Master examination

„Metallic Materials“

Part „Metallic Materials“

28.02.2017

Name, first name:

Matriculation number:

Declaration: I am healthy and able to take part in the examination.

Signature:

Task	Points:	Achieved Points:	Points after review: (additional points)
1	4		
2	4		
3	4		
4	3.5		
5	13		
6	5		
7	6		
8	6		
9	3		
10	9		
11	5		
12	4		
13	3		
14	12		
15	5		
16	5		
17	8.5		
Sum	100		

The overall grade for the examination of „Metallic Materials“ will be weighted from the results of the respective parts "Microstructure, Microscopy and Modelling" and "Metallic Materials" for a duration of 90 minutes each.

Task 1 steel systematic 4 Point(s)

Steel grades are either classified by their short name or material code. Give the approximate chemical composition of the following steels: (4 Points)

a) 22MnB5

b) 51 CrMoV 4

c) X100CrMoV 8-1-1

d) C40

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Task 2 elastic properties 4 Point(s)

a) Sketch the temperature dependency of the young's modulus of steel from room temperature to 600°C. Consider the approximate values of the young's modulus while labeling the axes. (3 Points)

b) Alloying elements can significantly alter the young's modulus. Sketch young's modulus for an increasing Carbon content. (1 Point)

Task 3 thermal properties of iron 4 Point(s)

a) Sketch qualitatively the temperature dependency of the lattice constant "a" of pure iron in the given Diagram in Figure 1. (2 Points)

