# Ph.D. Qualifying Examination

## *Materials Science*

### Spring 2009

Notes:

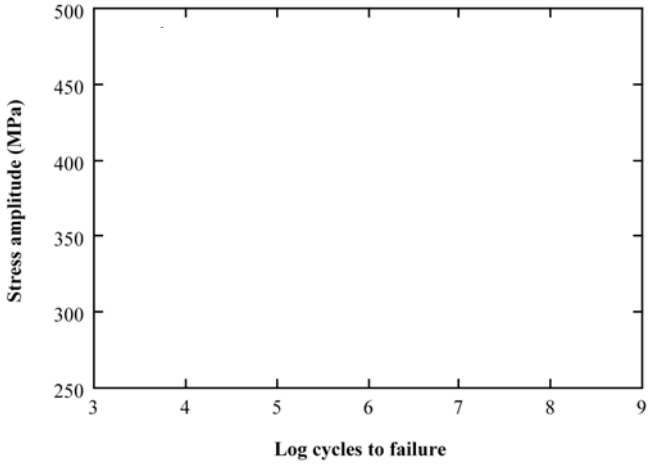
- There are a total of 4 problems.
- Time allowed: 2 hours.
- Exam is closed book and closed-notes.
- Problems count 25 points each (total=100 points).
- Show your work on these exam sheets. (Add additional sheets, if needed.)
- You may use a calculator.
- Laptops and cell phones are not allowed.

**Problem 1**

The fatigue data for a steel alloy are given as follows:

| *Stress Amplitude [MPa]* | *Cycles to Failure* |
|---|---|
| *470* | $10^4$ |
| *440* | $3 \times 10^4$ |
| *390* | $10^5$ |
| *350* | $3 \times 10^5$ |
| *310* | $10^6$ |
| *290* | $3 \times 10^6$ |
| *290* | $10^7$ |
| *290* | $10^8$ |

(a) Make an S–N plot (stress amplitude versus logarithm cycles to failure) using these data.




(b) What is the fatigue limit for this alloy?

(c) Determine fatigue lifetimes at stress amplitudes of 415 MPa and 275 MPa

(d) Estimate fatigue strengths at $2 \times 10^4$ and $6 \times 10^5$ cycles.

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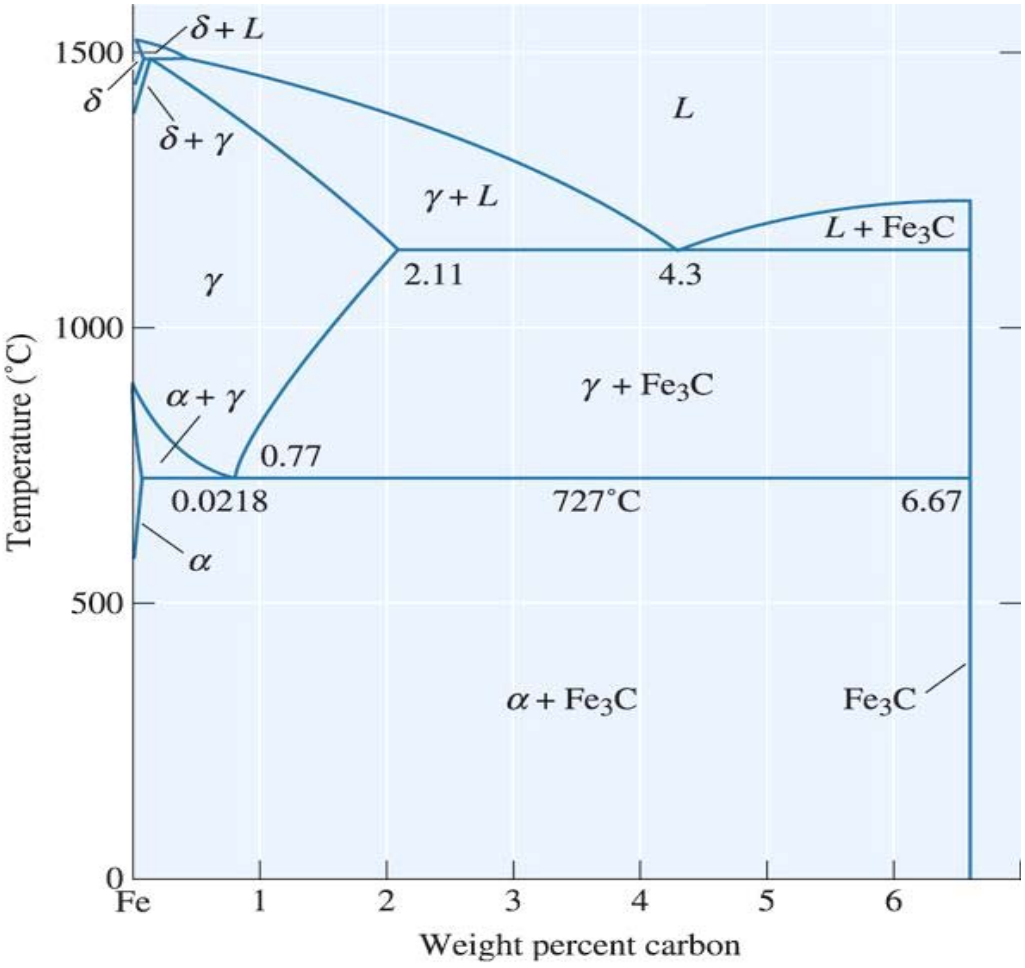
**Problem 2**

For an Fe–0.35%C alloy,
(a) determine the temperature at which austenite first begins to transform on cooling,
(b) name the primary microconstituent that forms,
(c) determine the composition and amount of each phase present at 728°C
(d) determine the composition and amount of each phase present at 726°C



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**Problem 3**

Consider ceramics made of ionic crystals. Stable ionic crystal structures form when the anions surrounding a cation are all in contact with that cation. Show that the minimum cation-to-anion radius ratio for a coordination number of 8 is 0.732.

**Problem4**

The diffusion coefficients for carbon in nickel are: $5.5\times10^{-14}$ $m^2/s$ at 600ºC, and $3.9\times10^{-13}$ $m^2/s$ at 700ºC. Calculate the diffusion coefficient at 780ºC assuming the same diffusion mechanism operates. (Gas constant $R$ = 8.31 J/mol-K.)