UNIVERSITY OF CALIFORNIA
CE 60
Fall 2010

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Excellent!

CE 60 PROPERTIES OF CIVIL ENGINEERING MATERIALS
FIRST MIDTERM EXAMINATION

October 5, 2010

Question 1: [11 **/ 11]**

1 a) Which bond types are based on electron sharing (circle)

electrons shared among metals

:O:O: ✓ ✓ electron cloud

i) **Ionic bonds,** [✓ **ii) covalent bonds,**] [✓ **iii) metallic bonds,**] **iv) Hydrogen bonds**

1 b) Why is Al_2O_3 so brittle? Because it is : (more than one answer may be correct)

[✓ **i) ionically bonded,**] **ii) covalently bonded,** **iii) has no dislocations,**
iv) has no slip planes, [✓ **v) dislocations in Al_2O_3 cannot move**]

1 c) Is Al_2O_3 a **conductor** or **insulator** ? (circle and explain briefly)

insulator, electrons are fixed in ionic bonds.

d) You are performing a tensile test with three different metallic materials: Aluminum (fcc), Magnesium (hcp), Tungsten (bcc); Compared to Aluminum and Magnesium, does ***Tungsten*** have: (circle)

2
i) [✓ **the highest**]**/ lowest yield strength;** **ii) the highest/**[✓ **lowest**] **total strain at fracture**

iii) least number/ [✓ **highest**] **number of slip planes;** **iv)** [✓ **lowest**]**/highest atomic density slip planes**

e) A tensile specimen has a cross section of 0.5" x 0.4" and a gage length of 4" attached to the specimen.

2 i) After a load application of 7000 lbs (but still in the elastic regime) the gage length increased to 4.014" and the final length of the specimen is 8.75". Determine the initial length of the specimen prior to the load application.

$$\epsilon = \frac{l - l_0}{l_0} \quad \frac{4.014 - 4}{4} = .0035 \text{ in/in.} \quad .0035 = \frac{l - l_0}{l_0} \text{ (overall)} \quad .0035 l_0 + l_0 = 8.75$$

$l_0 = 8.719"$ ✓
original length of specimen

1 ii) Determine the E-modulus of the specimen.

$$E = \frac{\sigma}{\varepsilon} \quad \sigma = \frac{P}{A} = \frac{7000 \text{ lb}}{.5" \times .4"} = 35000 \text{ psi} \quad E = \frac{35000 \text{ psi}}{.0035 \text{ in/in.}} = 1 \times 10^7 \text{ psi}$$ ✓

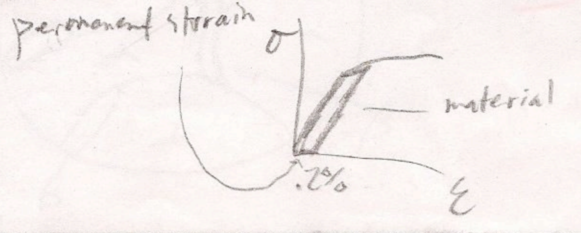
1 iii) After failure the specimen's cross section was reduced by 35%. What is the final cross section?

$(.5" \times .4") \times .65\%$ (what is left) $= .13 \text{ in.}^2$ ✓

1 f) Does the E-modulus measure the resistance of a material to [✓ **elastic**] or **plastic** deformation? (Circle)

1 g) 0.2% proof stress is often used instead of yield strength. Does the 0.2% correspond to

elastic/[✓ **plastic**]**/ total strain**? Please circle



Question 2 [23 /23] great!

This question deals with the Al-Mg phase diagram shown on the next page.