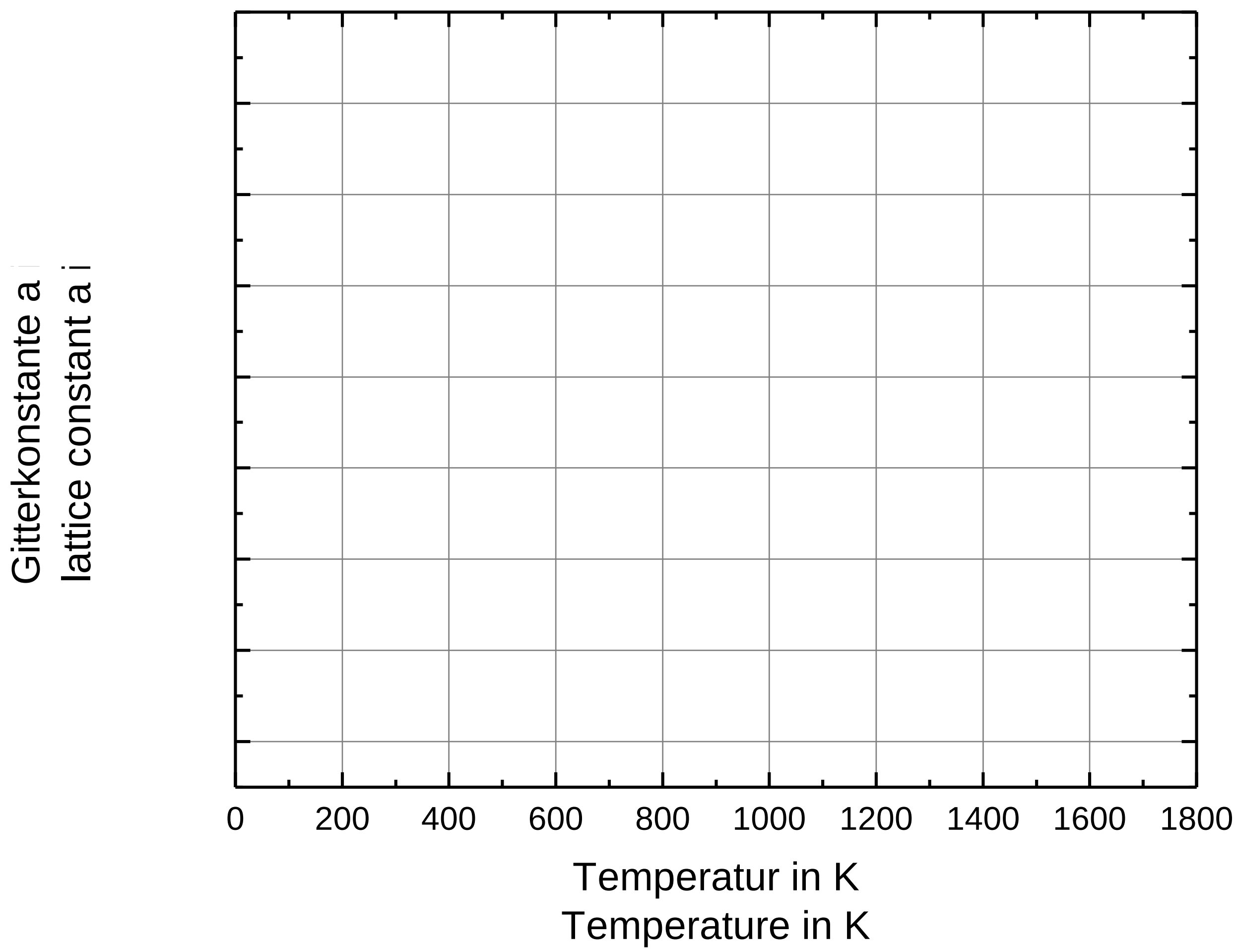

Figure 1: Temperature dependency of the lattice constant a of pure iron

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b) Which steel grade is used for precise length measurements, owing to its constant thermal expansion coefficient α in the temperature range up to 100°C? Which special alloying element is added up to 36 mass-% to this steel? (2 Points)

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Task 4 crystal structure of iron 3.5 Point(s)

Metals have defects in their lattice. Complete the given table by giving one or two examples for possible lattice defects for each of the corresponding dimensions. (3.5 Points)

Table 1: Dimensions, types and descriptions of lattice defects

Dimension	**Type of crystall structure defect**	**Description**
0-dimensional	Point defect	(2 Examples)
1-dimensional	Line defect	(1 Example)
2-dimensional	Planar defect	(2 Examples)
3-dimensional	Volume defect	(2 Examples)

