solidification and recrystallization?
10. Why is slip favored on close-packed planes?
11. What are the major factors which affect the fatigue strength of a metal?
12. What are the differences between the plastic deformations of single-crystal metals and that in polycrystalline metals?
13. Why could a favorable compressive residual stress pattern on the metal surface increase the fatigue life?
14. How do people detect the self-diffusion of atoms in a material?