ME 5120 Advanced Thermo-Fluids I  
(Spring 2015)

Class Meeting: Thursday 5 – 7:30 pm  UTEB 476 / Distance Learning
Instructor: Tai-Hsi Fan
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Prerequisites: Undergraduate Fluid Mechanics (ME3250 or equivalent), Engineering Analysis I (ME5507 or equivalent)
Other References: Incompressible Flow, Ronald L. Panton, Wiley.
Boundary Layer Theory, H. Schlichting, McGraw-Hill.

Course Description and Policy
This course is designed for the first-year ME graduate students majored in Thermal Fluid Sciences. Students are expected to have knowledge and skills on engineering mathematics and undergrad-level fluid mechanics. Starting from the tensor notation and analysis, we will go through the details of kinematics of fluid motion and derive the general and simplified conservation equations for fluid flow analysis. Analytical solutions for a variety of fluid flow problems in the laminar regime are included. Vortex dynamics and boundary layer theory will be introduced.

**Homework** There will be about 7 to 8 homework assignments. Missing half or more of the homework assignments will result in a failing grade. Students are encouraged to discuss homework problems with classmates, but the collected works must be individual effort. Homework must be clearly written on one side of the paper. No late homework will be accepted. A few selected homework problems will be practiced during the lectures. There will be minimum or no computer programming in this course, however, using symbolic mathematical software to validate the analytical results is encouraged. Online students should scan and email the completed assignments (each homework as a single file in pdf format) to the instructor.

**Midterm and Final Exams** Two midterm exams and a final exam will be hold in UTEB 476 in Storrs campus on Saturdays, exam time is usually about 2.5 hrs. All on-campus and online students are expected to participate the exams in Storrs.

**Grade Determination** Homework (20%), mid-term I (25%, closed book, closed note), mid-term II (25%, closed book, closed note), comprehensive final exam (30%, closed book, open note). No make-up exam will be given except as required per university policy.

Course Outlines and Reading
**Cartesian Tensors:** Scalar, vector, tensor and notation (Kundu 2.1, 2.4, handouts); Indicial notation (2.2, 2.4); Contraction and multiplication (2.5); Surface traction (2.6); Kronecker Delta function (2.7); Dot product, cross product, and derivative operators (2.8, 2.9, 2.10); Rotation of
axes (2.2, 2.4); Symmetric and antisymmetric tensors (2.11, 2.12); Integral theorems (2.13, 2.14).

**Kinematics:** Lagrangian and Eulerian descriptions, material derivative (3.1, 3.2, 3.3); Linear and shear strain rates (3.6, 3.7); Vorticity and circulation (3.8); Vortex flow (3.11); Stream function theory (3.13); Polar coordinates (3.14).

**Conservation Laws:** Reynolds transport theorem (4.1, 4.2); Conservation of mass and continuity equation (4.3); Force and stress in fluid (4.5, 4.6); Conservation of momentum and equation of motion (4.7); Control volume analysis (4.8); Constitutive equation for Newtonian fluid (4.10); Navier-Stokes equations (4.11); Mechanical energy equation (4.13); Thermal energy equation (4.14); Boundary conditions (4.19).

**Midterm I** 10 am to noon on Saturday, February 21, Location: UTEB 476

**Laminar Flow I:** Couette flow, Poiseuille flow, pipe flow, circular Couette flow, and the coupling with heat transfer (9.4, 9.5, 9.6).

**Vortex Dynamics:** Basic vortex flows (5.1, 5.3); Vortex lines and vortex tubes (5.2); Kelvin’s circulation theorem, Helmholtz' vortex theorem (5.4); Vorticity equation (5.5, 5.7); Biot-Savart law (5.6); Interaction of vortices (5.8); Introduction of irrotational flow (chapter 6); Vorticity-streamfunction method.

**Laminar Flow II:** Stokes’ first and second problems (9.7, 9.10); Diffusion of a vortex sheet (9.2, 9.7); Nondimensional parameters and order-of-magnitude analysis (8.7, 9.11); Unsteady flow (handouts); Low Reynolds number flow and Stokes-Einstein relation (9.12, 9.13).

**Midterm II** 10 am to noon on Saturday, April 4, Location: UTEB 476

**Boundary Layer Theory:** Boundary layer approximation and scaling (10.1, 10.2); Boundary layer thickness (10.3); Blasius similarity solution (10.5); Pressure gradient and flow separation (10.7, 10.8); Description of flow passing through a circular cylinder and a sphere (10.9, 10.10, 10.11).

**Selected topics to be covered if time permits:** Introduction of asymptotic method for solving boundary layer problems, characteristics of convective and diffusive boundary layers.

**Final Exam** 10 am to noon on Saturday, May 2, Location: UTEB 476