Lund University
Division of Materials Engineering

Examination in Materials Engineering – Basic Course
(FKMA01)

Friday, 20th March 2020, 14^{00} – 19^{00} hrs

Digital examination from home

NOTE! You can write this examination **only if you have cleared all the 3 labs**.
Approved laboratory work is valid till 31st December 2021.

Technical Aids allowed:
You are allowed to use the course textbook, calculator and other resource

Instructions:
Make sure that you READ THE QUESTIONS CAREFULLY.
Please write the answers in plain English.
You are advised to write your answers in a concise, clear and well formulated manner, which is easy to read and understand. Show, *step by step*, how you arrived at the answer.
Motivation for your claims will be decisive for the marks given.
Nothing is obvious or self-explanatory.
Explain clearly and properly the Concepts / Diagrams / Reasoning.
Remember to write / define the variables on x- and y-axes in all the figures and diagrams.

Grades
The Examination is for a total of **100 marks**. *Marks from the midterm examination (≥ 25) can be counted instead of marks from Part A in this Final Examination. In case you have answered questions in Part A despite passing the midterm exam, the best result will be considered in the final evaluation.* A pass (Grade 3) requires a minimum of 50% marks (Midterm exam of 25^{+} / Part A + Part B). Grade 4 is for a minimum of 70% marks, and Grade 5 a minimum of 85% marks.

Results
The results will be announced by 10th April 2020.

The time for checking your graded answer sheets will be announced later.

Part A (Questions 1-4, 50 marks)

1. Materials Science and Engineering Concepts – I

(a) What type(s) of bonding would be expected for each of the following materials: solid xenon, calcium fluoride (CaF_2), bronze, cadmium telluride (CdTe), rubber, and tungsten? (3p)

(b) Would you expect a material in which the atomic bonding is predominantly ionic in nature to be more or less likely to form a noncrystalline solid upon solidification than a covalent material? Why? (2p)

(c) Among Mo, C, Cr and W atoms which elements diffuse most rapidly in iron? Why? (2p)

(d) Which kind of a dislocation is formed by adding an extra half-plane of atoms to a crystal? What can you say about stress distribution around its core? (3p)

(e) What is the principal difference between congruent and incongruent phase transformations? (2p)

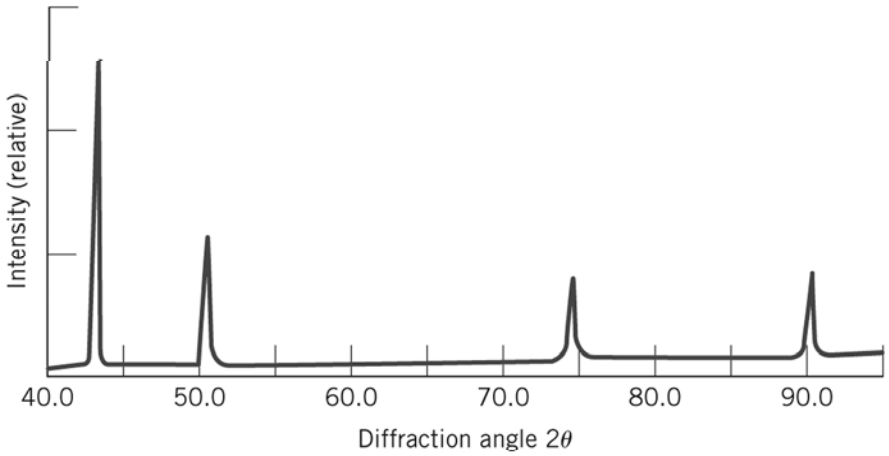
(f) Is brittle or ductile fracture (or both) associated with intergranular crack propagation? Why? (2p)

(14p)

2. Crystal Structure

(a) For each of the following crystal structures, represent the indicated plane, showing both anions and cations:
(i) (100) plane and [100] direction for the rock salt crystal structure
(ii) (110) plane and [110] direction for the cesium chloride crystal structure
(iii) (111) plane and [111] direction for the zinc blende crystal structure
(iv) (110) plane and [110] direction for the perovskite crystal structure (4p)

(b) Figure below shows the first four peaks of the x-ray diffraction pattern for copper, which has an FCC crystal structure; monochromatic x-radiation having a wavelength of 0.1542 nm was used.
(i) Index (i.e., give h, k, and l indices) for each of these peaks.
(ii) Determine the interplanar spacing for each of the peaks.
(iii) For each peak, determine the atomic radius for Cu, and compare these with the reference value of 0.1278 nm. (8p)



Explain how you arrived at all the answers. **(12p)**

3. Mechanical properties

(a) The tensile strength and number-average molecular weight for two polyethylene materials are given in the table on your right-hand side.
Estimate the number-average molecular weight that is required to give a tensile strength of 195 MPa. (6p)

Tensile Strength (MPa)	***Number-Average Molecular Weight (g/mol)***
85	*12,700*
150	*28,500*

(b) For the two polymers given: branched polyethylene with a number-average molecular weight of 250,000 g/mol; and linear and isotactic poly(vinyl chloride) with a number-average molecular weight of 200,000 g/mol;
State whether it is possible to decide if one polymer has a higher tensile modulus than the other. If this is possible, note which has the higher tensile modulus and cite the reason(s) for your choice; and if it is not possible to decide, state why. (6p)

Explain how you arrived at all the answers. **(12p)**

4. Phase diagrams

Construct the hypothetical phase diagram for metals A and B between temperatures of 600°C and 1000°C given the following information:

- The melting temperature of metal A is 940°C.
- The solubility of B in A is negligible at all temperatures.
- The melting temperature of metal B is 830°C.
- The maximum solubility of A in B is 12 wt% A, which occurs at 700°C.
- At 600°C, the solubility of A in B is 8 wt% A.
- One eutectic occurs at 700°C and 75 wt% B–25 wt% A.
- A second eutectic occurs at 730°C and 60 wt% B–40 wt% A.
- A third eutectic occurs at 755°C and 40 wt% B–60 wt% A.
- One congruent melting point occurs at 780°C and 51 wt% B–49 wt% A.
- A second congruent melting point occurs at 755°C and 67 wt% B–33 wt% A.
- The intermetallic compound AB exists at 51 wt% B–49 wt% A.
- The intermetallic compound AB_2 exists at 67 wt% B–33 wt% A.