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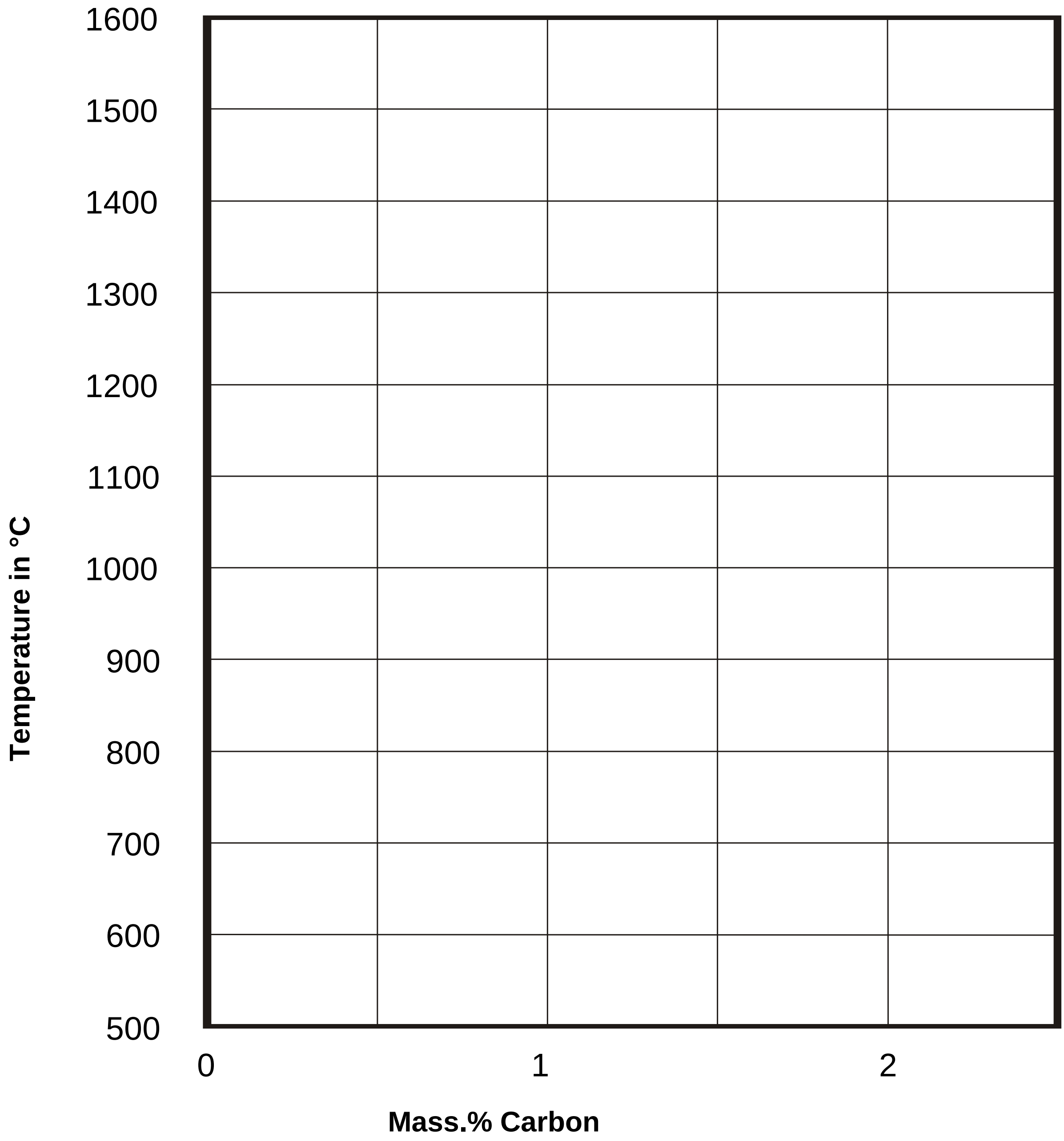
Task 5 alloying elements of iron 13 Point(s)

In the metastable Fe-Fe_3C phase diagram several phase transformation reactions can be found. Sketch the Fe-Fe_3C phase diagram in Appendix 1. Label all areas and indicate all characteristic temperatures and Carbon fractions. (8.5 Points)

Appendix 1



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b) Write down the respective transformation reactions (reacting phase(s) → produced phase(s)) and the carbon contents of all participating phases. (4.5 Points)

Eutectic reaction

Equation (phases) ____________________ → ____________________

C contents ____

peritectic Reaction

Equation (phases) ____________________ → ____________________

C contents ____

eutectoid reaction

Equation (phases) ____________________ → ____________________

C contents ____

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Task 6 stainless steels 5 Point(s)

Stainless steels can have fcc or bcc lattice structure depending on their chemical compositions.

a) What is the lattice structure of the following steels: (1 Point)

- X6Cr17
- X5CrNi18-10

b) Sketch a stress-strain diagram for steel X6Cr17 and X5CrNi18-10. Consider yield strength, strain hardening and total elongation. (3 Points)

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c) Is the corrosion layer of Cr-alloyed steels affected due to welding? Explain your answer briefly. (1 Point)

Task 7 stainless steels II 6 Point(s)

Chromium is an important alloying element for the design of corrosion resistant steels. Sketch a current density – potential curve of a stainless steel in Figure 1. Indicate all characteristic current density and potential points from the legend in the sketched diagram. (6 Points)

