Final Exam

Student ID:_____ Name:_____ Seat No:_____

2019. 06. 20. 15:00~16:50, Closed Book
Instructor: Seungtae CHOI

Question: Regarding the following questions, please make a circle on T if you think the statement is true, or make a circle on F if you think the statement is not true. It should be noted that minus points will be given to incorrect answers, and thus, if you are not sure about the correct answer, you would better not choose any one of T or F. Two points are allotted to each problem.

1. For a specimen that has been plastically deformed, if the applied load is removed, no elastic strain recovery occurs.	T	F
2. During a crack propagation, the reduction of potential energy mostly corresponds to the energy dissipated in plastic work and surface creation.	T	F
3. Martensite having body-centered tetragonal (BCT) crystal structure is a non-equilibrium single-phase structure formed from a diffusional transformation of austenite.	T	F
4. In a plane strain condition, the number of independent stress components at a material point is 4.	T	F
5. Four strategies for strengthening of polycrystalline metals are grain size reduction, solid solution alloying, phase transformation hardening, and strain hardening.	T	F
6. In binary eutectic systems, hypoeutectic cooling may form lamellar eutectic structure possibly with primary β phase particles.	T	F
7. Styrene-butadiene block copolymer consisting of "soft" (i.e., butadiene or isoprene) repeat unit center-chain segments and "hard" (i.e., styrene) domains (chain ends), which act as physical crosslinks at room temperature, is a typical example of thermoplastic elastomers.	T	F
8. Stress relaxation behavior in a viscoelastic polymer represents the tendency of a solid material to move slowly or deform under the influence of mechanical stresses.	T	F
9. In mechanical modelling of viscoelastic materials, Maxwell model may recover its original shape without any permanent deformation, if the applied load is removed.	T	F
10. Polymer fibers fabricated by thermal drawing processes may have highly aligned chains and fibrillary structure, and thus, increased elastic modulus in longitudinal direction.	T	F

Question: Please select **only one answer** to the following problems 11-30. Two points are allotted to each problem.

11. Please choose an answer including all the correct statements on the mechanical properties of metals.

Statements
A. In an elastic solid, if the applied load is released, the solid returns to its original shape.
B. The elastic modulus is proportional to the slope of the interatomic force-separation curve at equilibrium spacing.
C. In an elastic solid, the axial elongation is accompanied by lateral contraction, and the lateral strain is proportional to the axial strain.
D. If Poisson's ratio, ν, of a solid is 0.0, the solid is an incompressible material.

① A, B, C ② A, B, D ③ B, C, D ④ A, C, D ⑤ A, B, C, D

12. Please choose an answer best describing the macroscopic mechanical properties of a polycrystalline eutectic lamella structures with α phase particles of a binary eutectic alloy.
① Anisotropic & Inhomogeneous ② Anisotropic & Homogeneous
③ Isotropic & Inhomogeneous ④ Isotropic & Homogeneous

13. Please choose an answer including all the correct statements on the dislocations & strengthening mechanisms of metals.

Statements
A. Plastic deformation corresponds to the motion of large numbers of dislocations.
B. Dislocation motion is harder in metals rather than in ceramics.
C. Slip planes represent the planes on which dislocations can easily glide.
D. The critical resolved shear stress, i.e., the minimum resolved shear stress required to initiate slip of dislocations, is called as yield stress.

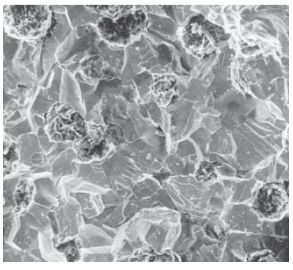
① A, B ② A, C ③ B, C ④ C, D ⑤ A, C, D

14. Please choose an answer including all the correct statements on the solid-solution strengthening.

Statements
A. Large impurities tend to concentrate at regions of tensile strains near dislocations.
B. Small impurities tend to concentrate at regions of compressive strains near dislocations.
C. Alloys are stronger than pure metals because impurity atoms that go into solid solution typically impose lattice strains on the surrounding host atoms.

