Faculty of
Environmental Sciences

Final State Examinations for Master Programmes – Thematic Areas

2022

Environmental Modelling - field

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 **Applied Hydropedology, 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 descrition 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 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 cleanning.

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

APPLIED HYDROPEDOLOGY

1. Main properties of water (density, viscosity) and soils (porosity, density, saturation)

2. Grain size distribution of soil particles, categories of soil texture, classification

3. Soil moisture and its measurement

4. Adsorption, desorption, basic hydrolimits connected to adsorption

5. Capillarity, contact angle, capillary rise, funicular and pendular water

6. Swelling of soil, dependence of swelling on soil moisture

7. Soil-water potential, components of soil-water potential, measurement of soil water potential

8. Retention curve, pF curve, hydrolimits (soil water constants)

9. Darcy law, validity of Darcy equation

10. Saturated hydraulic conductivity and its estimation

11. Continuity equation in saturated zone and its application

12. Infiltration, cumulative infiltration, infiltration rate, basic equations

MODELLING IN SOIL SCINECE

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