# Entrance Examination

for the Master Course

Mechanical Engineering

Name: _____________________________________

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<table>
<thead>
<tr>
<th>Specialised Part:</th>
<th>Result</th>
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<td>(chosen subject)</td>
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Duration: 120 min

Allowed utility: A non-programmable calculator

Tips: The test has a General Part. Any applicant should deal with these questions about Mechanics, Thermodynamics, Design Engineering, and Materials Sciences.

In the Specialised Part you may choose one (or more) of the subjects Production Engineering, Energy Technology & Chemical Engineering, or Mechatronics.

20.09.2004
1. The homogeneous block with the weight $G$ is fixed as sketched in points A and B and additionally by the two bars 1 and 2.

The reactive forces in A and B as well as the forces in the two bars (tensile forces be denoted as positive) are to be determined.
2. For the sketched beam with a rectangular stiff corner loaded in one part by a constant line load \( q \), the tensile and the shear forces \( N \) and \( Q \) and the bending moment \( M_b \) are to be determined.

They be presented by sketches with characteristic values.
1. The thermal efficiency of the CARNOT-cycle shall be deduced from the first and second law of thermodynamics as function of the temperature.

2. The entropy can decrease in which way in which of the following systems,
   a) closed adiabatic one or
   b) only closed one?

3. Two different gases are mixed. Which of the following excess properties is equal zero, which of them will increase or decrease (>0, <0): entropy, enthalpy, volume, free Gibbs` enthalpy?

4. Sketch qualitatively an ideal CLAUSIUS-RANKINE-cycle in a $T,s$ - diagram (Temperature $T$ as function of entropy $s$).
1. The following configurations of tension and compression springs consist of several springs. Every single spring has the same stiffness $c$.
   Please determine for each combination the total stiffness $c_{ges}$.

\[ a) \ c_{ges} = \_ \cdot c \quad b) \ c_{ges} = \_ \cdot c \quad c) \ c_{ges} = \_ \cdot c \quad d) \ c_{ges} = \_ \cdot c \quad e) \ c_{ges} = \_ \cdot c \]

\[ f) \ c_{ges} = \_ \cdot c \quad g) \ c_{ges} = \_ \cdot c \quad h) \ c_{ges} = \_ \cdot c \quad i) \ c_{ges} = \_ \cdot c \quad j) \ c_{ges} = \_ \cdot c \]
Materials Science

1) Name the main chemicals bonds. Which bonds are found in polymers? Subdivide the polymers into three groups depending on their structural constitution.

2) Which group of polymers is weldable? Explain its behavior shortly in comparison to the two other groups of polymers!

3) Describe the main deformation mechanism for metals in note form.

4) Explain briefly the metallurgical process of „work hardening“ and name three other mechanism to increase the mechanical strength.
5) Fill in the names and units of the axis and the two specific values marked in the given stress-strain diagram.

Assign the materials:
- constructional steel,
- stainless steel,
- ceramic and
- aluminium

to the four schematically drawn curves.
Specialisation

Production Engineering
1) As an engineer you are responsible for cutting a pump-case made of aluminium. Which cutting materials are favourable for this task? Please name them in order of their wear resistance.

2) In sandcasting processes models are needed. Please state the six features which need to be taken into account when creating a model.

3) The following figure shows the profile of a measured surface. Please sketch the parameters needed to evaluate the medium surface roughness \( R_z \) into the drawing, label them correctly and give the corresponding formula.

\[
R_z = \frac{1}{l} \int_{0}^{l} y(x) \, dx
\]

4) One of the general criteria applicable to every manufacturing process is the characterisation of errors. Please name the two general groups of defects which can be detected in the workpiece and give at least three examples for each of both failure categories.
5) Name the different parts (blankholder, drawing tie, punch, sheet) and the forces ($F_B$ - blankholder force, $F_P$ - punch force) of a deep drawing system in the figure below!

Explain the two steps of the deep drawing process!
6) Before starting drawing operations the size and form of the blank must be determined for the desired final part geometry and die layout. The formulas to calculate the circular blank diameter D for different types of cups are given in the figure on the right.

Question:

A cup with a conical outline is to be produced. The base diameter is 60 mm, the upper diameter is 100 mm and the can body measurement 75 mm.

Calculate the required diameter D of the blank piece!
7) The uniaxial tension is the simplest sheet-metal-forming operation, particularly in the form of the tensile test. The flow curve derived from the tensile test is the most important input data for the FE-Simulation of deep drawing processes.

a) Draw an *engineering stress - strain curve* as well as the *true stress - strain curve*.

b) Explain the difference between these two curves.

c) Please give the formulas for the *engineering stress* $\sigma_E$ and the *engineering strain* $\varepsilon_E$ as well as the *true stress* $\sigma$ and *true strain* $\varepsilon$.

d) Please give the relation between the *true strain* and the *engineering strain*.
Specialisation

Energy Technology
&
Chemical Engineering
1) Why are fluidized bed processes often better than fixed bed processes?

2) How is the void fraction defined in a fluidized bed?

3) Draw for a fluidized bed the void fraction as a function of the superficial velocity. Mark the superficial velocity at the fluidisation point.

