



Faculty of
Environmental Sciences

Final State Examinations for Master Programmes – Thematic Areas

Environmental Modelling

2023

The final state exam consists 4 exams of different fields. There are three compulsory exams – **Hydraulic and Hydrological Modelling, Groundwater Modelling and Transport of Contaminants in Atmosphere**. The last one can be chosen from **Hydrodynamics of Porous Media or Modelling in Soil Science or Physical – Chemical Aspects of Processes in Environment**.

HYDRAULIC AND HYDROLOGICAL MODELLING

1. Hydrological models, their classification, basic principles of hydrological systems, uncertainty of hydrological modeling
2. Calibration and validation of hydrological models
3. Calibration and validation statistics, AME, ME, NS, RMSE, MSE, NS, persistency index etc.
4. Black models, linear model for runoff forecasting, AR model for runoff forecasting, parameter estimation
5. Neural network models for forecasting of hydrological time series, parameter estimation, ANN architecture
6. Grey box models, linear reservoir, nonlinear reservoir, Q-S relationship, finite difference method for description of mass balance of reservoir oriented models
7. Lumped grey box models for the description of water balance: PDM model, HBV model, Bilan model
8. White box models their principles, hillslope overland flow models, St equations for overland flow models, finite difference methods
9. Optimization algorithms for calibration of hydrological models
10. Event based rainfall runoff models, components, effective rainfall, baseflow separation methods
11. Unit hydrograph theory, basic principles of unit hydrograph theory, S curve, type of unit hydrographs
12. Nash model of unit hydrograph, Diskin cascade, Clark unit hydrograph model
13. Linear time invariant transfer function model, izochron model, ordinary least squares and the estimation of discrete form of unit hydrograph, TA curve histogram of isochrones

GROUNDWATER HYDRAULICS MODELLING

1. Properties of fluids
2. Hydrostatics. Pressure and hydrostatic forces.
3. Hydrodynamics. Flow regimes. Basic equations.
4. Fundamentals of aquifer hydraulics, effective stress, compressibility and elasticity.
5. Basic equations. Darcy's law.. Limitations of the Darcian approach.
6. Properties of aquifers,(porosity, storativity,.....etc). Dupuits assumptions.
7. Multi-layered aquifer system. Seepage. Flow nets.
8. Steady and unsteady flow to wells – confined and unconfined aquifers.
9. Pumping and recovery tests – evaluation.
10. Image well theory.
11. Well flow near aquifer boundaries, multiple well problems.
12. Real wells. Wellbore storage, skin effect. Evaluation of well cleaning.

TRANSPORT OF CONTAMINANTS IN ATMOSPHERE

1. Gaussian plume model and its principled limits
2. Justification of moment equations for flow field (compressibility and incompressibility versions), transport theorem
3. Reynolds averaging, derivation of Reynolds equations and Reynolds tensors of turbulent fluctuations
4. Turbulence closure problem, the structure of moment equations for time derivative of Reynolds tensors (Keller - Friedman equations)
5. Boussinesq hypothesis, approximate models for turbulence in the atmosphere and order of this models
6. Principle of control volumes numerical method
7. Local discretization of moment equations, coordinates transformation
8. Principle of pressure correction in numerical calculation of flow field

HYDRODYNAMICS OF POROUS MEDIA

1. Application of differential calculus in hydrology. Relationship between rainfall and rainfall intensity, thermal expansion of liquids including water anomaly in density x temperature relationship. Compressibility of liquids, including the importance of the modulus of elasticity. Determination of the volume of a retention basin from a time series of flow rates.
2. Heat conduction. Fourier's law, temperature gradient, heat. Dirichlet and Neumann boundary condition for heat conduction. Material parameters for the heat conduction equation.
3. Darcy's law, pressure head and hydraulic head. Hydraulic conductivity, units. Experimental determination of hydraulic conductivity by single cylinder test. Difference between hydraulic conductivity and permeability.
4. Unsaturated soil environment. Moisture content of porous media and its moisture limits. Soil moisture retention curve, its relationship with statistical pore size distribution. Capillary barrier.
5. Darcy-Buckingham law, Richards equation. Types of boundary conditions for the Richards equation, specific boundary conditions of the free drainage and ejection surface type.

MODELLING IN SOIL SCIENCE

1. Methods applicable for soil porous systems description, pore-system models, capillary models and their application.
2. Equation describing transient water flow in soils, soil hydraulic properties and their determination.
3. Pedotransfer functions for soil hydraulic properties estimation.
4. Equation describing gas transport in soils, basic properties describing gas behavior in soil and their determination.
5. Equation describing heat transport in soils, soil thermal properties and their determination.
6. Convective-dispersion equation for description of conservative solute transport in soils, hydrodynamic dispersion coefficient and its determination.
7. Methods applicable for description of non-conservative solute transport in soils.
8. Equilibrium solute adsorption onto soil particles, adsorption isotherms.

9. Equation describing reaction rate, reaction order, half-life.
10. Multiphase transport definition, methods for description of multiphase transport, basic characteristics.
11. Inverse modeling and its application for soil properties determination.

PHYSICAL – CHEMICAL ASPECTS OF PROCESSES IN ENVIRONMENT

1. The second theorem of thermodynamics, the concept of entropy and its derivation
2. The third theorem of thermodynamics, the principle of adiabatic demagnetization
3. Gibbs energy - definitions, relations Gibbs energy with equilibrium constant of chemical reactions
4. Kinetics processes of the first to n-th order, solutions of simple ODE by separation of variables
5. Kinetics of simultaneous processes, solutions of ODE for the subsequential processes and similar type of equations.
6. Formulation of systems of ODE (dynamical systems) for more complex kinetic schemes
7. Euler methods for numerical solution of ODE and systems of ODE
8. Runge-Kutta numerical methods for ODE solution – only basic principle, an indication of the deriving of second order scheme.
9. Definition of PDR, Galerkin approximation method
10. Principle of finite elements method