EXEMPLARY QUESTIONS – Environmental Transport Phenomena

LECTURE 1 (BC):

- Dimensional analysis: use the pi-theorem to reduce the number of variables involved in the modeling of a problem.
- Aerosol settling velocity: example of pollen grains, simplifying assumptions, derivation and interpretation.
- Definition of the concept of (self-) similarity.
- Examples of dimensionless variables relevant for fluid dynamics.

LECTURE 2 (BC):

- Derivation of the advection equation from the continuity equation.
- Microscopic origin of molecular diffusion.
- Discrete Random Walk: derivation of the mean squared displacement as function of number of time steps.
- Diffusion coefficient and Discrete Random Walk: definition of the diffusion coefficient, link with physical parameters, units and orders of magnitude. Estimation of the characteristic length associated with diffusion in dependence of time.
- Derivation of the one-dimensional Fick's law using the macroscopic stochastic approach
- Derivation of the one-dimensional Diffusion Equation (DE) from the continuity equation and the one-dimensional Fick's law.

LECTURE 3 (BC):

- Solution of the one-dimensional DE with one point source in an infinite domain: no derivation will be asked, but only questions related to the interpretation (e.g. link with the normal distribution) or related to its use to model applied problems.
- Formulation of appropriate initial (point sources, continuous initial conditions) and boundary conditions (fixed concentration/fixed flux) in bounded (finite) and unbounded (infinite) domains to model applied problems.

LECTURE 4 (BC):

- Solution of the one-dimensional DE for an arbitrary continuous initial condition within an infinite domain: general solution, application to specific cases.
- Solution of the one-dimensional DE: semi-infinite domain, fixed boundary concentration (e.g. oxygen diffusion in a water body)
- Application of the method of images to solve the DE in the presence of reflecting boundaries
- Derivation of the solution of the ADE from the solution of the DE without advection (point source within an infinite domain)
- Peclet number (definition and interpretation)

LECTURE 5 (BC):

- 2D and 3D ADE: formulation and point-source solution
- Steady-state solution of the 2D ADE: example of joining rivers
- First order reactions, definition, timescales and solution
- Derivation of the Advection-Reaction-Diffusion Equation (ARDE)
- Solution of the ARDE: first order reaction, point source and infinite domain

LECTURE 6 (FT):

Qualitative description of numerical weather models (basic concepts):

- Processes, scales and resolution
- Assimilation and simulation
- Error propagation, uncertainty and ensemble forecasts
- Post-processing