Part I:

a) Is this phase diagram a complete solid solution phase diagram? **Yes/**[✓ **No**] (Circle)

b) At which temperature does the "α" phase exhibit the highest solubility? 451°C

c) Is "γ" a single phase or a two phase mixture? single

d) Let's consider **alloy compositions** with **weight% of Mg** **above 50%:**

i) What is the range of alloy compositions that will exhibit a eutectic lamellar microstructure? 59.8 wt% - 87.3 wt% Mg below eutectic temperature
(Please indicate this range in the phase diagram as well).

ii) What is the range of alloy compositions that will exhibit a two phase mixture without the eutectic microstructure? 56-99.9 wt% Mg above eutectic temperature oe
L+δ exists at at 99.9% wt Mg
L+γ exists at 56% onward
(Please indicate this range in the phase diagram as well). γ+δ from ~~5 7 to~~ 97% at 100°C

Part II:

We are interested in the two alloy compositions" alloys with 10 wt% Mg and 80 wt% Mg, respectively.

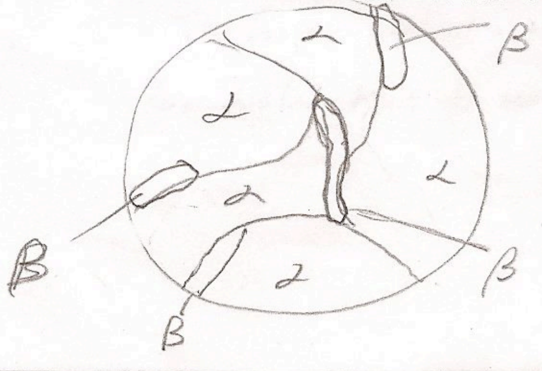
I) Alloy with 10 wt% Mg:

i) The alloy is heated to 700°C and then quenched. Will the alloy be *liquid/* [✓ *solid*]*/ crystalline/* [✓ *amorphous*]? Please circle the appropriate answers. ✓

ii) The alloy is heated to 700°C and then slowly cooled to 400°C:
What is the composition of the phase/phases?
α with 10 wt% Mg

What is the weight fraction of the phase/phases?
100 wt% α

iii) The alloy is heated to 700°C and then slowly cooled to 100°C.
Sketch the microstructure at 100°C (indicate the phase/phases in your sketch).



β formed at α grain boundaries

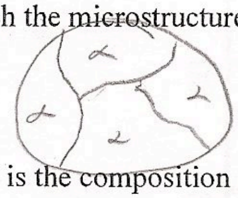
What is the composition of each of the phase/phases you drew in the microstructure above?

α is about 1 wt% Mg

β is about 34 wt% Mg ✓

iv) The alloy is heated to 700°C, slowly cooled to 400°C and then <u>quenched from 400°C to 100°C.</u>

Sketch the microstructure at 100°C (indicate the phase/phases in your sketch).



✓

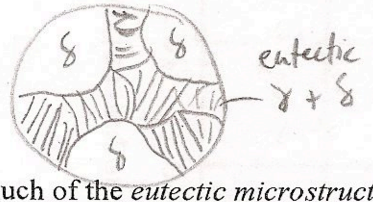
What is the composition of the phase/phases you drew in the microstructure above?

α has 10 wt % Mg in this case, β was unable to form and α is therefore super saturated ✓

II) Alloy with 80wt% Mg

a) The alloy is slowly cooled from the melt to 100°C.

i) Sketch the microstructure at 100°C (indicated the phase/phases in your drawing).



✓

ii) How much of the *eutectic microstructure* has formed just below 437°C?

above 437°C $\frac{87.3-80}{87.3-67.7} = 37.2\%$ Liquid → eutectic microstructure

37.2% eutectic microstructure below 437°C ✓

iii) How much γ is present at 100°C?

$\frac{97-80}{97-57} = .425$

γ = 42.5 wt% of whole composition ✓

iv) How much δ has formed just prior to the eutectic transformation?

