Department of Mechanical Engineering
University of Saskatchewan

ME324.3 Engineering Materials

Mid-Term Examination (Closed Book)

Student Name: **Student #:**

Instructor: **I. Oguocha**
Time Allowed: **2 Hours** **24 October, 2003.**

Section A: Multiple Choice Questions (50 Marks)
Answer ALL questions. There is NO Penalty for Guessing.
Circle the correct answer where required (i.e., Questions 6 to 50)

In **Questions 1-5** indicate whether a statement is **True** (***T***) or **False** (***F***)

1. _____ An *edge dislocation* is characterized by its burgers vector, which is perpendicular to the dislocation line vector.

2. _____ *Allotropy* or *polymorphism* is a property exhibited by many elements that they crystallize in different crystal structures at different ranges of temperature and pressure.

3. _____ A *screw dislocation* is characterized by its burgers vector, oriented at an obtuse angle with the dislocation line vector.

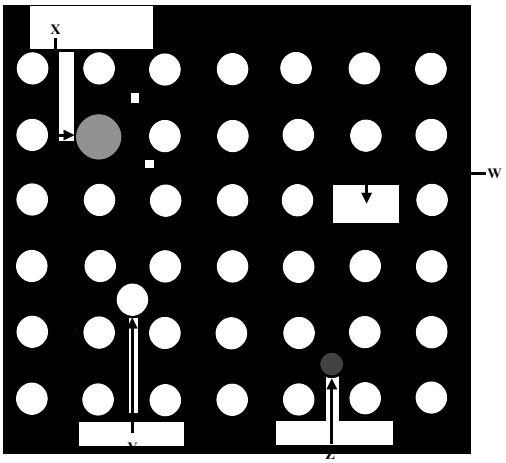
4. _____ Electron microscopes probe crystal structures with greater resolution and magnification than optical microscopes.

5. _____ An *intermetallic compound*, such as AB_2, always has the crystal structure of one of the components A or B

6. The property of a metal that causes it to break with little or no bending is
   (A) Hardness (B) Toughness
   (C) Fatigue (D) Brittleness

7. The property of a metal that refers to its ability to withstand shock without cracking is:
   (A) Hardness (B) Toughness
   (C) Strength (D) Elasticity

Use the Figure below to answer Questions 8 to 11.



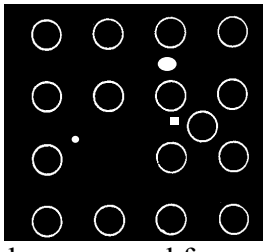
8. The defect labelled ***W*** is
   (A) Frenkel defect (B) Vacancy
   (C) Interstitial atom (D) Schottky defect

9. The defect labelled ***X*** is
   (A) Frenkel defect (B) Substitutional atom
   (C) Intersticialcy (D) Schottky defect

10. The defect labelled ***Y*** is
    (A) Self-interstitial (B) Substitutional atom
    (C) Interstitial atom (D) Schottky defect

11. The defect labelled ***Z*** is
    (A) Self-interstitial (B) Substitutional atom
    (C) Interstitial atom (D) Schottky defect

12. The figure below shows the formation of
    (A) Dislocation (B) Schottky defect
    (C) Frenkel defect (D) Planar defect



13. Regions within a metal that are high energy and form as a result of cooling into a polycrystalline solid
    (A) Voids (B) Boundaries
    (C) Interstices (D) Lattice

14. Which of the following statements is **false**?
    (A) Doping of silicon with phosphorus is made possible by diffusion
    (B) Formation of pearlite from austenite is brought about by diffusion
    (C) Diffusion makes it possible for a bottle of perfume uncapped in one part of a room to be felt in a distant corner of the room.
    (D) Martensite forms by a diffusional process.