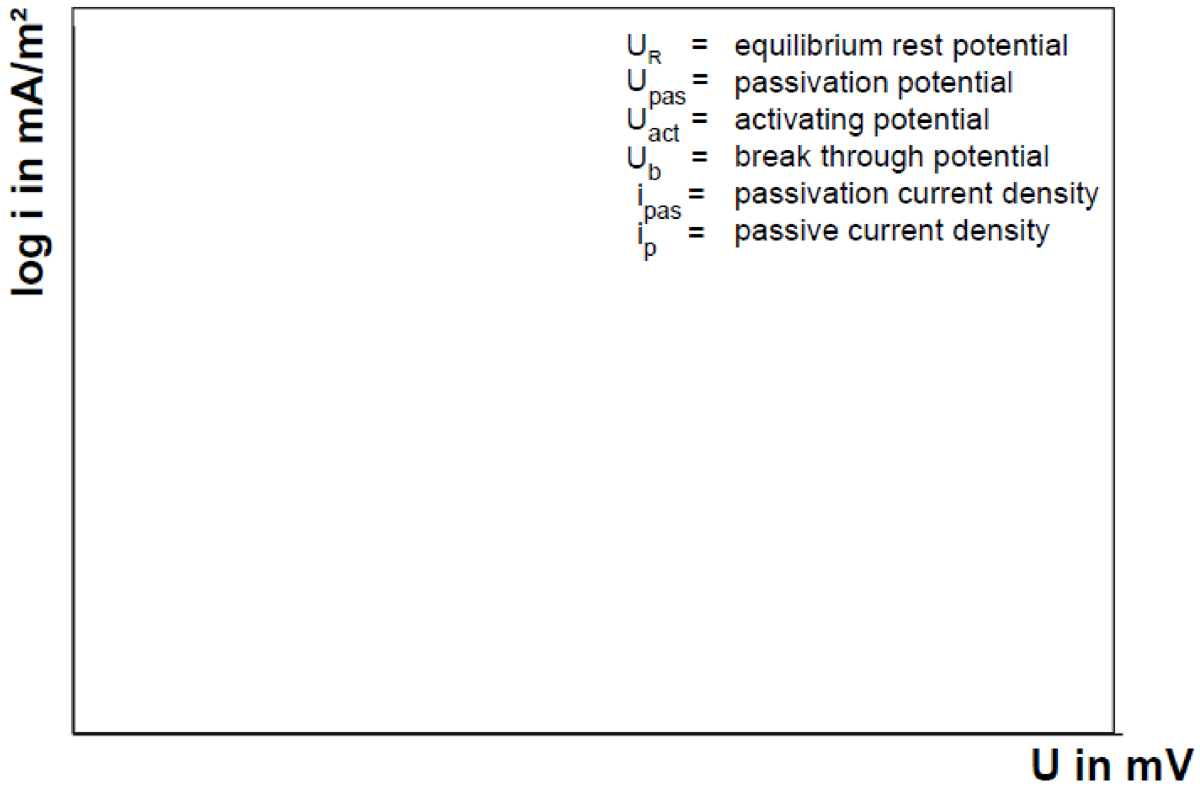

Figure 1 current density – potential curve of a stainless steel

Task 8 phase transformation from austenite 6 Point(s)

A non-alloyed steel with a carbon-content of 1.2 mass-% C is heated to the following temperatures:

1. above A_{ccm},
2. between A_{c1} and A_{ccm} and
3. just below A_{c1}

In all cases the steel is held just as long as full soaking of the material is guaranteed.

a) Which microstructures occur at each of the 3 given temperatures (3 Points)?

b) How are the microstructures from a) affected when quenching in salt brine (3 Points)?

Task 9 ferritic-pearlitic phase transformation 3 Point(s)

A steel with 0.25 mass-% Carbon is cooled down with near-equilibrium conditions. What should be the equilibrium fractions of ferrite and pearlite for this steel at room temperature? (3 Points)

Note: use the lever-rule!

Assumption: C cannot be dissolved in ferrite at room temperature.

