National Exams **December 2014**

10-Met-B6, Physical Metallurgy of Iron and Steel

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 CLOSE BOOK EXAM.
   Any non-communicating calculator is permitted.

3. SEVEN (7) questions constitute a complete exam paper.

4. The value of each question is given on the same page.

5. For questions requiring an answer in essay format, clarity and organization of the answer are important.

I (a total of 20 marks; each is worth of 2 marks)

Select the best answer only from the multiple choices provided for each question or statement; or determine the statement given is "True" or "False".

I.1 It is well known that γ iron has much bigger solubility of C than α iron, because

(a) γ iron has a lattice structure that is less densely packed and thus the total "empty space" in the structure is bigger.

(b) γ iron has a lattice structure that is close-packed with a higher density and thus the total "empty space" in the structure is bigger.

(c) γ iron has a lattice structure that is close-packed with a higher density and thus the total "empty space" in the structure is smaller. However, there are individual empty sites in the structure that have bigger space.

(d) α iron has a bigger total "empty space" due to its smaller density.

I.2 The major purpose of the end quench test of a Jominy specimen is to determine the _____ of a quenched steel.

(a) hardness.

(b) hardenability.

(c) ductility.

(d) machinability.

I.3 In terms of the nature of strengthening micro-mechanism, which mechanism in the following list does not contribute in any major way to martensite strengthening.

(a) Solid state solution strengthening.

(b) Dislocation strengthening.

(c) Grain size strengthening.

(d) Dispersion hardening.

I.4 It is well known that martensite transformation and deformation twinning are both diffusion-less process. But the two processes result in a number of differences. The most important difference between these two processes is that

(a) Martensite transformation occurs only in steels.

(b) Deformation twinning happens only in HCP materials.

(c) Deformation twining is generally not a major strengthening mechanism and, unlike martensite transformation, it does not result in a different phase.

(d) Deformation twining is generally a major strengthening mechanism, although it does not result in a different phase.

I.5 Which condition in the following list may promote deformation twinning in low C steel?

(a) The strain rate is very high.
(b) The plastic strain accommodation is very small.
(c) The deformation temperature is high.
(d) Deformation twinning may never form in low carbon steel.

I.6 In all cast irons, carbon always exists in the form of graphite. (True – False)

I.7 Austenite in all steels can always be quenched into martensite provided that the cooling rate is high enough. (True – False)

I.8 Generally speaking, during tensile test of IF steels, one cannot detect any Luder's bands because there is no yield point phenomenon. (True – False)

I.9 Both pearlite and bainite are mixture of ferrite and cementite. (True – False)

I.10 For a given steel, the hardness of the steel after being quenched to the martensite structure depends mainly on the concentration of alloying elements in the steel. (True –False)

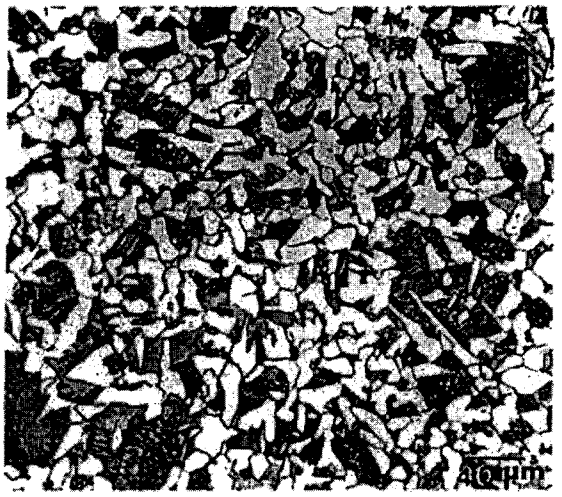
II. (a - 10 marks, b – 5 marks)

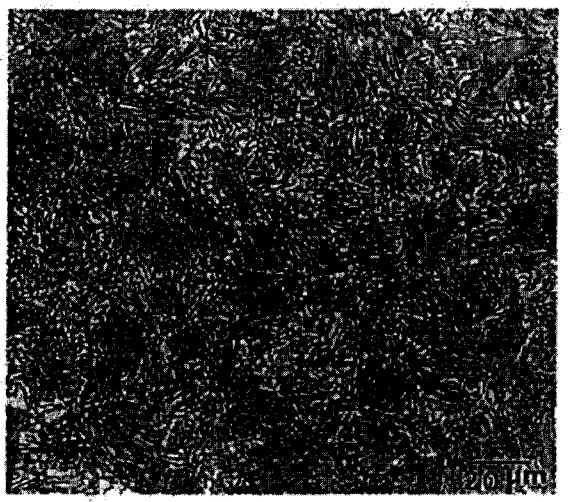
a) What is the weight fraction of pearlite if a steel of 1wt%C is slowly cooled down from pure Austenite region to room temperature? (Assuming that the eutectoid composition is 0.77wt%C.)
b) In quantitative metallography investigations of the steel with the above composition and annealed microstructure, it is always found that the fraction of the eutectoid cementite in pearlite is smaller than the value theoretically calculated. Why?

III. (a – 5 marks; b—5 marks)

a) In the following micrographs for two plain carbon steels, please estimate the carbon content in each steel, respectively.

b) What was the heat treating procedure that has produced these microstructures, respectively?





IV (i) 7 marks. (ii) 8 marks.

(i) **Describe step by step how you would experimentally construct a *CCT* curve for a given steel.**

(ii) **Explain the reason(s) qualitatively behind the "C" shape of a typical *TTT* curve, i.e. explain why a typical TTT curve has a "C" shape.**

V (i) 5 marks, (ii) 5 marks, (iii) 5 marks.

(i) What is the driving force for a martensitic transformation in steel?
(ii) What is the phase-transformation micro-mechanism of martensite formation in steel?
(iii) Why does the hardness of martensite increase with increasing C content for most structural steels?

VI (i) 5 marks, (ii) 5 marks, (iii) 5 marks

(i) For many tool steels, such as high speed steel T1, see its chemistry in the table below

Grade	C	Cr	Mo	W	V	Co	Mn	Si
T1[11]	0.65–0.80	3.75–4.00	-	17.25–18.75	0.9–1.3	-	0.1–0.4	0.2–0.4

for austenization the heating temperature must be as high as 1250^0C (+/-). Explain the reason.

(ii) For this kind of steels, often the cooling for the quenching operation can be done either in still air or simply by a slow fan cooling in air. Why is such a processing procedure recommended and workable?

(ii) In addition, for these steels, especially for T1 steel, there is a general requirement to temper the steel after quenching a minimum of three times. Why?

VII. (i) 5 marks, (ii) 5 marks, (iii) 5 marks

In the modern manufacturing, especially auto-manufacturing, industry, the following newly developed steels are being used more and more frequently for their respective special properties.
Please provide the full names for these steels, and briefly explain the significance of these names, respectively.

(i) **TRIP steels,**
(ii) **DP steels,**
(iii) **IF steels,**