① A, B ② C ③ A, C ④ B, C ⑤ A, B, C

15. The following SEM (scanning electron microscope) image shows a fractured surface of a polycrystalline metal. What kind of fracture can be inferred from the SEM image?
① Transgranular fracture
② Intergranular fracture
③ Ductile fracture
④ Cup-and-cone fracture



16. Please choose a statement incorrectly describing binary isomorphous system.
① Cu-Ni system belongs to binary isomorphous system.
② One component is completely soluble in another component.
③ Melting temperature is dependent on the concentration.
④ Liquid and solid phases cannot coexist.

17. Please choose an answer including all the correct statements on the fracture of solids.

Statements
A. Ductile fracture involves sufficient plastic deformation before fracture.
B. The plastic-zone size at the crack tip depends on the thickness of a compact tension specimen.
C. If temperature increases, materials become more ductile.
D. Hydrogen segregation near grain boundaries may cause transgranular fracture.

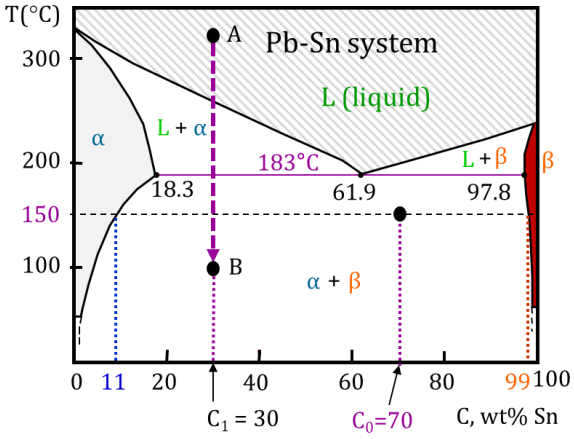
① A, B ② A, B, C ③ B, C, D ④ A, B, D ⑤ A, C, D

18. Please choose an answer including all the correct statements on creep behavior of metals.

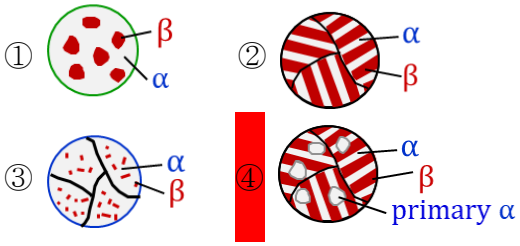
Statements
A. Creep represents time-dependent and permanent deformation of materials when subjected to constant load or stress.
B. In the secondary creep stage, strain rate ($\Delta\varepsilon/\Delta t$) is constant.
C. In the secondary creep stage, strain rate ($\Delta\varepsilon/\Delta t$) may increase if temperature increases.
D. In creep, time to rupture increases as stress increases.

① A, B, C ② A, B, D ③ B, C, D ④ A, C, D ⑤ A, B, C, D

19. For a 70 wt% Sn-30 wt% Pb alloy at 150°C as shown in the following figure, choose an answer correctly representing the α phase composition and its weight fraction.
① C_α = 18.3 wt% Sn, W_α = 0.67
② C_α = 18.3 wt% Sn, W_α = 0.33
③ C_α = 11.0 wt% Sn, W_α = 0.67
④ C_α = 11.0 wt% Sn, W_α = 0.33



20. For a 30 wt% Sn-70 wt% Pb alloy cooling down from the state A to the state B (about 100°C) as shown in the figure, please choose a possible microstructure at the state B.



21. Please choose an answer correctly connecting the phase of Fe-C system into its crystal structure.
① Ferrite (α) – FCC (face-centered cubic)
② Austenite (γ) – BCC (body-centered cubic)
③ Martensite – BCT (body centered tetragonal)
④ Pearlite – alternating layers of α (ferrite) and austenite (γ) phases

22. Please choose an answer including all the correct statements on the viscoelastic deformation of polymers.

Statements
A. A polymer can exhibit all intermediate range of properties between an elastic solid and a viscous liquid.
B. Viscoelastic materials possess a fading memory of past events.
C. Two types of viscoelastic behavior are creep and stress relaxation.