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Task 10 martensitic phase transformation 9 Point(s)

The phase transformation from austenite to martensite occurs at very high undercooling. A characteristic of martensite is its higher strength in comparison austenite.

a) Name four additional characteristic features of the martensite transformation! (4.0 Points)

-
-
-
-

b) Which model can be used to explain the phase transformation from austenite to martensite? Explain the individual steps and consider the lattice parameter. (3.5 Points)

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c) What is the effect of an initial higher carbon content in austenite on the tetragonality of martensite? (1.5 Points)

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Task 11 bainitic phase transformation 5 Point(s)

Bainite is a microstructure which can have several constituents and morphologies.

a) Name at least two different second phases of bainite. (2 Points)

b) Divide bainite into two groups based on their transformation temperature. Describe the microstructure for each case. (2 Points)

1.

2.

c) Which of the following elements diffuse during the bainitic phase transformation: Si, Mn, C? (1 Point)

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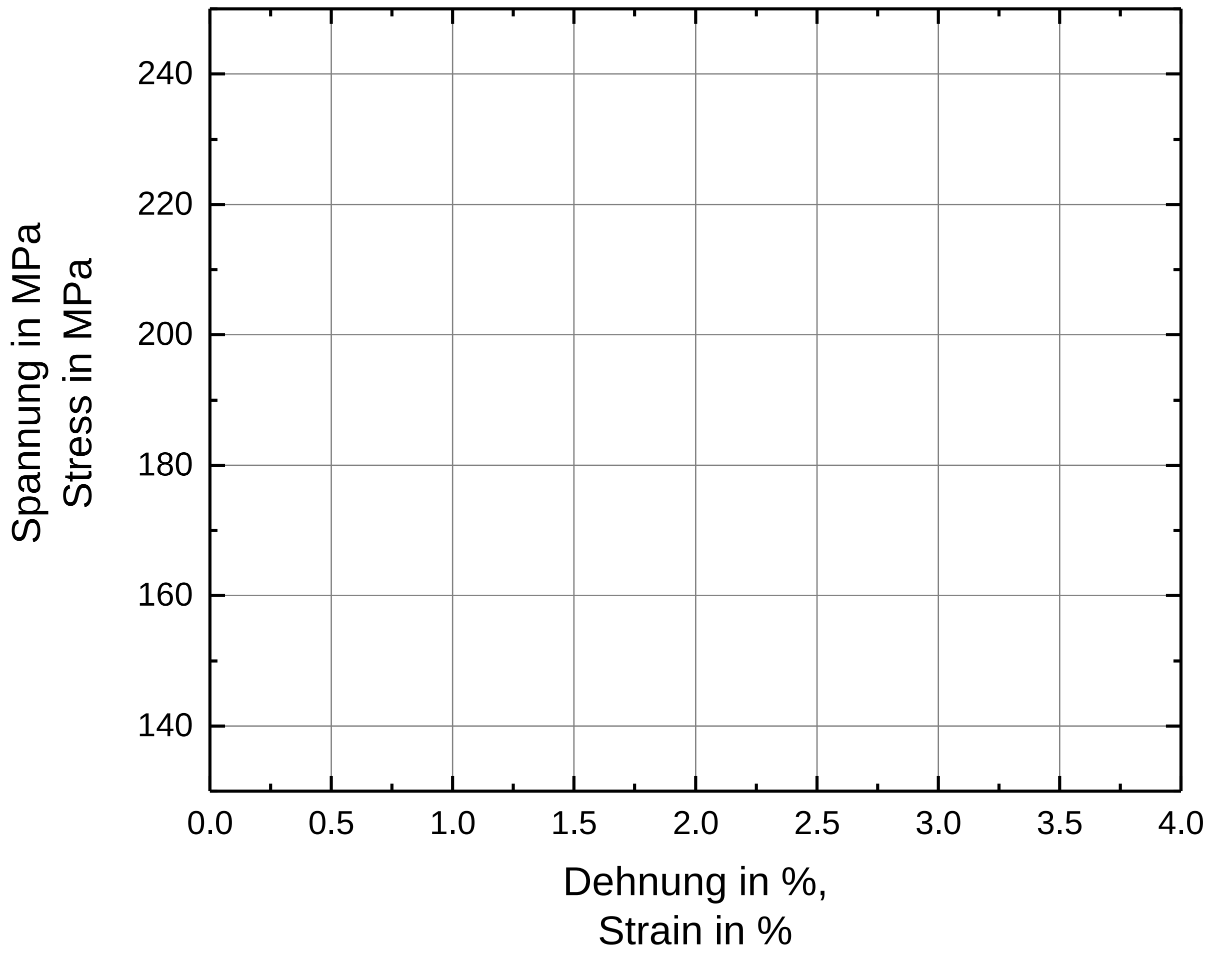
Task 12 aging of steel 4 Point(s)

a) What is described with the term „aging of steel“? (1 Point)

