List of subjects for the State (Leaving) Exam

Study Programmes:

- **AN406 Chemical Engineering and Bioengineering**
- **AND406 Chemical Engineering and Bioengineering – DD**

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The state final examination consists of i) a thesis defense and ii) an oral part. During the oral part, the student answers the questions of the members of the examination committee from four (out of the six) thematic areas in accordance with the approved accreditation of the Master's degree programme.

List of thematic areas

I. Compulsory

1. Chemical and Process Engineering (contains topics covered in courses *Process and System Engineering, Process Engineering and Design, Unit Operations of Chemical Engineering III, Safety Engineering, Mathematical modeling of processes in chemical engineering*)

II. Selectable (student selects 3 of 5)

2. Mass Transfer (contains topics covered in courses *Mass transfer, Mass-transfer Process Design*)

3. Fluid Mechanics (contains topics covered in course *Fluid Mechanics*)

4. Reactor Engineering (contains topics covered in courses *Chemical Reactor Engineering, Industrial Reactors*)

5. Bioengineering (contains topics covered in courses *Trends in Biotechnologies, Separation Methods in Biotechnologies*)

6. Heat transfer (contains topics covered in course *Heat transfer*)

Contents of thematic areas

1. Chemical and Process Engineering

(Guarantees: Šoóš, Štěpánek, Jahoda, Kosek)

1. Crystallisation: principle, equilibria, supersaturation, nucleation and growth kinetics, mass balance, population balance.
2. Adsorption: principle, equilibria, breakthrough curve, means of periodic operation, mass and enthalpy balance.
3. Agglomeration: mechanisms, equipment, wet granulation, population balance.
4. Milling: mechanisms, equipment, selection and breakage functions, population balance.
5. Choice of physical properties in process simulation programs, parameters of physical properties equations, data regression.
6. Material and enthalpy balance of basic unit operations (mixer, splitter, pipe, pump, heat exchanger), degrees of freedom – definition and application, separation unit operations (rectification, absorption, extraction) and methods of their solution (short-cut and rigorous methods).
7. Separation of multicomponent mixtures, identification of recycle streams and minimization of their amount (algorithm M a L).
8. Design of reactor for *n*-th order kinetics with consequent separation of reactants from products and their recycling, multiple steady states.
9. Pinch-point analysis for network of heat exchangers.
10. Safety risks in chemical industry – heating, absorption, adsorption and chemical reactors.
11. PID control of the liquid level in the tank with feed and outlet streams. PID control of temperature in mixed reactor.
12. Semi-batch reactor with non-constant density of liquid phase. Definition of the problem as a set of differential-algebraic equations.
13. Finite volume method employed on the reaction-diffusion problem in spherical particle.

2. Mass Transfer

(Guarantees: Rejl, Moucha)

1. Phase equilibria, distribution coefficients, description of vapour-liquid equilibria in ideal systems and in systems with non-ideal liquid phase. Relative volatility.
2. Bubble point and dew point. Calculation for multicomponent systems, including two liquid phases, non-condensing and non-volatile components.
3. Multicomponent flash distillation: scheme, mass and enthalpy balances, calculation of f_V (=V/F) or temperature.

4. Multicomponent single stage differential distillation: scheme, mass and enthalpy balances, calculation of the distillation curve.
5. Diffusivities in gases and liquids – comparison. Diffusion in porous media, Knudsen diffusion
6. Steady state diffusion, 1-st Fick's law, convective flow, diffusion across a thin film, film theory.
7. Steady state diffusion in 3D space with point and axial symmetry.
8. Non-stationary diffusion, 2nd Fick's law, diffusion in a semi-infinite slab, absorption into a falling film, penetration theory.
9. Chemisorption with instantaneous chemical reaction in the film and at the interface.
10. Diffusion with homogenous chemical reaction, application in the process of chemisorption.