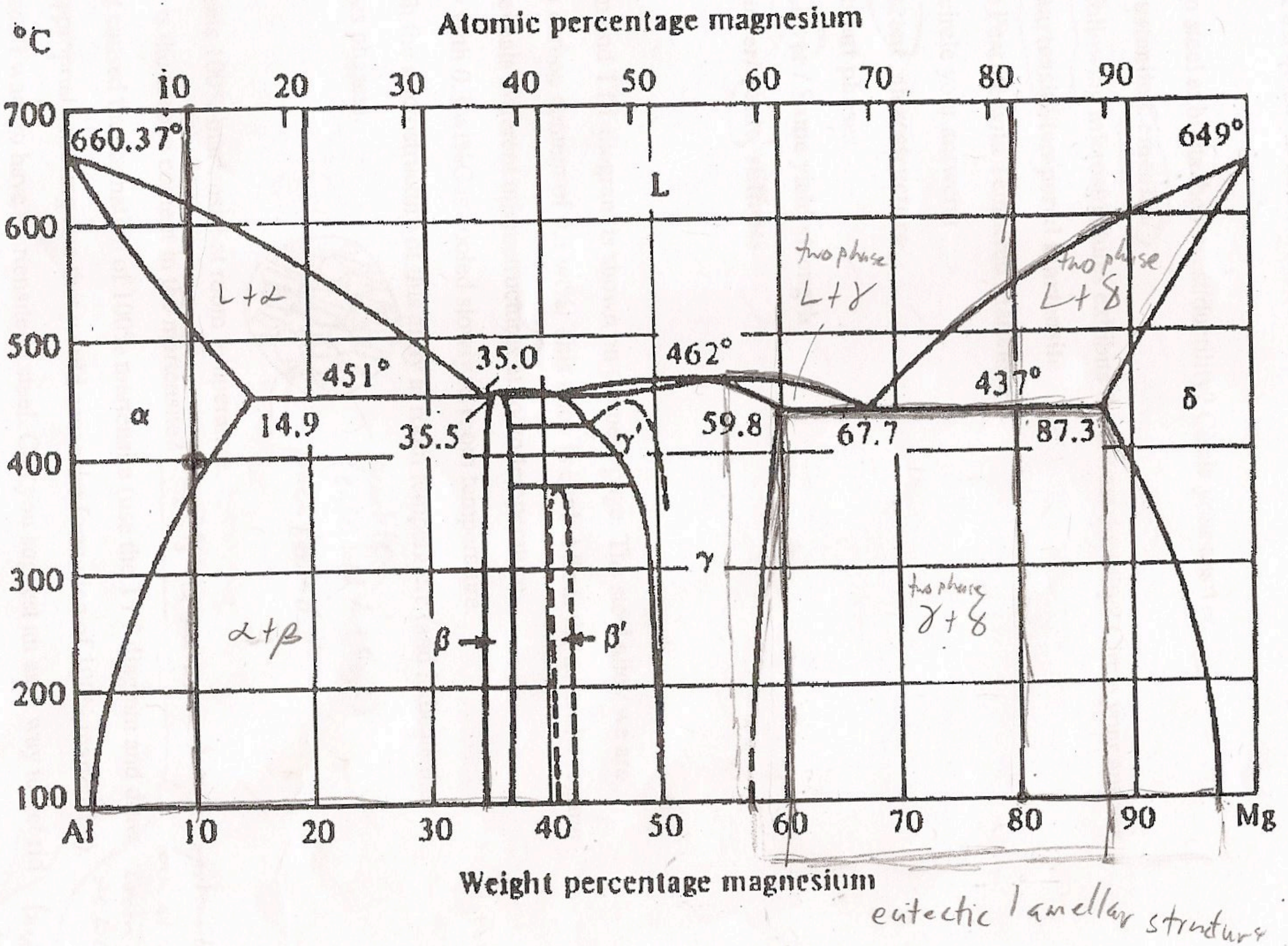
$\frac{80-67.7}{87.3-67.7} = .628$ ✓

62.8% of the composition is δ before eutectic transformation

b) The same alloy is cooled with a fast cooling rate from the melt to 100°C.

i) Would you expect **the same/lower/[✓ higher]** yield strength at 100°C as the slowly cooled alloy above (in question IIa)? Circle and explain briefly.