① A, B ② A, C ③ B, C ④ A, B, C

23. Please choose an answer correctly stating what happens in stress-strain curve of thermoplastics when temperature increases.

① Young's modulus increases. ② Tensile strength decreases.
③ Ductility decreases. ④ Thermoplastics become brittle.

24. Please choose an answer including all the correct statements on the fracture mechanics of solids.

Statements
A. The energy release rate is also called the crack extension force or the crack driving force.
B. In linear elastic fracture mechanics, stresses become singular near a sharp crack tip.
C. Fracture mechanics provides a design criterion of structural components by predicting when cracks can be created and propagate.

① A, B ② A, C ③ B, C ④ A, B, C

25. Please choose an answer including all the correct statements on the plastic deformation of polycrystalline materials.

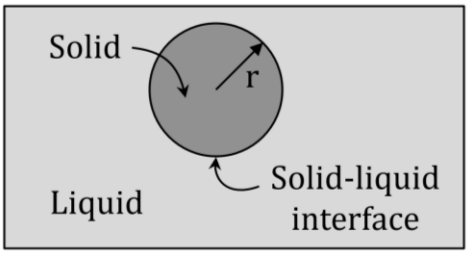
Statements
A. Polycrystalline solids are stronger than single crystals
B. Dislocations can easily move along grain boundaries.
C. The grain with the largest resolved shear stress on slip planes yields first.
D. Geometric constraints are imposed on the grains during deformation.

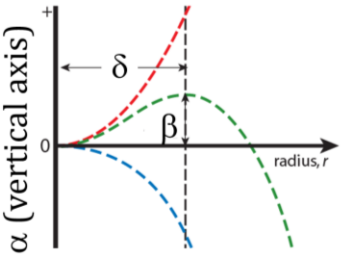
① A, B, C ② A, B, D ③ B, C, D ④ A, C, D ⑤ A, B, C, D

26. Please choose an answer including all the correct statements on the kinetics of phase transformation.

Statements
A. α in the following figure represents the Gibbs free energy, G = U + pV – TS = H – TS.
B. β in the following figure represents the free energy required for the formation of stable nuclei.
C. δ in the following figure represents the critical radius for the nucleation of solid phases.
D. Surface free energy destabilizes the nuclei (it takes energy to make an interface), while volume (bulk) free energy stabilizes the nuclei (releases energy).

① A, B, C ② A, B, D ③ B, C, D ④ A, C, D ⑤ A, B, C, D





27. Please choose an answer correctly denoting the microstructure of alternating layers of α (ferrite) and Fe_3C that are relatively thick.

① Spheroidite ② Martensite
③ Coarse pearlite ④ Fine pearlite

28. Please choose an answer including all the correct statements on the spheroidite microstructure.

Statements
A. Fe_3C particles exist within an α-ferrite matrix.
B. The spheroidite microstructure can be formed without diffusion.
C. Reduction of α-ferrite/Fe3C interfacial area is the main driving force.

① A, B ② A, C ③ B, C ④ A, B, C

29. Please choose the name of phase transformation at which one solid phase transforms to two other solid phases.
① Eutectic ② Eutectoid
③ Hypoeutectic ④ Hypereutectic

30. Please choose an answer including all the correct statements on the phase transformation.

Statements
A. Three types of phase transformations are two diffusion-dependent transformations and diffusionless phase transformation.
B. By the two diffusion-dependent transformations, no change in either the number or composition of the phase present can take place.
C. By the diffusionless phase transformation, a metastable phase is produced.

① A, B ② A, C ③ B, C ④ A, B, C

Question: Please write down a short answer to the following questions. Two points are allotted to each problem.

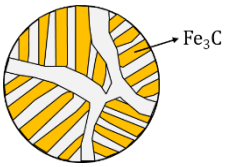
31. In fracture criterion, a crack may propagate when an applied (**stress intensity factor** **or** **energy release rate**) reaches the fracture toughness of the material.

