National Exams December 2018

12-Mtl-A6, Thermal Treatment of Metals, Glasses and Ceramics

3 hours duration

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is a CLOSED BOOK EXAM.
   An approved Casio or Sharp calculator is permitted.

3. FIVE (5) questions constitute a complete exam paper.
   The first five questions as they appear in the answer book will be marked.

4. Each question is of equal value.

5. Some questions require an answer in essay format. Clarity and organization of the answer are important.

Question 1: (20 marks)

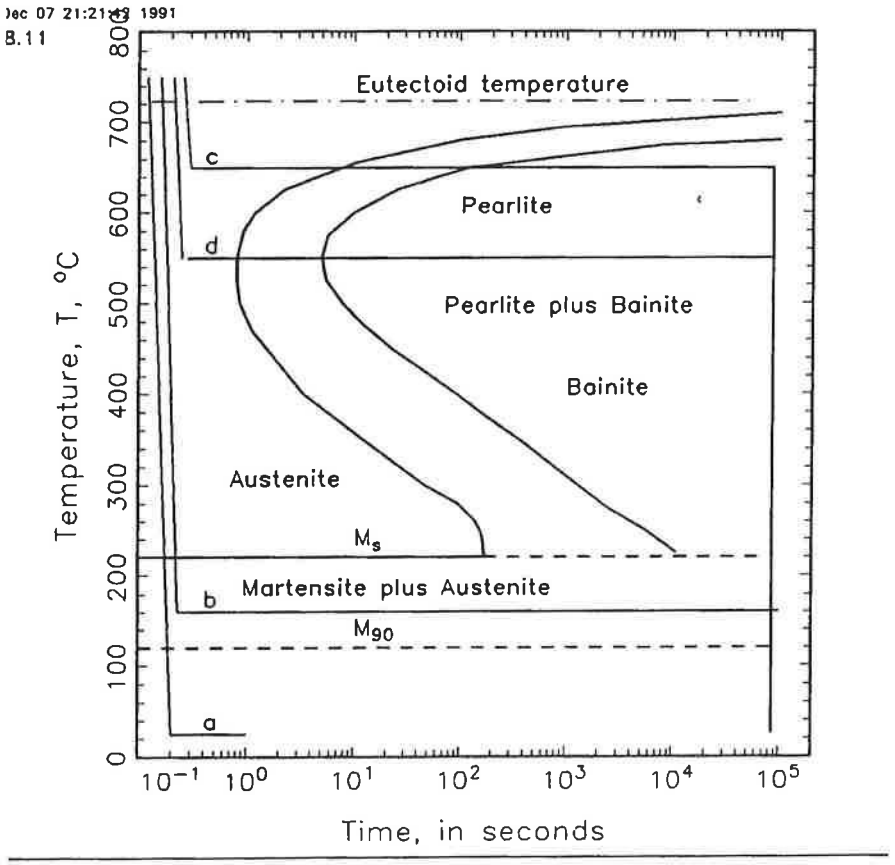
The TTT diagram below is for a steel of eutectoid composition. Assuming that the specimens involved in the various cooling paths were cut from a thin sheet and austenitized at 750 °C before cooling, describe (including sketches) the microstructures resulting from the following heat treatments:

(a) Cooling to room temperature in less than 1 second ***(5 marks)***

(b) Cooling to 160 °C in less than 1 second and then maintained at this temperature for several years ***(5 marks)***

(c) Quenched to 650 °C and held at this temperature for 1 day, then quenched to room temperature ***(5 marks)***

(d) Quenched to 550 °C and held at this temperature for 1 day, then quenched to room temperature ***(5 marks)***



Question 2: (20 marks)

(a) Describe briefly how ceramic powder is consolidated by (i) die pressing and (ii) slip casting ***(8 marks)***

(b) Explain the advantages and disadvantages of die pressing in comparison with slip casting. ***(8 marks)***

(c) Differentiate between the terms apparent porosity and true porosity used to characterize ceramics. ***(4 marks)***

Question 3: (20 marks)

The annealing of cold worked metals involves three stages: recovery, recrystallization and grain growth.