The faster cooling rate creates finer grains which are harder for dislocations to move through. This creates a higher yield strength. ✓


Atomic percentage magnesium
°C
10
20
30
40
50
60
70
80
90
700
600
500
400
300
200
100
660.37°
649°
L
two phase
L+γ
two phase
L+δ
L+α
451°
35.0
462°
437°
δ
α
14.9
35.5
γ'
59.8
67.7
87.3
γ
two phase
γ+δ
α+β
β
β'
Al
Mg
Weight percentage magnesium
eutectic lamellar structure

Question 3: [14/16] This question deals with Steel

Part I:

i) Which phase in steel exhibits the lowest ductility? Circle your answer.

Ferrite /Austenite/[✓ Cementite]

ii) Which of the following microstructures exhibits the lowest ductility? Circle your answer.

Pearlite/[✓ martensite]/tempered martensite

iii) Let's compare Pearlite with Tempered Martensite.

Pearlite has: (circle your answers)

Same/[✓ different] microstructure

[✓ Same]/different phases

Higher / [✓ Lower] / Same yield strength

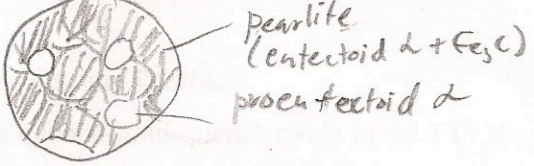
Higher/ Lower/ [✓ Same] stiffness

Part II:

The phase diagram and TTT diagram is shown on the next page. The steel alloy we are interested in has a carbon content of 0.3 wt%. This alloy is cooled from the austenite regime (i.e. 900°C) and reveals different microstructures at room temperature.

a) The steel alloy with 0.3 wt%C is cooled slowly to room temperature.

i) Sketch the microstructure of this alloy at room temperature (and indicate the various phases).



b) The alloy reveals 100% martensite at room temperature.

i) what is the carbon content in the martensite? .3% is same as part a

martensite can form at other carbon contents as well

ii) What caused the formation of 100% martensite (use the TTT diagram and draw the appropriate cooling rate that would cause the formation of 100% martensite).

fast cooling rate, quenching, no time for nucleation and growth they were suppressed carbon was locked and unable to diffuse

iii) We don't want to have martensite in steel. Can you suggest an easy way to get rid of the martensite?

tempering, heat martensite to over 400°C and hold to form tempered martensite, which isn't the same microstructure anymore

or when steel was cooling, do not quench and let slowly cool

c) The same alloy reveals pre-α and martensite at room temperature.

i) The carbon content in the martensite is 0.6 wt%. How was the sample treated to reveal 0.6wt%C in the martensite? Use the phase diagram and <u>determine the temperature</u> at would lead to a martensite formation with 0.6wt% C.

The sample was slowly cooled to between ~730°C to ~600°C before quenching.

Need: under cooling

750 C

ii) Draw the cooling curve as quench-hold-quench cycle in the TTT diagram that would produce martensite and pre-α at room temperature.

-2

iii) Both martensites [i.e. the martensite from question b) and c) in Part II] are being indented. Do you expect the martensite in c) to have the **same/lower/[✓ higher]** hardness compared to the martensite in b)? Please circle and explain.