3. Fluid Mechanics

(Guarantees: Slouka, Jahoda)

1. Hydrostatics – hydrostatic pressure, hydrostatic forces acting on solid walls.
2. Continuity equation – integral and differential form.
3. Equation of motion for ideal fluid – derivation of Euler equation.
4. Bernoulli equation, Free jet – flow through a small hole, time of tank discharge.
5. Navier-Stokes equation for incompressible Newtonian fluid, viscosity, analytical solutions of NS equation for laminar flow in simple geometries (Couette flow, flow on an inclined plane).
6. Laminar flow in a circular pipe – velocity profile, mean velocity, maximum velocity, volumetric flow rate, Hagen-Poiseuille Equation.
7. External flow around solid bodies (thin plate, sphere) – drag, lift, laminar, and turbulent boundary layers.
8. Reynolds transport theorem – application to linear momentum, forces between fluid jets and solid surfaces
9. Pumps – connection in pipelines, head developed by a pump (characteristics of a pump), total head of a pipeline (characteristics of a pipeline), the working point of a pump.

4. Reactor engineering

(Guarantees: Kočí)

1. Reaction rate, kinetics, types of rate laws, stoichiometry, extent of reaction, conversion, reaction enthalpy. Evaluation of kinetic parameters from experimental data.
2. Reaction equilibrium, equilibrium constant, equilibrium conversion, dependence on temperature and pressure. Optimization of product yield.

3. Mechanisms of heterogeneous catalytic reactions. Adsorption isotherms. Pseudo steady state, rate-limiting step. Inhibition effects.
4. Mass transfer in heterogeneous reactors. External mass transfer, Thiele number, effectiveness factor.
5. Material and enthalpy balances of continuous stirred tank reactor and batch reactor. Cascade of tank reactors.
6. Material and enthalpy balances of tubular reactor with plug flow, extension with axial dispersion. Boundary conditions.
7. Residence time distribution. Probability density function, cumulative distribution function. Impulse response method. Applications to reactor models.
8. Kinetics of enzymatic reactions: Michaelis-Menten, enzyme deactivation. Kinetics of microorganism growth: logistic function, Monod equation, yield of biomass and product.
9. Substrate and biomass balances in bioreactors: batch fermenter, chemostat (optimum productivity, washout).

5. Bioengineering

(Guarantees: Přibyl, Kubáč?)

1. Typical sequences of separation processes, overview of separation processes, biotechnology products.
2. Cell disintegration, chemical and mechanical techniques. Flocculation, flocculants, electrostatic interaction, electric double layer, Schulze-Hardy rule.
3. Centrifugation, force balance, sedimentation velocity and time, centrifuges – tubular, disk.
4. Microfiltration, ultrafiltration, reverse osmosis, membrane modules and their arrangements, kinetics, concentration polarization, mass transfer coefficient, determination of membrane area.
5. Supercritical extraction, physical and chemical properties of supercritical fluids, devices for supercritical extraction, fractionation, mathematical description of the free diffusion model of SC extraction.
6. Adsorption and chromatography, adsorption equilibrium, adsorption in ideally mixed tanks and packed-bed systems, adsorption model with axial dispersion, parameterization of the equilibrium model without dispersion, shock waves.
7. Protein precipitation, phases of precipitation, distribution of particles of a precipitate in CSTR, distribution function, particle growth rate, precipitation methods.
8. Crystallization, nucleation, crystal growth, mass transfer in crystallization. Crystallization kinetics in a batch crystallizer without volume change, moments of distribution functions, their evaluation and meaning, momentum equations.

9. Lyophilization (freeze drying), principle, devices, driving forces, shrinking-core model of lyophilization.

6. Heat Transfer

(Guarantee: Přibyl)

1. Heat conduction, Fourier law, Fourier equation, formulation for general control volume, boundary conditions.
2. Biot number. Steady heat conduction in a rod. Heat transport through surface with ribs, transformation to a spatially one-dimensional problem ("fin approximation").
3. Fourier-Kirchhoff equation, formulation for general control volume. Heat transport in plug flow.
4. Nusselt number, qualitative description of entrance and developed region in pipes with laminar flow. Expression of Nusselt number in entrance region, asymptotic solution.
5. Heat transport in creeping flow past spheres. Thermal and velocity sublayer, Prandtl number.
6. Free convection, volumetric thermal expansion, Boussinesq approximation. Grashof number. Free convection between vertical slabs.
7. Heat transport in boiling medium, phases of boiling, boiling in still fluid. Heat transport in condensing medium, film condensation on wall.
8. Heat transport in turbulent flow, thermal fluctuations, averaged Fourier-Kirchhoff equation, constitutive equation for turbulent heat flow.
9. Radiation, Stefan-Boltzmann law, black body, heat exchange by radiation between two black bodies, view factor.