4) Call in each case 3 flow regimes (2-phase-flow, water and air) in horizontal and vertical pipes.

5) A single oil droplet rises up in tap water. The motion is stationary. Give a picture which contains the forces action on the droplet.

6) Describe the term batch process!

7) Call 5 physical parameters, which have an influence on the reaction during the fermentation.
8) To which concentration ranges does the HENRY-law apply?

9) The HENRY coefficient \( H = \frac{P}{x} \) of chlorine (\( \text{Cl}_2 \)) is smaller around the factor 100 than from methane (\( \text{CH}_4 \)) for small concentrated solutions in water. What means this for the solubility of both gases?

10) A close vessel contains water and gas. The gaseous phase consists of Ammonia. Ammonia diffuses so long from the gaseous phase into the water, until an equilibrium is reached. Outline the process of the local density of diffusing Ammonia at the times \( t_0 \) (beginning), \( t_1 \) and \( t_\infty \) for the instationary density equilibrium!

11) Powdered milk is manufactured by spray drying. Therefore milk is sprayed through nozzles and generates fine droplets in a column. In addition dry air flows cocurrent to the droplets. Water migrates from the milk droplets into air.

   a) Mark in the figure in and outgoing massflows.
b) Air is blown with a velocity of the $w_{\text{air}}=30.0 \, \text{m/s}$ through a tube with the diameter of $d_{\text{tube}}=25 \, \text{cm}$ into a column. The sink rate of the milk droplets has to be calculated. The Reynolds number of the milk droplets is $\text{Re}=1275$. Moreover the following data are given:

- Column diameters: $d_{\text{column}}=1.0 \, \text{m}$
- Diameter of the milk droplets: $d_{\text{drop}}=1.0 \, \text{mm}$
- Density of the air: $\rho_{\text{air}} = 1.1 \, \text{kg/m}^3$
- Viscosity of air: $\mu_{\text{air}} = 18.0 \times 10^{-6} \, \text{Pas}$

For the calculation all mentioned physical properties can be assumed as constant. Remember that the droplets diameter is much smaller than the column diameter.

c) The droplet diameter decreases linearly from the entrance to the outlet of the column. Describe the influence on the gravity force? Give a chart of the dependence of the gravity force of the droplets as function of the distance from the inlet to the outlet of the column. All other attitudes can be assumed as constant.
12) In a pumped-storage power station, water is pumped from a reservoir UW up to a reservoir OW during the night. In times of high power demand during the day, it can then be let off and be used in a turbine to produce electricity.

Determine the power demand of the water pump during the night.

The water flow may be assumed incompressible and frictionless. Due to the large extension of both the upper and the lower reservoir, the variation of the water levels may be neglected.

Given:
- Difference between the water levels of the two reservoirs: \( H = 500 \) m
- Water level in the upper reservoir OW: \( t = 25 \) m
- Cross section of the pipe at the upper reservoir: \( A_1 = 0.4 \, \text{m}^2 \)
- Volume flow through the pipe: \( V = 2 \, \text{m}^3/\text{s} \)
- Ambient pressure at the lower reservoir UW: \( p_0 = 1.013*10^5 \, \text{Pa} \)
- Ambient pressure at the upper reservoir OW: \( p_{OW} = 9.56*10^4 \, \text{Pa} \)
- Density of water: \( \rho = 1000 \, \text{kg/m}^3 \)
Specialisation

Mechatronics

Name: _____________________________  20.09.2004
1) The system above can oscillate around the sketched equilibrium position. The mass \( m \) moves without friction. The mass of the bars is zero.

Given: \( \ell, m, c_\phi \)

Evaluate the equation of motion for small oscillations around the sketched equilibrium position!
2) For the two single-degree-of-freedom systems below sketch the magnification function $V$ versus the frequency rate $\eta \left( \eta = \frac{\Omega}{\omega}, \omega_0^2 = \frac{c}{m} \right)$ for $0 < D \ll 1 \left( D = \frac{d}{2\sqrt{m \cdot c}} \right)$. 

\[20.09.2004\]
3) Given is the transfer element \( G(s) = \frac{K}{(T_1 s + 1)(T_2 s + 1)} \).

Calculate the phase angle as a function of the parameters \( K, T_1, T_2 \). 

4) A closed loop system containing a controller \( G_R(s) \) and a plant \( G_S(s) \) is given

\[
G_S(s) = \frac{K}{(s^2 + s + 1)}, \quad G_R(s) = K_R(T_D s + 1).
\]

Determine the final value of a step response on the closed loop transfer function

\[
G_w(s) = \frac{X(s)}{W(s)} \text{ with parameters } K = 3, K_R = 7, T_D = 0.5.
\]
5) A Bode-diagram of an open loop system is given in the figure below. What is the maximally allowable dead time if the closed loop system must not become unstable?
6) Sketch the functional principal of an inductive LVDT (Linear Variable Differential Transformer) sensor and describe shortly the measuring principal.

What kind of equipment in addition to the LVDT-sensor is necessary to measure a dynamic displacement in a frequency range between 10 Hz and 200 Hz under industrial conditions.

7) Describe shortly the differences in amplitude and phase characteristics for the following filter types: BESSEL, BUTTERWORTH, CHEBYSHEV