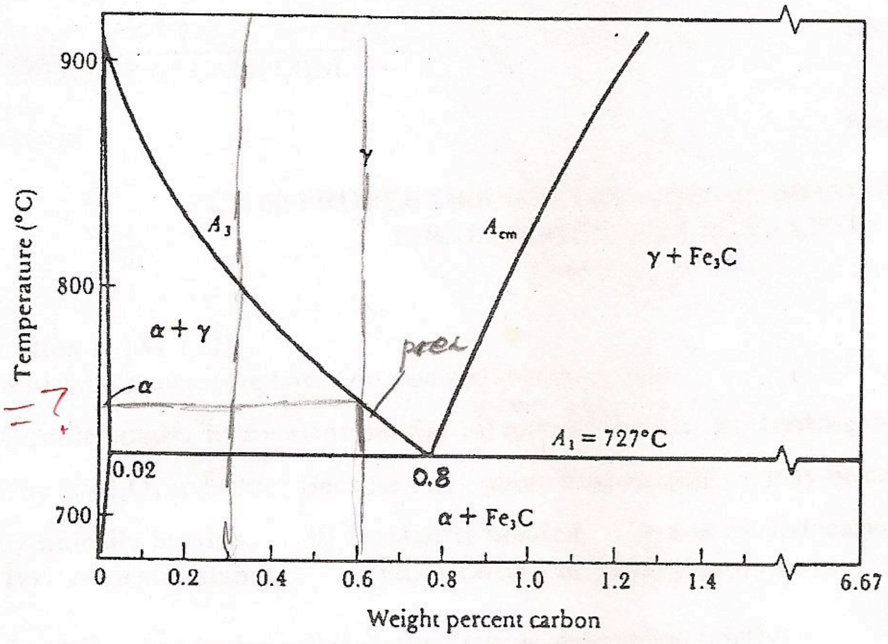
The martensite in part C would have a higher hardness. The more carbon added creates more martensite. The bcc structure is further pushed towards bct structure. ✓

d) The steel alloy with 0.3 wt% C exhibits 50% Pearlite and 50% Martensite at room temperature.

i) Draw the cooling curve as quench-hold-quench cycle in the TTT diagram that would lead to 50% Pearlite and 50% Martensite.

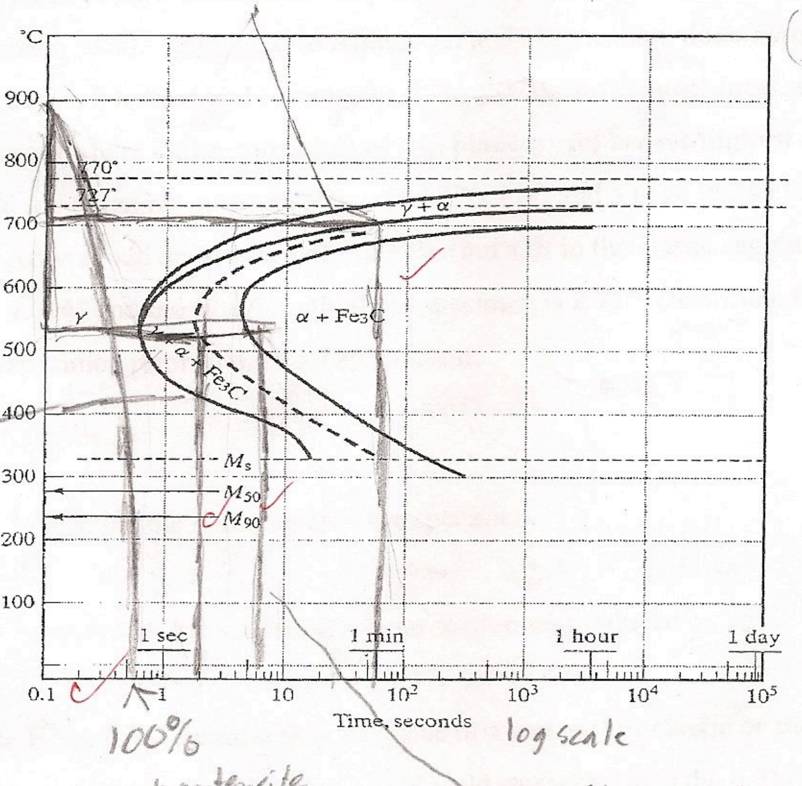
e) The steel alloy with 0.3 wt% C exhibits only Pearlite.

i) Draw the cooling curve as quench-hold-quench cycle in the TTT diagram that would lead to 100% Pearlite.



The eutectoid portion of the Fe-Fe$_3$C phase diagram.

preα forms then quenched to form martensite (quench before hitting γ+α+Fe₃C line)



50% pearlite 50% martensite if dotted line indicates 50% pearlite production

log scale

100% martensite constant fast cooling quenching so carbon has no time to diffuse cannot hit phase lines

100% pearlite, as long as you past solid line, composition is 100% pearlite, can quench anytime after

TTT Diagram