Explain how you arrived at the answer. **(12p)**

Part B (Questions 5-9, 50 marks)

5. Materials Science and Engineering Concepts – II

(a) Which of the following describes recrystallization? (i) Diffusion dependent with a change in phase composition; (ii) Diffusionless; (iii) Diffusion dependent with no change in phase composition; or (iv) All of the above. Why? (2p)

(b) For the pair of polymers (linear polyethylene that has a degree of polymerization of 5,000; and linear and isotactic polypropylene that has a degree of polymerization of 6,500), do the following: (i) state whether it is possible to determine whether one polymer has a higher melting temperature than the other; (ii) if it is possible, note which has the higher melting temperature and then cite reason(s) for your choice; and (iii) if it is not possible to decide, then state why. (3p)

(c) What is the principal difference between natural and artificial aging processes? (2p)

(d) What is the distinction between glass transition temperature and melting temperature? (2p)

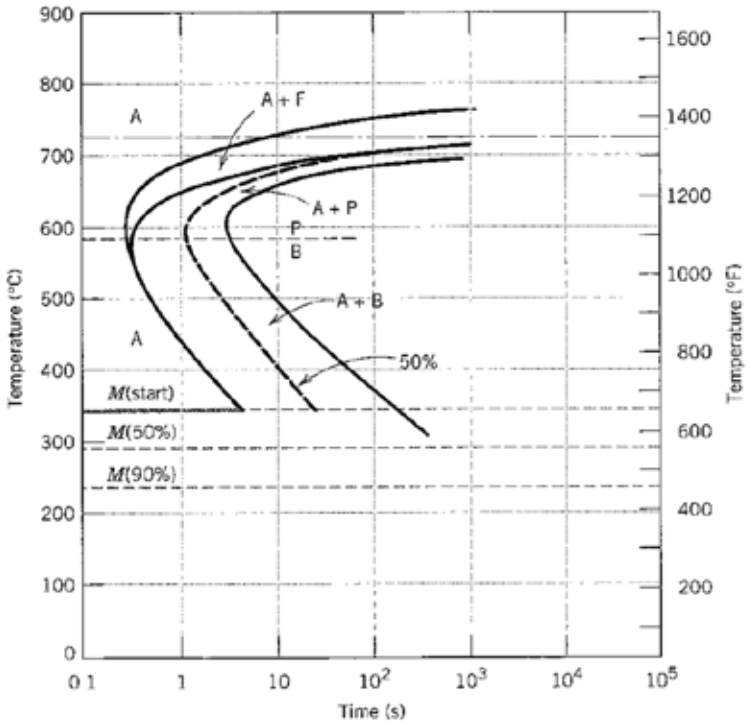
(e) What would be advantages and disadvantages of using transparent polymeric materials for eyeglass lenses. Note at least three polymers that may be candidates for this. (3p)

(f) Some ceramic materials are fabricated by hot isostatic pressing. Cite some of the limitations and difficulties associated with this technique. (2p)

(14p)

6. Non-equilibrium phase transformations

Using the isothermal transformation diagram for a 0.45 wt% C steel alloy below,



(a) Assume that a small specimen begins at 845°C, and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure. Afterwards, it is subjected to the following treatments: rapidly cool to 625°C, hold at this temperature for 10 s, rapidly cool to 400°C, hold at this temperature for 5 s, then quench to room temperature. *Determine the final microstructure in terms of the microconstituents present.* (4p)

(b) Determine the approximate percentages of the microconstituents that form. (4p)

(c) Which heat treatment could be used to isothermally convert a resulting microstructure into one composed of proeutectoid ferrite and martensite? (4p)

Explain how you arrived at all the answers. **(12p)**

7. Composites

A generalized expression for the transverse modulus of elasticity of an aligned fiber-reinforce composite has the following form:

$$E_{ct} = \frac{E_m E_f}{V_m E_f + V_f E_m} = \frac{E_m E_f}{(1 - V_f) E_f + V_f E_m}$$

Derive a generalized expression analogous to the equation above for the transverse modulus of elasticity of an aligned hybrid composite consisting of two types of continuous fibers. (6p)

Explain how you arrived at the answer. **(6p)**

8. Thermal Properties

The two ends of a cylindrical rod of 1025 steel 75.00 mm long and 10.000 mm in diameter are maintained rigid. If the rod is kept initially at 25°C.

To what temperature must it be cooled to have a 0.008-mm reduction in diameter? (10p)

Explain how you arrived at all the answers. **(10p)**

9. Materials and the Environment, Material selection

Some modern kitchen cookware is made of ceramic materials.

(a) List at least three important characteristics required of a material to be used for this application. (3p)

(b) Compare the relative properties and cost of three ceramic materials. On the basis of this comparison, select the material most suitable for the cookware. (5p)

Explain how you arrived at all the answers. **(8p)**