15. A combination of two or more metals, one of which is *intentionally added* to the base metal, is called a(n):
    (A) Mixture (B) Solution
    (C) Compound (D) Alloy

16. In an alloy, the material that dissolves the alloying element is called the
    (A) Solute (B) Solvent
    (C) Allotrope (D) Matrix

17. The furnace for converting iron ore into *pig iron* is called the
    (A) DR furnace (B) Open hearth furnace
    (C) Basic oxygen furnace (D) Blast furnace

18. The type of iron made by using a *direct reduction (DR)* furnace is called
    (A) Reduced iron (B) Sponge iron
    (C) Wrought iron (D) Alpha iron

19. The material used in ironmaking process that combines with the ash and iron ore impurities to form slag is
    (A) Hematite (B) Coke
    (C) Limestone (D) Hot air

20. The purest form of iron that is commercially available that is used in making chains and hooks
    (A) Pig iron (B) Sponge iron
    (C) Wrought iron (D) White cast iron

21. The IPSCO steelmaking plant in Regina uses _____ as a major source of raw materials.
    (A) Scrap (B) Aluminum
    (C) Silica (D) Lead

22. Metal alloys that can be mechanically deformed at ambient and elevated temperatures are
    (A) Cast alloys (B) Deformed alloys
    (C) Wrought alloys (D) Plastic alloys

23. *Malleable iron* is made from which of the following irons
    (A) Pig iron (B) White cast iron
    (C) Gray cast iron (D) Wrought iron

24. Another name for **nodular** cast iron is
    (A) Malleable (B) Gray
    (C) Ductile (D) Pearlitic

25. From thermodynamic viewpoint, the **driving force** for a phase transformation is
    (A) Dislocations (C) Change in enthalpy (ΔH)
    (B) Change in entropy (ΔS) (D) Change in free energy (ΔG)

26. Which of the following statements is **false** about the change in free energy of a reaction:
    (A) If $\Delta G = 0$, the reaction is at equilibrium
    (B) ΔG determines the rate of a spontaneous reaction
    (C) If $\Delta G < 0$, the reaction is spontaneous in the specified direction
    (D) If $\Delta G > 0$, the reaction is not spontaneous in the specified direction.

27. Which of the following statements about binary equilibrium phase diagrams is **false**:
    (A) Maps that show the melting points of the constituents
    (B) Maps that show different phases of the binary system
    (C) Maps that show the different constituents of the binary system
    (D) Maps that show the relative amounts of phases present in the binary alloy system
    (E) None of the above

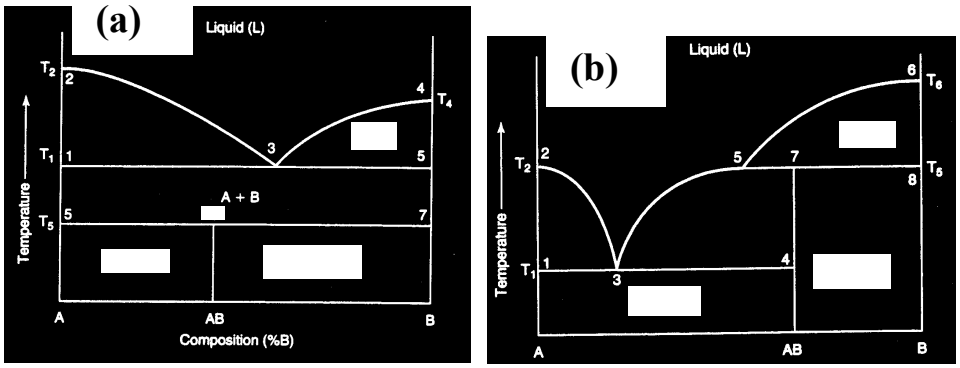
28. In phase diagrams, lines of maximum solubility of *terminal* or *first-formed solid solutions* are called
    (A) Liquidus lines (B) Solidus lines
    (D) Solvus lines (D) Invariant lines

29. The curve that represents the temperatures at which solidification begins is called
    (A) Liquidus (B) Solidus
    (D) Solvus (D) Eutectic

30. An *isomorphous* binary alloy system is one with
    (A) Complete liquid and solid solubility
    (B) Complete solid solubility and partial liquid solubility
    (C) Complete liquid solubility and partial solid solubility
    (D) Complete liquid solubility and solid insolubility
    (E) None of the above

31. What pressure is normally used in constructing equilibrium phase diagrams of alloys?
    (A) 10 psi (B) Depends on the material
    (C) Ambient (D) Normal atmospheric pressure

Use the Figures (a) and (b) below to answer Questions 32 and 33



32. **Figure (a)** above contains this type of material a(n)
    (A) Congruent intermetallic (B) Incongruent intermetallic
    (C) Dissociating intermetallic (D) Terminal solid solution