(a) Use a general schematic diagram to show how the following mechanical properties change during the three stages of annealing: (i) yield strength, (ii) ductility and (iii) elastic modulus. ***(6 marks)***

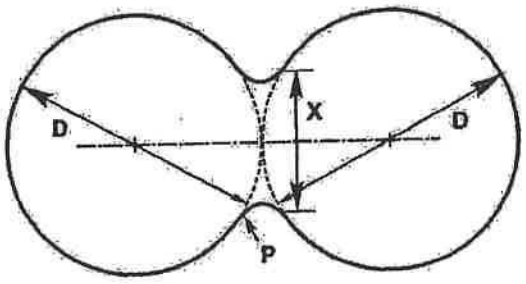
(b) Briefly explain why grain boundaries move toward their centre of curvature during grain growth but away from their centre of curvature during recrystallization. ***(8 marks)***

(c) In light of your considerations in **(b)** describe the difference between strain-induced boundary migration and secondary recrystallization in annealing transformations. ***(6 marks)***

Question 4: (20 marks)

Tungsten carbide (WC) is liquid phase sintered with the addition of Co because high density, single phase WC cannot be attained by solid state sintering.

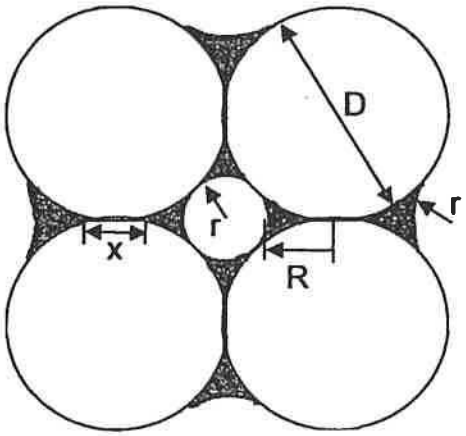
(a) Using the drawing below, show the *5* pathways of mass transport during the initial stage of solid state sintering. ***(5 marks)***



(b) Write an equation for the driving force for mass transport between the source and sink locations on the drawing would produce no shrinkage during the initial stage of solid state sintering, as observed for single phase WC. ***(5 marks)***

(c) What requirements does Co have to satisfy in order for effective liquid phase sintering to occur? ***(5 marks)***

(d) Derive an expression for the compressive stress acting across the areas of contact due to the liquid capillary pressure for the situation shown in the drawing below, where r is the radius of a pore. Assume the gas pressure in the pore is zero, and $x << r$. ***(5 marks)***



Question 5: (20 marks)

(a) Explain the role of heterogeneous nucleation and phase separation in the formation of glass-ceramics. ***(5 marks)***

(b) Draw a typical heat treatment profile encountered in processing of glass-ceramics. ***(5 marks)***

(c) Compare the kinetics of crystallization of glass with the TTT and CCT curves encountered in the heat treatment of steels. ***(10 marks)***

Question 6: (20 marks)

In the thermomechanical processing (TMP) of steel, the resultant nonequilibrium phase transformations can be described using a time-temperature-transformation (TTT) curve or a continuous cooling transformation (CCT) diagram.

(a) Using a steel alloy of your choice, differentiate between a TTT curve and a CCT curve for the same alloy. ***(7 marks)***

(b) What is the primary objective of TMP? ***(4 marks)***

(c) Using your schematic TTT diagram in **(a)** illustrate the difference between the following heat treatment methods: ***(9 marks)***

(i) ausforming

(ii) martempering

(iii) marstraining

Question 7: (20 marks)

(a) The heat treatment of hardenable aluminum alloys normally involves a three-stage procedure. Briefly describe the nature of the three stages and the microstructures that result following each stage. ***(10 marks)***

(b) The production of sheet material for structural applications requires careful control of annealing-induced transformations, either during rolling (i.e. hot working) or after cold rolling. Discuss <u>two</u> factors that control grain growth (i.e. ultimate grain size) during the annealing of aluminum alloy deformed to a specific strain. ***(10 marks)***

Question 8: (20 marks)

(a) Explain how phase separation and metastable immiscibility are used to make a borosilicate glass. ***(5 marks)***

(b) Describe the process of how annealed borosilicate glass plate can be tempered to significantly increase its tensile strength. ***(5 marks)***

(c) Explain the devitrification heat treatment used for some glasses and the effect on mechanical properties. ***(5 marks)***

(d) Explain the difference between the properties of photochromic and photosensitive glasses. ***(5 marks)***