AEROSPACE 508
Fall 2015

FOUNDATIONS OF FLUID MECHANICS

CENGIZ CAMCI

PROFESSOR OF AEROSPACE ENGINEERING
TURBIMACHINERY AERO-HEAT TRANSFER LABORATORY
PLACE:
221 Hammond

TIME:
9:45 – 11:00 am   Tuesday & Thursday

Cengiz Camci

Dept. of Aerospace Engineering
223 Hammond Building

University Park, PA, 16802

cxc11@psu.edu
Office Hours:

11:00 - 12:00 pm

Tuesday & Thursday

and

by appointment
COURSE OUTLINE

BASIC CONSERVATION LAWS [9 LECTURES]
INVISCID FLOWS [6 LECTURES]
VISCOUS FLOWS [9 LECTURES]
COMPRESSIBLE FLOWS [7 LECTURES]
My own research interests
AEROTHERMODYNAMICS OF
TURBOMACHINERY AND HEAT TRANSFER

Cengiz Camci

Ph.D., Von Karman Institute for Fluid Dynamics, Brussels
Katholieke Universiteit, Leuven
Belgium

Research interests focus on studies in fluid mechanics and heat transfer in
Aerospace Engineering

Turbomachinery/UAV Systems/Rotorcraft
Air Breathing Propulsion
Most current research

• as of August 2010

• P&W HP turbine aerodynamics
• non axisymmetric endwall contouring  SIEMENS ENERGY
• Ducted Fan Tip and Casing Region Improvements (USARO/VLRCOE)

• Sand Erosion of Helicopter Balde Tip Region
  (SIKORSKY/USARO/VLRCOE)
• Axial Flow Turbine Experiments (GE CRD/ GE PS)

• Squealer Tip Aerodynamics in Turbines (GE PS)
• Turbine Tip Injection (DOE/SCIES)
• ASDE-X (FAA) Airport Antenna Fluid Dynamics
• Helicopter Rotor Test Facility (ARO/NASA)

• GE Power Systems (Outer casing treatment)
Established capabilities:

36 inch Axial Flow Turbine Research Facility
   Turbine aerodynamics/heat transfer/tip mitigation/secondary flow reduction/leakage flows

Axial Flow Fan Research Facility

Heat Transfer Wind Tunnel with heated air capability

Low Speed Turbine Cascade

High Speed Cascade Facility

Icing Test Facility (19 x 19 x 19 Cubic feet) -15 F capability
   Currently for helicopter blade testing/instrument icing

25 Processor Xeon Cluster for High Performance Computations

3D Viscous Flows/time dependent flows/rotational frame/heat transfer
Established capabilities:

- Sub-miniature aerodynamic probe making capability
- Surface heat Transfer and shear stress measurement capability
- Thermographic liquid crystals for surface Imaging
- Pressure sensitive paints
- Infrared Imaging
- Planar Particle Image Velocimetry
- Stereoscopic Particle Image Velocimetry
- Turbomachinery performance tests
New Areas

• Sand Erosion on helicopter rotor blade tips

• Ducted Fan performance improvements for UAV applications

• Mems based rocket and propulsion system development

• Small Engine research for UAV/MAV propulsion

• Aerodynamics of rotating radar antennas ASDE-X

• Viscous flow predictions in rotating machinery (absolute frame)
TEXT BOOK :

Course notes will be available

Recommended software :

Multimedia Fluid Mechanics
Cambridge University Press

ISBN 0-521-78748-3
OTHER USEFUL BOOKS:

1) Incompressible Flow, R.L. Panton, Wiley Interscience
2) Viscous Fluid Flow, F.M. White, McGraw Hill
4) Fundamental Mechanics of Fluids, I.G. Curie, McGraw Hill
5) Analytical Fluid Dynamics, G. Emanuel, CRC Press
Grading criteria:

HOMEWORK & PROJECTS: 30/100
MIDTERM EXAMS: (20+20)/100
FINAL EXAM: 30/100
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BASIC CONSERVATION LAWS [9 LECTURES]

INVISCID FLOWS [6 LECTURES]

VISCOUS FLOWS [9 LECTURES]

COMPRESSIBLE FLOWS [7 LECTURES]
BASIC CONSERVATION LAWS

1. INTRODUCTION, VECTORS, DEFINITION OF TENSORS
   SYMMETRIC ANTI-SYMMETRIC TENSORS, OPERATIONS
   WITH TENSORS

2. VECTOR CROSS PRODUCT, DERIVATIVES, GAUSS AND STOKES
   FORMULAS, LEIBNITZ THEOREM

3. LAGRANGIAN AND EULERIAN VIEWPOINTS, SUBSTANTIAL
   DERIVATIVE

4. DECOMPOSITION OF MOTION, ELEMENTARY MOTIONS IN A
   LINEAR SHEAR FLOW

5. RATE OF STRAIN, RATE OF EXPANSION, STREAMLINE
   COORDINATES

6. CONTINUITY & MOMENTUM EQUATIONS, SURFACE
   FORCES, STRESS TENSOR

7. PRESSURE AND VISCOUS STRESSES, DIFFERENTIAL
   MOMENTUM EQUATION

8. CONSERVATION OF ANGULAR MOMENTUM, ENERGY
   EQUATION

9. MECHANICAL AND THERMAL ENERGY EQUATIONS,
   SECOND LAW OF THERMODYNAMICS
INVISCID FLOWS

1. PLANE IDEAL FLOWS, LINE SOURCE AND LINE VORTEX
2. FLOW OVER A NOSE AND DOUBLETS
3. CYLINDER IN A STREAM, CYLINDER WITH CIRCULATION
4. CONCEPTS OF LIFT AND DRAG, MAGNUS EFFECT
5. CONFORMAL TRANSFORMATIONS
6. JOUKOWSKI TRANSFORMATION, KUTTA CONDITION
1. NEWTON'S VISCOSITY LAW, MOLECULAR MODEL OF VISCOUS EFFECTS

2. NON-NEWTONIAN LIQUIDS, NO-SLIP CONDITION
   FOURIER'S HEAT CONDUCTION LAW

3. PRESSURE DRIVEN FLOW IN A SLOT, PLANE COUETTE FLOW

4. PRESSURE DRIVEN FLOW IN A SLOT WITH MOVING WALLS,
   DOUBLE FALLING FILM ON A WALL

5. BOUNDARY LAYERS, BLASIUS SOLUTION FOR A FLAT PLATE,
   DISPLACEMENT THICKNESS, MOMENTUM THICKNESS

6. MOMENTUM-INTEGRAL TECHNIQUE, POHLHAUSEN METHOD

7. FALKNER-SKAN SOLUTIONS

8. TRANSITION AND TURBULENT FLOWS

9. SEPARATION, AXISYMMETRIC BOUNDARY LAYERS
COMPRESSIBLE FLOWS

1. SPEED OF SOUND, ISENTROPIC RELATIONS, MACH NUMBER
2. SHOCK WAVES, NORMAL SHOCK RELATIONS
3. HUGONIOT RELATION AND ONE DIMENSIONAL FLOW WITH HEAT ADDITION
4. OBLIQUE SHOCK RELATIONS
5. DIFFERENTIAL CONSERVATION EQUATIONS OF INVISCID COMPRESSIBLE FLOWS
6. DIFFERENTIAL EQUATIONS IN NON-CONSERVATION FORM, CROCCO’S THEOREM
7. THE VELOCITY POTENTIAL EQUATION, THE LINEARIZED VELOCITY POTENTIAL EQUATION