33. **Figure (b)** above contains this type of material a(n)
    (A) Congruent intermetallic (B) Incongruent intermetallic
    (C) Dissociating intermetallic (D) Terminal solid solution

34. The following *invariant reactions* occur in low-carbon steels (i.e., wt% C ≤ 0.25):
    (A) Eutectic and monotectic
    (B) Eutectic and eutectoid
    (C) Eutectic, eutectoid, and peritectic
    (D) Euectoid and peritectoid
    (E) Eutectoid and peritectic

35. A *two-phase mixture* of ferrite and cementite is called
    (A) Austenite (B) Steel
    (C) Pearlite (D) Ledeburite

36. One of the following phases/microconstituents is best described by the following:
    - *Low yield strength, very ductile, low carbon solubility*
    (A) Cementite (B) Pearlite
    (C) Austenite (D) Ferrite

37. One of the following phases/microconstituents is best described by the following:
    - *Medium yield strength, medium ductility, fixed carbon content*
    (A) Cementite (B) Pearlite
    (C) Austenite (D) Ferrite

38. One of the following phases/microconstituents is best described by the following:
    - *High yield strength, low ductility, Fe:C ratio of 3:1*
    (A) Cementite (B) Pearlite
    (C) Austenite (D) Ferrite

39. In the Iron-Fe_3C system, the maximum solubility of carbon in α-iron is approximately
(A) 0.008 wt.% (C) 0.77 wt.%
(B) 0.022 wt.% (D) 2.11 wt.%

40. The amount of pearlite in unhardened plain-carbon steels increases as the carbon content is increased up to what percentage?
A. 0.08 wt.% C. 1.70 wt.%
B. 0.022 wt.% D. 0.77 wt.% E. 6.69 wt.%

41. Carbon content of cast iron ranges roughly from
(A) 0.022 to 0.77 wt.% (B) 0.6 to 1.0 wt.%
(C) 2 to 4.5 wt.% (D) 4 to 6 wt.%

42. Graphite in a metal promotes
(A) Toughness (B) Malleability
(C) Lubricity (D) Magnetism

43. Two major types of martensite form in steel alloys, depending on the carbon content.
(A) Upper martensite and lower martensite
(B) Upper martensite and nodular martensite
(C) Plate martensite and nodular martensite
(D) Lath martensite and nodular martensite
(E) Lath martensite and plate martensite

44. Two major types of bainite form in steels, depending on the quenchant temperature
(A) Upper bainite and lower bainite
(B) Upper bainte and nodular bainite
(C) Plate bainite and nodular bainite
(D) Upper bainite and pearlitic bainite
(E) Long bainite and short bainite

45. Which of the following statements is **inconsistent** with the decomposition of *retained austenite* in plain-carbon steels.
(A) Retained austenite decomposes at tempering temperatures between 200 and 300°C with austenite transforming into bainite.
(B) Retained austenite decomposes at tempering temperatures between 200 and 300°C with austenite transforming into pearlite.
(C) Large dimensional changes and some softening occur when austenite transforms to bainite.
(D) Retained austenite is present only in plain-carbon steels containing more than 0.4% C.

46. The process of changing the mechanical properties of metals by heating and cooling them while in a solid state is called:
(A) Isoforming (B) Tempering
(C) Hardening (D) Heat treating

47. The type of heat treatment process in which the metal is rapidly cooled
    (A) Annealing (B) Equilibrium
    (C) Non-equilibrium (D) Normalizing

48. Annealing operation that is intended for the sole purpose of relieving stresses is called
    (A) Supercritical anneal (B) Tempering
    (C) Martempering (D) Stress relief

49. Heat treatment of steels that yields maximum machinability, minimum hardness, and maximum ductility
    (A) Tempering (B) Annealing
    (C) Spheroidizing (D) Austenitizing

50. A heat treatment process used to relieve stresses and refine grains that requires heating well above the upper critical temperature followed by cooling in air is called
    A. Austempering C. Intercritical annealing
    B. Normalizing D. Full annealing