A pure iron-carbon-alloy with 0.01 % C was soaked at 720°C until homogenitisation and subsequently quenched.

b) Sketch the stress-strain-curve of this steel i) immediately after quenching and ii) after 10 minutes aging. Explain the difference between these curves from a metallurgical point of view. (3 Points)



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Task 13 aging of steels II 3 Point(s)

a) Which alloying elements are mandatory for aging in steels? Where are these elements located in the lattice? (2 Point)

b) Which industrial process uses aging to achieve a higher yield strength? (1 Point)

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Task 14 CCT-diagrams 12 Point(s)

Heat treatments can be used to control the microstructure and the mechanical properties of steels. In Appendix 1 there is a TTT-diagram for the bearing steel 100Cr6. The following microstructures should be achieved:

- 100 % pearlite and carbides with maximum hardness
- 100 % bainite and carbides with lowest hardness.

a) Based on the TTT diagram given in Appendix 2, suggest heat treatment schedules of 100Cr6 for obtaining the two desired microstructures above by sketching the complete temperature – time diagrams starting and ending at room temperature in the given diagrams in Appendix 1. Assume a small sample size. Start from room temperature and show the temperature and time period for each step. (8 Points).

Appendix 1:
a) 100 % pearlite and carbides with maximum hardness

b) • 100 % pearlite and carbides with maximum hardness

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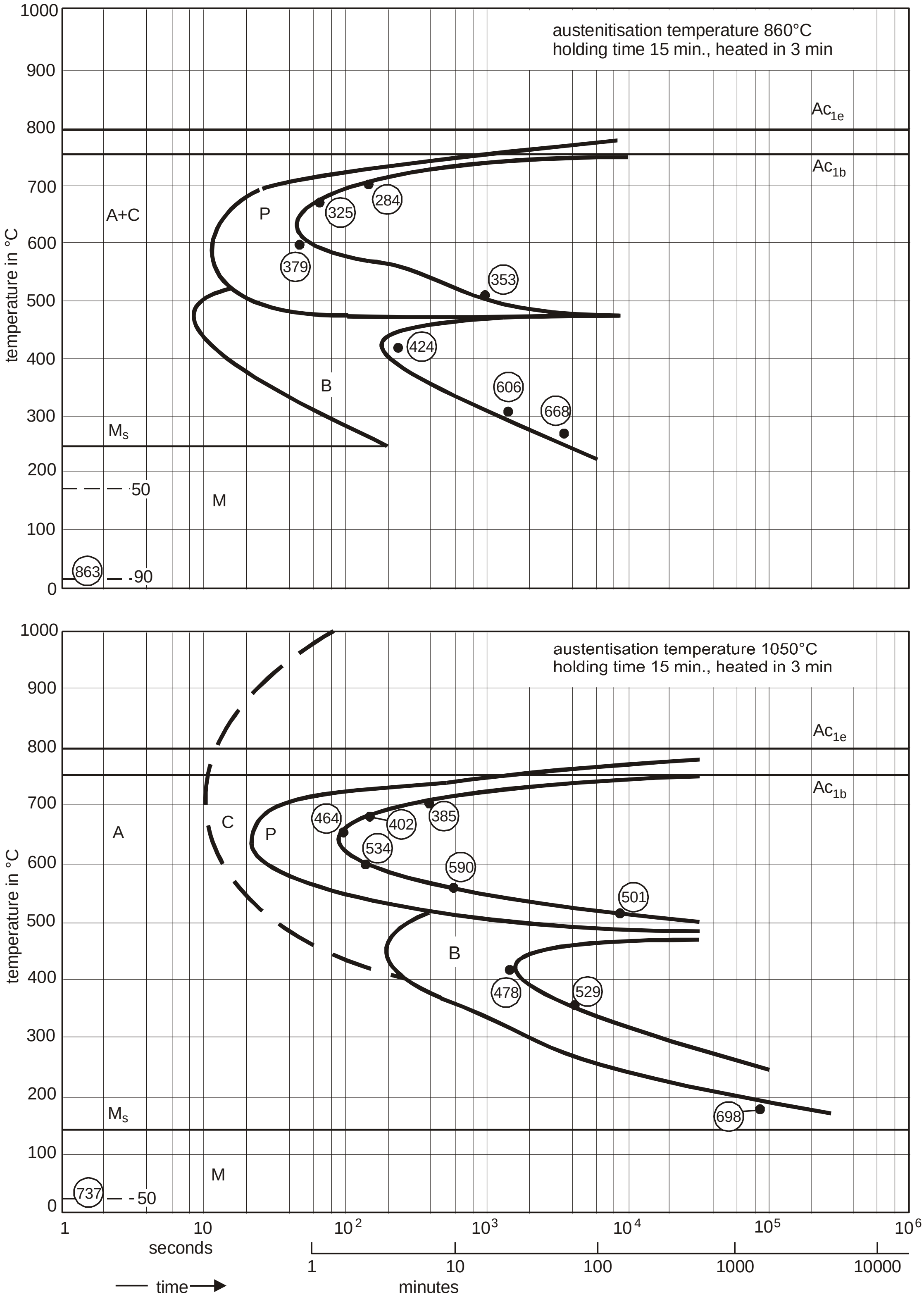
Appendix 2

