NE 795-002, Problems of High-Energy-Density Physics

(Advanced Topics in Nuclear Engineering)

Spring 2025

- **Instructor**
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  - office hours: by appointment
- **Course Structure:**
  - on-campus lectures
  - 2 lectures per week
  - each lecture is 75 minutes long
- **Class Schedule**
  - Tuesdays and Thursdays, 4:30-5:45 pm
  - Classroom: 2111 Burlington Labs
- **Course website**: https://wolfware.ncsu.edu/
- **Text**: lecture notes
- **Prerequisites**
  - NE 401/501 or NE 520
  - knowledge of a computer language (e.g. Fortran, C++, MATLAB, Python) and basic programming skills
- **Major Topics**

1. The Boltzmann transport equation (BTE) and fundamental elements of kinetic theory
   (a) Derivation of the BTE
   (b) Properties of collision integral
   (c) H-theorem and equilibrium solutions
   (d) Maxwell-Boltzmann distribution
   (e) Linearized BTE for mixture of neutrons and moderator
   (f) Macroscopic equations
   (g) Chapman-Enskog method
   (h) Grad's method

2. Elements of theory of radiative transfer
   (a) Monochromatic specific intensity of radiation, distribution function, number density of photons, occupancy numbers
   (b) Thermodynamic equilibrium
   (c) Radiative transfer equation (RTE)
   (d) Moment equations
   (e) Radiation conduction approximation
   (f) Approximate models of radiative transfer
      i. P_1 and $P_{1/3}$ models
      ii. diffusion approximation
      iii. Flux-limited diffusion
      iv. Minerbo closure
   (g) The quasidiffusion (QD) / variable Eddington factor (VEF) method
   (h) Thermal radiative transfer (TRT) problems (super sonic model)
   (i) Asymptotic equilibrium diffusion limit of TRT
   (j) Radiative hydrodynamics
3. Computational methods for TRT in high-energy-density physics
   (a) Semi-implicit method for TRT
   (b) Grey transport acceleration method for TRT
   (c) Multilevel QD/VEF method for TRT
   (d) Iterative stability analysis of multilevel QD method for TRT problems
   (e) Multilevel methods with multigrid in frequency for TRT problems
   (f) A multilevel QD method with mixed-order temporal discretization
   (g) The RTE in the α-approximation
   (h) Reduced order models for TRT problems based on moment equations and data compression techniques
   (i) TRT problems in curvilinear geometries
   (j) Problems on arbitrary and unstructured spatial grids
4. On numerical methods for solving time-dependent transport (advection) equation
   (a) Initial-value problem for advection equation
   (b) Traveling-wave solution of the advection equation
   (c) Discretization schemes for advection equation
   (d) Stability of discretization schemes for the advection equation
   (e) Monotonicity of schemes for the advection equation
   (f) Modified equation of discretization schemes
   (g) Conservative discretization schemes
5. Current topical problems in mathematical modeling of high-energy-density physics, particle transport and computational transport methods

- **List of Recommended Books**
  - J.J. Duderstadt & W. R. Martin, Transport Theory.
  - M. M. R. Williams, Mathematical Methods in Particle Transport Theory.
  - R. Liboff, Kinetic Theory.
  - D. Mihalas, Radiation Hydrodynamics, Chapter in Computational Methods for Astrophysical Fluid Flow (ed. R. Leveque, D. Mihalas, E. Dorfi, & E. Muller).
  - F. Shu, The Physics of Astrophysics, v. 1 & 2.
  - D. Mihalas & B. Mihalas, Foundations of Radiation Hydrodynamics
  - Ya. B. Zel'dovich & Yu. P. Raizer, Physics of Shock Waves and High-Temperature Hydrodynamic Phenomena.
  - G. C Pomraning, The equations of radiation hydrodynamics.
  - R.P. Drake, High-Energy-Density-Physics: Foundation of Inertial Fusion and Experimental Astrophysics
  - E.E. Lewis & W.F. Miller, Jr., Computational Methods of Neutron Transport.
  - G.I. Marchuk & V.I. Lebedev, Numerical Methods in Theory of Neutron Transport.
  - F. Graziani (editor), Computational Methods in Transport.
  - R. LeVeque, Numerical Methods for Conservation Laws.

- **Grading**: Grading will be based on the following:

Homeworks:	50%
Computational project(s):	30%
Paper review and presentation:	20%

  I reserve an option to give class and final examinations.

- **Final Presentation**: December 4 (Thursday)

- **Assignments**
  - Completed assignments must be turned in at the beginning of the class on the due date.
  - The grade for an assignment submitted with a delay will change in the following way:
    - After the class: -11%
    - Next day : -21%
    - Two days or later : -41%
  - It is planned to give assignments that will be due during the last week of the semester.

- **Missed Examinations and Quizzes**: If you miss an examination or quiz without either a certified medical excuse or prior instructor approval, it will result in zero points for this exam or quiz.

- **Students with disabilities** are invited to schedule an appointment with the instructor to discuss academic accommodations.

- **Online class evaluations**: Online class evaluations will be available for students to complete during the last two weeks of class. You will receive an email message directing you to a website where you can login using your Unity ID and complete evaluations. All evaluations are confidential; instructors will never know how any one student responded to any question, and students will never know the ratings for any particular instructors.

  Evaluation website: https://go.ncsu.edu/cesurvey
  Student help desk: classeval@ncsu.edu
  More information about ClassEval: https://uda.ncsu.edu/for-the-pack/classeval/