SECTION B: ANSWER ALL QUESTIONS

Question 1: (6 Marks)
Use the schematic equilibrium phase diagram of pure iron shown in **Fig. Q1** to answer the following questions:

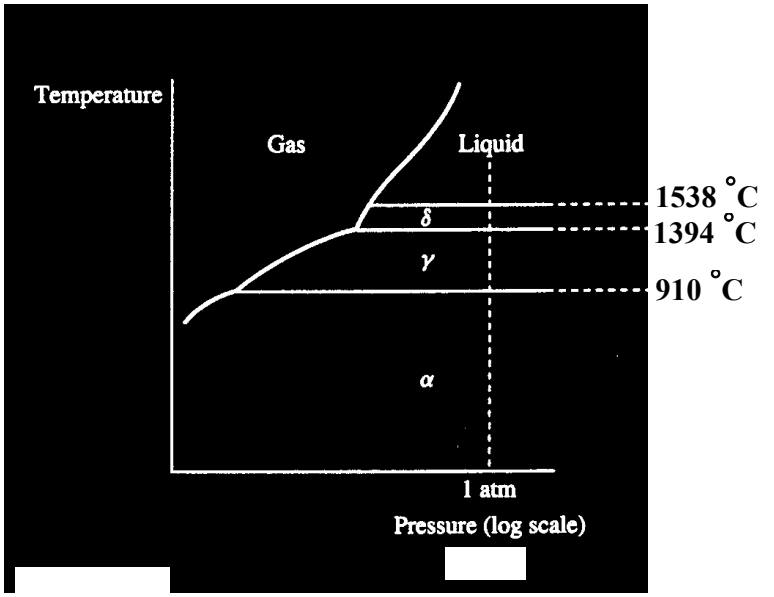


Fig. Q1.

	Marks
(a) How many *triple points* appear in **Fig. Q1**?	**1**
(b) State the *phases* that co-exist at each of the triple points identified in (a)	**3**
(c) How many *degrees of freedom* are there at the three triple points?	**1**
(d) How many degrees of freedom are there along the liquid-gas condensation line?	**1**

Question 2: (5 Marks)

