ENE 630

Physical Processes in Environmental Systems (ENE 630)
Spring 2024

Description:
A graduate course dealing with physical processes in various media (open water, porous media) under various hydraulic regimes (laminar and turbulent). Transport by diffusion, convection, and dispersion is considered along with sorption. Design of systems is addressed with a particular attention to key processes. Each lecture will have a fundaments part covering basic concepts followed by an application part. Class notes will be handed out to students prior to lectures. Students would be able to annotate on the hardcopy during the lecture.

Prerequisites: Calculus II, Fluid Mechanics, or permission of instructor.

Classes
When: Monday 6-8:50 pm
Where: CKB 310
Attendance in person is expected.

Instructor
Michel C. Boufadel, PhD, PE
Distinguished Professor, Civil and Environmental Engineering
boufadel@njit.edu; Ph:(973) 596-5657
Room 435 Colton Hall; Office hours: Monday 2-5 pm or by appointment.

Textbook:
Transport modeling for environmental engineers and scientists, Second Edition, by Mark M. Clark, Wiley Intersciences, 664 pp., 2009. ISBN-10 0470260726.

Additional reading books:
Walter J. Weber, Jr., and Francis A. DiGiano, Process dynamics in environmental systems John Wiley and Sons, inc.
Fischer, H.B, E. J. List, R. Koh, J. Imberger, and N. H. Brooks, Mixing in inland and coastal waters, by, Academic Press, 1979.
Levenspiel, O.,,Chemical Reaction Engineering, John Wiley, Third Edition, 1999.
Cussler, E. L.,Diffusion, Mass Transfer in Fluid Systems, John Wiley, paperback edition.
Reid, R. C., J. M. Prausnitz, B. E. Poling, The Properties of Gases and Liquids, Fourth Edition, Mc.Graw Hill, 1987.
Hughes, S. A., Physical models and laboratory techniques in coastal engineering, Advanced series on ocean engineering, World Scientific, 2005.

Schedule/Topics:

Fluid Mechanics of Chemical Transport (Chapter 5)
Simplification of the governing equations for transport (the Navier-Stokes equations).
Boundary Layer: Laminar range and universal velocity laws. Flow between flat plates.
Application: This lecture forms the basis for numerous applications in water treatment and movement of chemicals in streams.

Properties of Suspensions. (Chapter 2).
Motion of discrete particles in fluids (water, air, etc.). Correction for Slippage.
Type II settling.
Application: Design of settling tanks. Movement of aerosols in the atmosphere.

Turbulent flows.

Turbulent scales. Mixing energy in vessels. Kolmogorov scale.
Application: Design of impellers. Coagulation and flocculation energy needs. How to scale up?

Flow through porous media (Chapter 5).

Laminar flow: Darcy's law. Relation between structure and specific permeability: Capillary-tube models, Permeability equations for laminar flow.
Turbulent flow: Ergun and Burke Plummer equations.
Applications: Design of granular (sand, carbon) filters in water treatment. Clogging of filters. Movement of water in aquifers.

Dimensional analysis (Class notes).

Non-dimensionalization through equations. The Pi-theorem.
Applications: Reynolds number.

Diffusion of solute (and temperature) in dilute solutions (Chapter 6)

Macroscopic approach. The diffusion/heat equation. Formulas for the diffusion coefficient.
Microscopic approach. Brownian motion. Einstein's law of diffusion.

Dispersion (Chapter 7)

Dispersion in laminar flow: Taylor's dispersion. (Fischer et al., p 82-91)
Hagen-Poiseuille flow. Turbulent flow. Turbulent diffusion. Eddy diffusivity model, Prandtl's mixing length. (Fischer et al., p 91-94) Turbulent dispersion. Reynolds Averaging. Eddy-Viscosity.
Application: Chlorine boosting in water distribution system. Transport of chemicals in streams and in aquifers.

Free convection.

Stability of layers in the atmosphere and in water. Rayleigh number

Interaction of Discrete Particles (Chapter 3).

Double layer. DLVO theory.
Application: Coagulation and flocculation in water treatment. Formation of river deltas.

Adsorption Partitioning and Interfaces (Chapter 4).

Surface tension. Isotherms. Dalton's law. Raoult's law. Henry's law. Partitioning coefficients.

Filtration (Chapter 8).

Mechanisms of filtration (interception, inertial, and diffusion). Straining.

Reaction kinetics(Chapter 9).

Empirical estimation of reaction kinetics. Mass transfer limitations (diffusion, reaction).

Reactor Design (Chapter 10)

Completely stirred tank reactor, plug flow.
Wastewater treatment. Chemostat.

Mass Transfer Processes (Chapter 7).

(If there is time). Mass transfer equation. The Graetz-Nusselt problem. Mass and heat transfer to a sphere. Forced convection.

Grading

Mid-term exam	30%
Final Exam	40%
Homeworks	20%
Class Participation, including quizzes	5%

Homework Instructions

- Homeworks should be turned in at the beginning of the class on the due date. Late homeworks will receive a zero grade.
- The questions sheets should be provided in the beginning of the homework solution.
- Only one side of a 8.5x11 sheet must be used.

- Include the information that is given and clearly state any assumption. To receive credit for a problem, you must show your work.
- No credit will be given if you only write the answer.
- If you think that your answer is not correct (i.e., it does not make sense to you) but you don't know what else to do, say so.
- Homeworks should be written as technical reports. The text should be reported first followed by tables and then figures. The text should present the question and the solution, and point to the figures and tables. All tables should be numbered, and all figures should be numbered. Tables should have titles but no captions. Figures should have captions but no titles.
- All axes in graphs should have titles displaying the name of the variable and the units that are being used in the graph.
- Straight lines should be used to connect between data points in graphs. Use of smooth lines from a spreadsheet software, such as Excell, will be penalized.
- Printout of columns of numbers from a spreadsheet will be penalized.
- Discussing the problems with your colleagues is permitted but copying is not.

Exams Instructions

- Quizzes might be given at the beginning of any lecture.
- Bring a **non-programmable calculator** with you to the class, you might need it for a pop quiz.
- Make-up examinations will only be offered with advance permission from the instructor and only under the most extreme circumstances. A typed request and explanation must be provided. But regardless, expect make-up exams to be more difficult.
- To receive credit for a problem, you must show your work. No credit will be given if you only write the answer. If you think that your answer is not correct (i.e., it does not make sense to you) but you don't know what else to do, say so.

Accessibility

Any student who has a need for accommodation based on the impact of a disability should contact the Instructor privately to discuss the specific situation as soon as possible. Contact Disability Resources and Services to coordinate reasonable accommodations for students with documented disabilities. The NJIT web site below provides additional information: http://www.njit.edu/counseling/services/disabilities.php

Academic Honesty

Student's expected to abide by the NJIT's Academic Honesty Policy. Any work submitted by a student for academic credit will be the student's own work. You are encouraged to study together and to discuss information and concepts covered in lecture and the sections with other students. You can give "consulting" help to or receive "consulting" help from such students. However, this permissible cooperation should never involve one student having possession of a copy of all or part of work done by someone else. During examinations, you must do your own work. Talking or discussion is not permitted during the examinations, nor may you compare papers, copy from others, or collaborate in any way. Any collaborative behavior during the examinations will result in failure of the exam, and may lead to failure of the course and University disciplinary action.