CHEE 611 Heat and Mass Transfer Fall 2021

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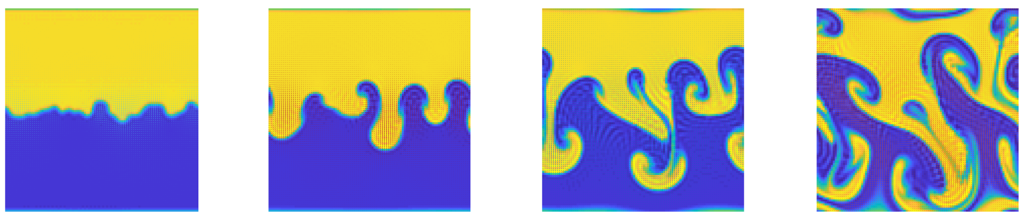

CHEE 611 course-evaluation metrics (2020):

- Q1. Overall, this is an excellent course. Hill 4.6 (DCM 3.6)
- Q2. Overall, I learned a great deal from this course. Hill 4.8 (DCM 4.0)
- Q3. Overall, this instructor is an excellent teacher. Hill 4.6 (DCM 4.2)
- Q4. Overall, I learned a great deal from this instructor. Hill 4.6 (DCM 4.3)

DCM = department course mean.

2021 offering will be an in-person offering of the 2020 online course (course-evaluation metrics above):

1. *Undergraduate transport review.* Basic fluxes, conservation equations, dimensional analysis, scaling/non-dimensionalization, heat- and mass-transfer-coefficient boundary conditions. Steady-state analysis of a hot-wire anemometer.

2. *Tensors.* Orthogonal basis, components, projection, Einstein notation, algebra, calculus (grad, div, curl, etc.), real and pseudo tensors, symmetry.

3. *Tensor analysis.* Dimensional analysis, evaluating multi-dimensional integrals, model formulation using symmetry and linearity. Analysis of conduction in a lamellar composite.

4. *Conservation relations.* Leibniz rule and divergence theorem, conservation of species and mass, total energy, momentum, mechanical energy, internal energy. Bernoulli equation. Analysis of the efficiency of uni-directional shear-flow pumps.

5. *Conduction and diffusion.* Fundamental, decaying and growing solutions of Laplace's equation. Unsteady Greens function and superposition for conduction and diffusion in unbounded domains. Analysis of the source and dipole disturbances of spherical inclusions in composites.

6. *Time-dependent diffusion.* Binary diffusion of a solute and solvent. Analysis of the mass-averaged velocity (similarity solutions) and interface displacement (integration of non-linear ordinary differential equation) at low Péclet number.

7. *One-dimensional time-dependent problems.* Separation of variables for self-adjoint operators, eigenfunction expansions and characteristic equation, weight functions, post-solution analysis. Analysis of a propagating bi-molecular reaction front for arbitrary Biot and Damkhöler number in a finite domain.

8. *Inhomogeneous and non-linear problems.* Homogenizing models for separation of variables. Finite-difference method for inhomogeneous and non-linear models. Analysis of a propagating reaction front (non-linear model) into an unbounded half-space.

9. *Interfacial balances.* Moving interfaces without surface fluxes or capacity, interfaces with surface fluxes and capacity, local equilibrium and isotherms.

10. *Marangoni effects for drops and bubbles.* Analysis of the dynamic exchange of surfactant between a solution and drop/bubble interface, and impact on the steady sedimentation/rise velocity. Transition to rigid-sphere behaviour by an adsorbing surfactant/contaminant.

11. *Time-dependent heat transfer with phase change.* Application of similarity solutions for freezing and melting problems in finite and unbounded domains at small Péclet (Stefan) number.

12. *Effective conductivity and diffusivity of composite materials.* Volume averaging. Maxwell model for dilute dispersions. Solubility and mobility contributions to membrane permeability, nanoparticle-doped hydrogels.

13. *Diffusion-limited reaction rate constant.* Distinctions between two- and three-dimensional conduction and diffusion. Concept of screening. Bessel functions. Self-consistent analysis of the diffusion-limited binding of ligands to immobile receptors in cell-membranes and nanoparticle-doped hydrogels.

14. *Perturbation methods.* Perturbation analysis of algebraic equations. Regular and singular perturbations. Perturbation of differential equations. Matched asymptotic expansions. Composite expansion. Analysis of advection-diffusion and reaction-advection-diffusion problems at large Péclet number. Linearizing reaction-diffusion problems.

15. *External flows.* Nusselt and Sherwood number for sphere. Singular nature of the low-Péclet number limit. Boundary-layer analysis of diffusion with laminar flow at high Reynolds/Péclet number.

16. *Unidirectional flow problems.* Boundary-layer and eigenfunction expansion analyses of the Graetz problem.

    Depending on the pace and participant demand, the following topics may not be covered:

17. *Kinetic theory.* Maxwell distribution. Analysis of collisions, collision rate, mean-free-path.

18. *Boltzmann equation.* Non-uniform gasses. Analysis of the binary gradient diffusivity, shear viscosity, and drag on nanoparticles in the Knudsen regime. Diffuse and specular emission.

19. *Lattice Boltzmann simulation.* Discrete Boltzmann distribution, moments, and relaxation. Writing a lattice-Boltzmann code in Matlab to simulate finite-Reynolds number hydrodynamics, tracer diffusion, and buoyancy-driven convection. Analysis to determine lattice transport coefficients.