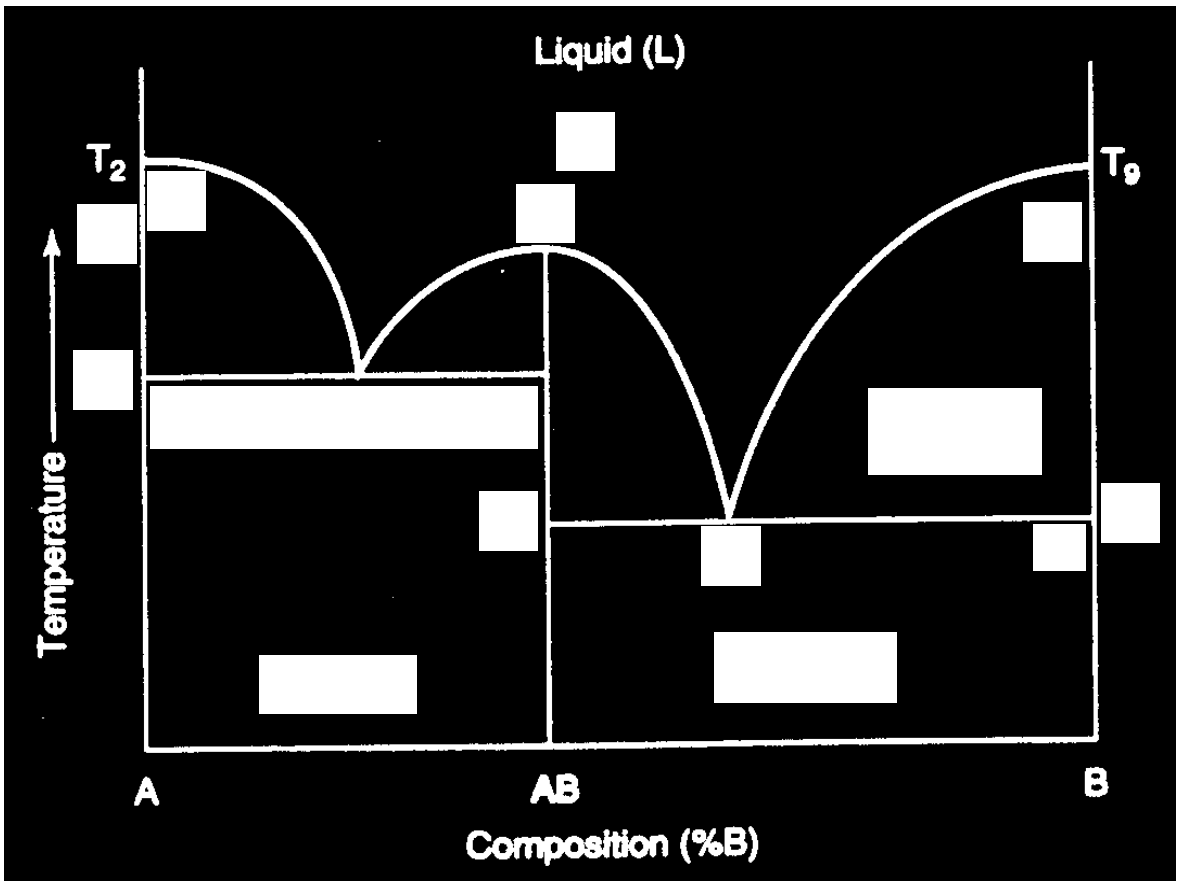


Fig. Q2.

(a) Label the **six** regions of **Fig. Q2**. A and B forms an intermetallic phase *AB*. **3**

(b) How many *eutectic* points are there in **Fig. Q2**? **1**

(c) What *type* of intermetallic phase is formed by A and B? **1**

Question 3: (9 Marks)
Use **Fig. Q3** to answer the following questions

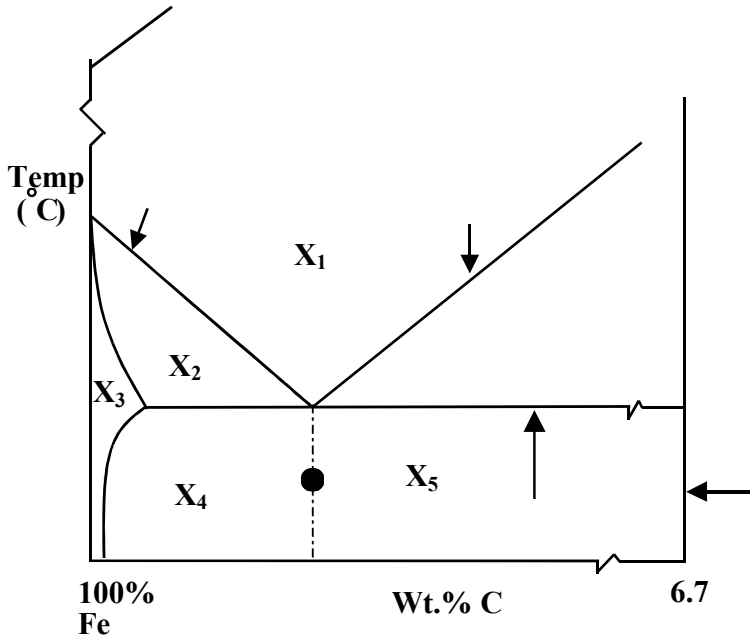


Fig. Q3.

(a) State the *phase*(s) that exist(s) in the region marked

(i) $\mathbf{X_1}$: **0.5**

(ii) $\mathbf{X_2}$: **1**

(iii) $\mathbf{X_3}$: **0.5**

(iv) $\mathbf{X_4}$: **1**

(v) $\mathbf{X_5}$: **1**

(b) Label the lines indicated by the arrows, using $\boldsymbol{A_1, A_2, A_3, A_4, A_{cm}}$, ***Iron carbide***. **2**

(c) After cooling a steel through the eutectoid, what *phase or microconstituent* exists in the region marked by ● in **Fig. Q3**? **1.5**

(d) What is the wt.% of carbon in the phase/microconstituent in (c)? **1.5**

Question 4: (7 Marks)

(a) Use well-labelled diagrams to distinguish between a *grain boundary* and a *phase boundary*. **3**

(b) How is the strength of pearlite affected by the interlamellar spacing? **2**

(c) Name the **two stages** involved in the formation of particles of a new phase. **2**