Chemical composition, mass contents in %	C	Si	Mn	P	S	Cr	Cu	Mo	Ni	V
	1,04	0,26	0,33	0,023	0,006	1,53	0,20	<0,01	0,31	<0,01



A region of austenite

A+C region of austenite and carbide

C region of carbide transformation

◯ hardness in HV

P region of pearlite transformation

B region of bainite transformation

50,90... microstructure constituents in %

b) Give an explanation, why the region of metastable austenite is marked with “A+C”. Furthermore, explain the terms „inhomogeneous“ and „homogeneous“ austenite. (4 Points)

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Task 15 Heat treatment I 5 Point(s)

A normalizing heat treatment can be used to eliminate changes in the mechanical properties based on microstructural modifications.

a) What is the typical microstructure after a normalizing treatment? What is the temperature range for normalizing? List the temperature range depending on the C concentration; i) for hyper-eutectoid steels, and ii) for hypo-eutectoid steels? (3 Points)

b) Name two typical examples where a normalizing treatment is performed. (2 Point)

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Task 16 heat treatment II 5 Point(s)

Crystal segregations can occur during the solidification of steel.

a) Describe the term “segregation” briefly. (1 Point)

b) Which heat treatment is used to eliminate these segregations? Sketch the annealing cycle in Appendix 1 and add the temperature range and the annealing time. (3 Points)

c) Why is this annealing treatment only used for high quality components? (1 Point)

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Task 17 quenching and tempering 8.5 Point(s)

Quenching and tempering is a typical annealing treatment to produce components which require high strength.

a) What is the purpose of the quenching step? What is the purpose of the following tempering? (2 Point)

b) Define the „lower“ and “upper” critical cooling rate? What is the effect of a high critical cooling rate on the hardenability of large components? (3 Points)