32. The (**Arrhenius equation**) represents a formula for the temperature dependence of reaction rates. For many common chemical reactions at room temperature, the reaction rate doubles for every 10 degree Celsius increase in temperature. It can be used to model the temperature variation of diffusion coefficients, population of crystal vacancies, creep rates, and many other thermally-induced processes and reactions.

33. In (**Peritectic**) reaction, liquid and one solid phase transform to a second solid phase.

34. When bainite or pearlite phases are maintained at temperature just below eutectoid for long times, a (**spheroidite**) phase having Fe_3C particles within an α-ferrite matrix is formed by diffusion.

35. The following figure represents a typical microstructure of a (**hypoeutectoid**) steel.



36. Please rearrange the following microstructures of Fe-C alloys from ductile to brittle phases: bainite, spheroidite, martensite, fine pearlite, and coarse pearlite.
spheroidite, coarse pearlite, fine pearlite, bainite, martensite

37. (**Solubility limit**) represents a maximum concentration of solute atoms that may dissolve in the solvent to form a solid solution.

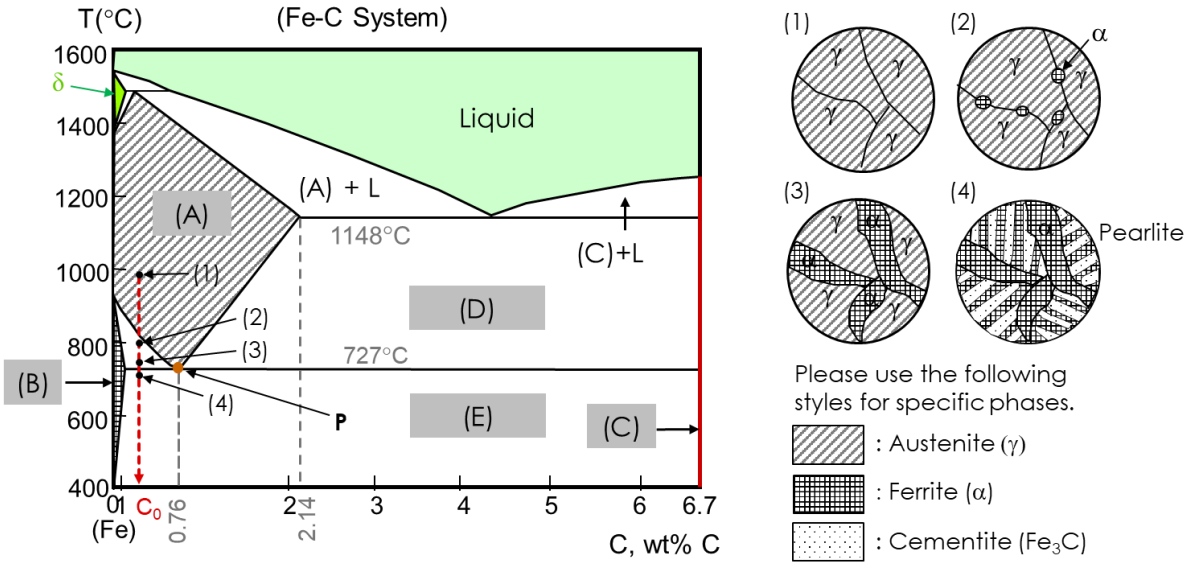
38. In Fe-C alloys, (**martensite**) phase represents a supersaturated solid solution that is capable of rapidly transforming to other structures if heated to temperatures at which diffusion rates become appreciable.

39. Upon heating through (**glass transition**) temperature, the amorphous solid polymer transforms from a rigid into a rubbery state.

40. In a (**crazing**) phenomenon, regions of very localized plastic deformation lead to the formation of small and interconnected microvoids. Fibrillar bridges form between these microvoids wherein molecular chains become oriented.