Question 5: (10 Marks)

(a) State **two differences** between an *equilibrium phase diagram* and a *TTT diagram*. **2**

(b) State **two differences** between *pearlite* and *martensite*. **2**

(c) If a thin sample of a *eutectoid* plain-carbon steel is austenitized, hot-quenched in a molten salt bath at 270 °C and held there until transformation is complete, what will be its final microstructure? **2**

(d) If a thin sample of a *eutectoid* plain-carbon steel is water-quenched from the austenitic region to room temperature (25 °C), what will be its final microstructure? **2**

(e) State **two** heat treatment processes that do not involve phase transformation. **2**

Question 6: (13)

(a) Why are *thin specimens* used for constructing TTT diagrams? **2**

(b) State **two** major structural problems (*defects*) encountered when quenching thick steel parts. **2**

(c) State **two** isothermal heat treatment techniques employed in steel processing industry to overcome the two problems mentioned in (b). **2**

(d) Five thin samples of AISI-SAE 1080 steel are austenitized at 800 °C for 1 h. The different samples are subjected to the following thermal treatments. Use the given TTT diagram and other knowledge to determine the microstructure of the steel samples after each heat treatment.

(i) One sample is quenched to 700 °C in molten salt bath for 5 s and quenched to -100 °C. **1**

(ii) One sample is quenched to 650 °C in molten salt bath for 10^3 s and quenched to -100 °C. **1**

(iii) One sample is quenched to 300 °C in molten salt bath for 500 s and quenched to -100 °C. **1**

(iv) One sample is quenched to 250 °C in molten salt bath for 100 s and air-cool. What is the name of this thermal treatment? **2**

(v) One sample is quenched to -100 °C, reheated to 650 °C and held for 20 h and then quenched to room temperature. What is the name of this thermal treatment? **2**

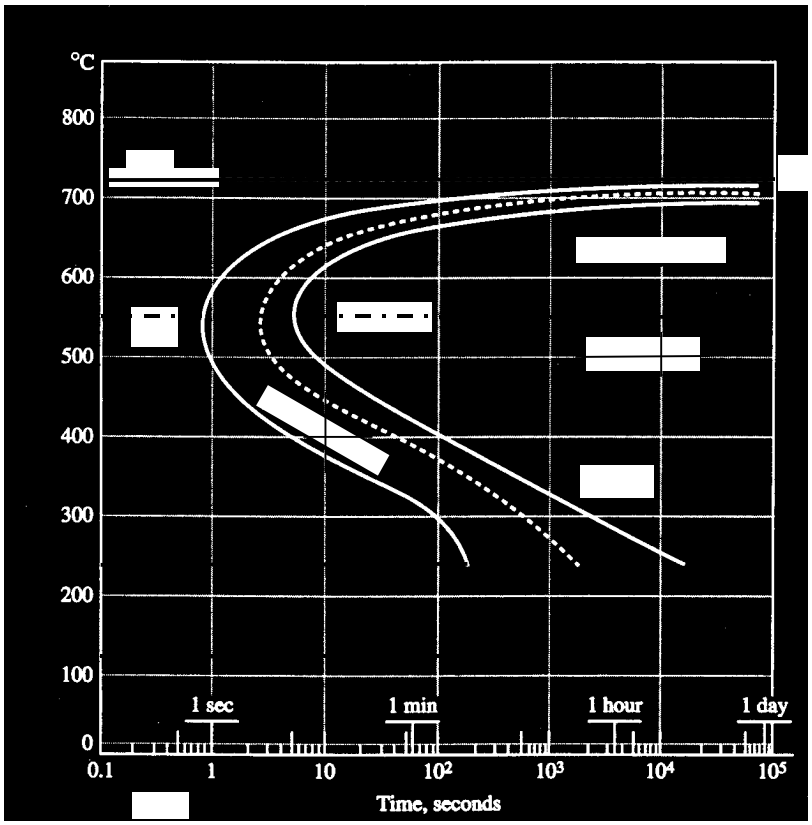

°C
800
700
600
500
400
300
200
100
0
1 sec
1 min
1 hour
1 day
0.1
1
10
10²
10³
10⁴
10⁵
Time, seconds

Fig. Q5