MATE 201
Fall 2019

Homework #6

It is due 5:00 pm on January 2nd, 2020
No late submissions!

Group submission (up to 4 students per group) is allowed.

Your homework submission should have a cover page which contains the following information;
your name, student number, course name, homework number and date of submission.

Question 1:

Calculate the critical radius r^* and the activation free energy ΔG^* for the solidification of pure iron by homogeneous nucleation.

Values for the latent heat of fusion and surface free energy are -1.85×10^9 J/m^3 and 0.204 J/m^2, respectively.

Assume a lattice parameter of 0.295 nm for solid iron at its melting temperature.

Question 2:

a) **Rewrite the expression for the total free energy change for solidification nucleation for the case of a cubic nucleus of edge length a (instead of a sphere of radius r).**
b) **Differentiate this expression with respect to a and solve for both the critical cube edge length, a*, and also ΔG*.**
c) **Is ΔG* greater for a cube or a sphere? Why?**

Question 3:

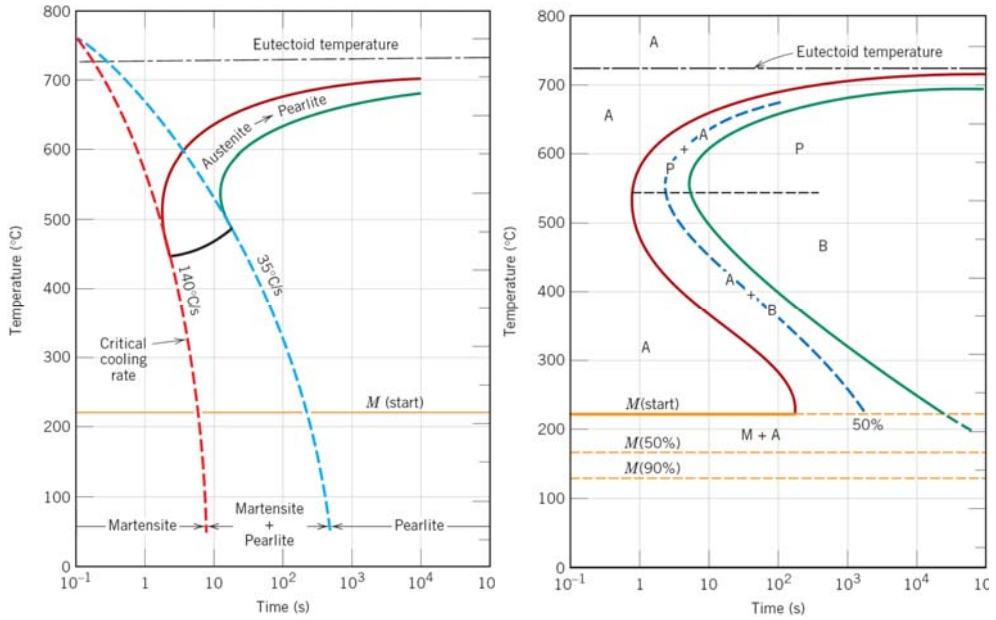
It is known that the kinetics of recrystallization for some alloy obey the Avrami equation, and that the value of n in the exponential is 4.0. If, at some temperature, the fraction recrystallized is 0.35 after 120 min, determine the fraction recrystallized after 180 min at this temperature.

Question 4:

After being completely austenized at 800°C, four different eutectoid steel samples are given the following heat treatments:
A. Instantaneously quenched to 675°C, held for 20 minutes, then cooled to room temperature;
B. Instantaneously quenched to 575°C, held for 2 minutes, then cooled to room temperature;
C. Instantaneously quenched to 475°C, held for 2 minutes, then cooled to room temperature; and
D. Instantaneously quenched to 100°C, held for 2 minutes, then cooled to room temperature.

a) List these samples in the order of decreasing hardness (hardest to softest) and write the names of their respective microstructures,

b) Sketch the final microstructure of the samples A and B.

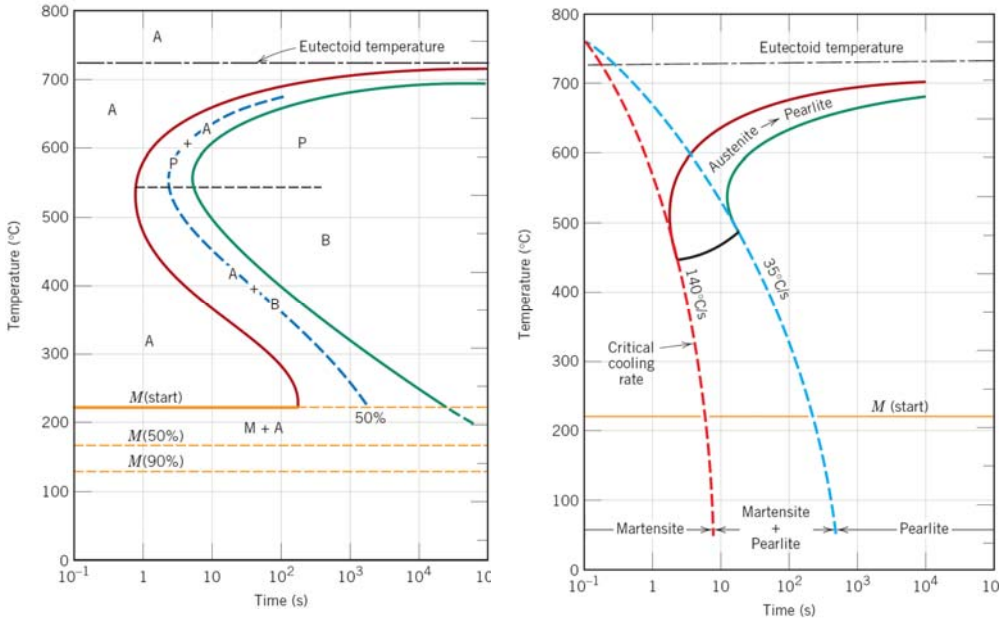


Question 5:

Using the isothermal and continuous cooling transformation diagrams, briefly describe *the simplest heat treatment procedure* that would be used in converting a 0.76 wt% C steel (eutectoid steel) from one microstructure to the other, as follows:

a) Spheroidite to martensite
b) Pearlite to bainite
c) Spheroidite to pearlite
d) Martensite to spheroidite

TTT and CCT curves of a eutectoid steel



Question 6

A cylindrical piece of steel 83 mm in diameter is to be austenitized and quenched such that a microstructure consisting of a <u>maximum</u> of 50% martensite will be produced throughout the entire piece. Of the alloys 4340, 4140, 8640, 5140, and 1040, which will qualify if the quenching medium is moderately agitated oil?

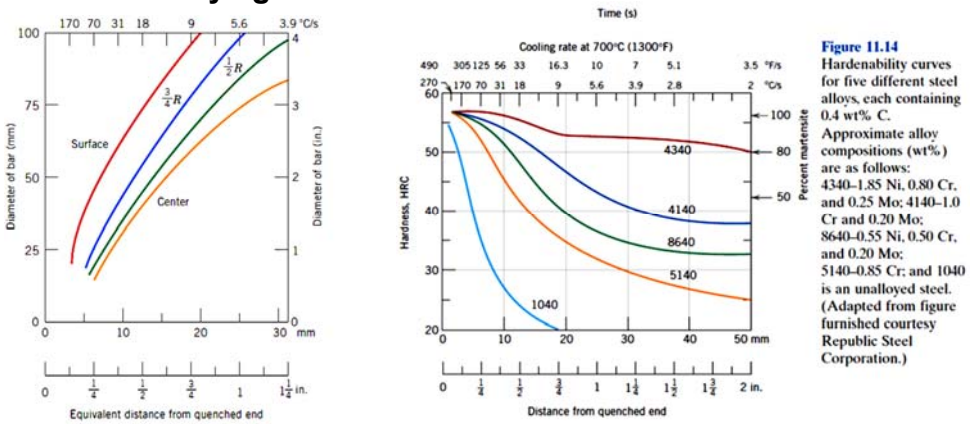


Figure 11.14 Hardenability curves for five different steel alloys, each containing 0.4 wt% C. Approximate alloy compositions (wt%) are as follows: 4340–1.85 Ni, 0.80 Cr, and 0.25 Mo; 4140–1.0 Cr and 0.20 Mo; 8640–0.55 Ni, 0.50 Cr, and 0.20 Mo; 5140–0.85 Cr; and 1040 is an unalloyed steel. (Adapted from figure furnished courtesy Republic Steel Corporation.)

Question 7 Fill in the blanks

•The microstructure a eutectoid steel (0.76wt.%C) that is slowly cooled through the eutectoid temperature consists of alternating layers of the two phases ……..…….. and ……..…… that form simultaneously during the transformation. This microstructure is called ……..

•In iron-carbon alloys, ……..…… microstructure has the highest hardness whereas …… microstructure has the lowest hardness.

•The ductility and toughness of martensite may be enhanced and the …….. stresses can be relieved by a heat treatment known as ……

•…… is a term that is used to describe the ability of an alloy to be hardened by the formation of martensite as a result of a given heat treatment.

•The term …….. refers to a heat treatment in which a material is exposed to an elevated temperature for an extended time period and then slowly cooled.

- Precipitation hardening (also known as …… hardening) is the hardening and strengthening of a metal alloy by extremely …….. and uniformly dispersed particles that precipitate from a …… solid solution. This hardening technique is carried out in three steps: i) solutionizing, ii) …….. and iii) ……. There are many commercial alloys such as Al-…….. alloys which utilize this hardening technique.
- Pseudoelasticity is a mechanical analogue of ……. shape memory effect with the difference that the driving force for the formation and reversion of martensite is …… rather than ……...
- …….. are alloys of copper and several other elements, including ……., ……, silicon, and nickel.
- Some disadvantages of steels and cast irons that limit their use are:
  i. a comparatively low ……..,
  ii. an inherent susceptibility to …… in some common environments
  iii. a relatively high ……

- Types of cast iron include, white, **……**, ductile (**……**/spheroidal), **……**, and vermicular (**……** graphite) cast iron.
- The presence of **……** elements other than carbon (e.g., Cr, Ni, Mo, and W) may cause significant changes in the positions and shapes of the curves in the isothermal transformation diagrams. These changes include: (**i**) shifting to **……** times the nose of the austenite-to-**……** transformation and (**ii**) the formation of a separate **……** nose.
- Although copper is a better conductor of electricity, there are some electrical applications where aluminum is preferred over copper due to its **……**.
- The progress of a phase transformation may be broken down into two distinct stages: **……** and **……**