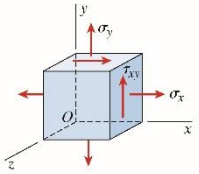
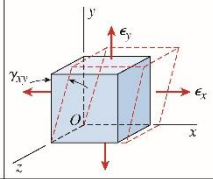
Question: Please answer the following questions, 41-42.

41. (10 points) Please answer to the following questions about the following phase diagram of Fe-C system.
    (a) Fill out the possible phases in the regions (A)-(E).
    (A) Austenite (γ) (B) Ferrite (α) (C) Cementite (Fe_3C)
    (D) Austenite (γ) + Cementite (Fe_3C) (E) Ferrite (α) + Cementite (Fe_3C)
    (b) Draw the microstructures at the points (1)-(4) shown in the following figure, when it cools down from 1,000 °C to 600 °C.
    (c) Please write down the name of the point P: Eutectoid point



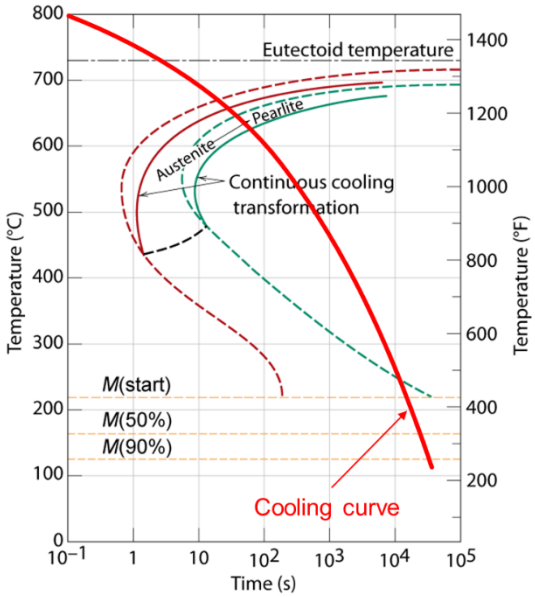
42. (10 points) Please answer to the following questions.
    (a) Explain the solid solution alloying for strengthening.
    - Alloys are stronger than pure metals because impurity atoms that go into solid solution typically impose lattice strains on the surrounding host atoms.
      - Impurity atoms distort the lattice & generate lattice strains.
      - These strains can act as barriers to dislocation motion.
    - Small impurities tend to concentrate at regions of compressive strains near dislocations.
      - Partial cancellation of dislocation compressive strains and impurity atom tensile strains.
      - Reduce mobility of dislocations and increase strength.
    - Large impurities tend to concentrate at regions of tensile strains near dislocations.

    (b) Explain a plane stress condition and plane strain condition.

	Plane stress	Plane strain
		
Stresses	$\sigma_z = 0 \quad \tau_{xz} = 0 \quad \tau_{yz} = 0$ σ_x, σ_y, and τ_{xy} may have nonzero values	$\tau_{xz} = 0 \quad \tau_{yz} = 0$ σ_x, σ_y, σ_z, and τ_{xy} may have nonzero values
Strains	$\gamma_{xz} = 0 \quad \gamma_{yz} = 0$ ϵ_x, ϵ_y, ϵ_z, and γ_{xy} may have nonzero values	$\epsilon_z = 0 \quad \gamma_{xz} = 0 \quad \gamma_{yz} = 0$ ϵ_x, ϵ_y, and γ_{xy} may have nonzero values

* Plane stress condition is applicable for thin plate.
* Plane strain condition is applicable for thick plate.

(c) Explain the continuous cooling transformation diagrams.



* A continuous cooling transformation (CCT) phase diagram is the plot beginning with the transformation start point, cooling with a specific transformation fraction and ending with a transformation finish temperature for all products against transformation time for each cooling curve.
* Isothermal transformation diagram can be converted into continuous cooling transformation diagram.
* This diagram is used to represent which types of phase changes will occur in a material as it is cooled at different rates.

(d) Explain when the bainite phases can be formed in Fe-C system.

* Bainite phases are another diffusion-controlled Fe-Fe3C transformation product.
* Bainite phases have elongated Fe3C particles in α-ferrite matrix.