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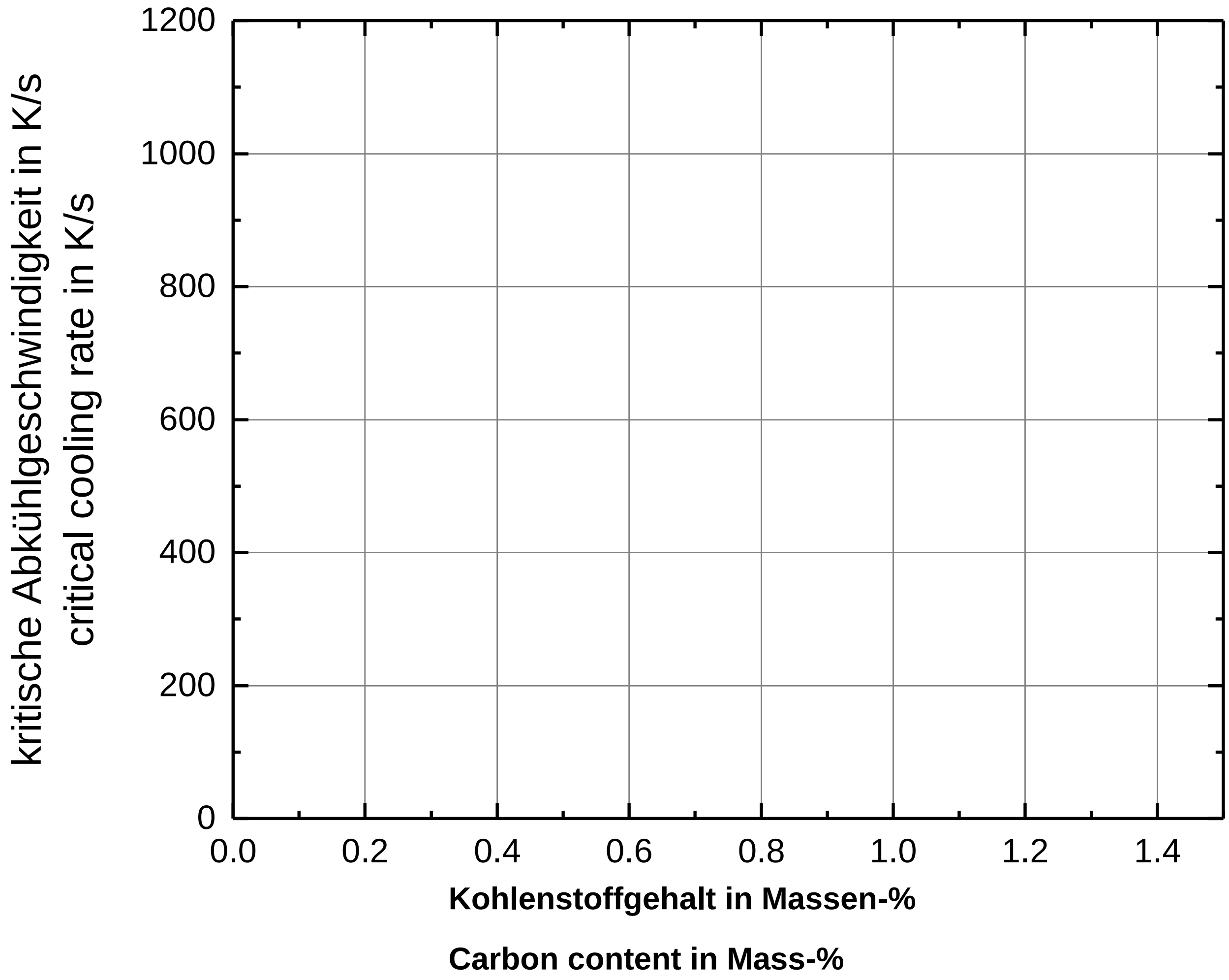
c) Sketch the influence of the carbon content on the critical cooling rate in the Diagram in Appendix 1. (1.5 Points)



d) Name two additional factors which influence the critical cooling rate. (1 Point)

e) Match the steel grades C45 and 51CrV4 with the CCT-diagrams in Appendix 2. Which Steel has the higher critical cooling rate? (1 Point)

CCT-Diagram 1:

CCT-Diagram 2:

Higher critical cooling rate: Material