AE 2010–Thermodynamics and Fluids Fundamentals

HOURS: 4-0-4

CATALOG DESCRIPTION:

Thermodynamic and fluid properties. Conservation laws. Isentropic flow, shocks and expansions, introduction to flows with friction and heat transfer. Applications to aerospace devices.

PREREQUISITES:

Math 2551 Multivariable Calculus
Physics 2211 Physics I
Chem 1310 or Chem 1211K

COURSE OBJECTIVES:

1) Provide students a fundamental understanding of the conservation laws and properties used to analyze fluids, flows and energy conversion devices;
2) Enable students to analyze basic compressible flows, including applications to nozzles, diffusers and simple airfoils.

LEARNING OUTCOMES:

Students will gain a master level understanding of:

1. Properties of Fluids (Temperature, Density, Pressure, Viscosity, Speed of Sound)
2. Thermodynamic Properties and State Equations (Including gases, incompressible substances and two-phase mixtures)
3. Basic Concepts of Thermodynamics (systems, work, heat)
4. 1st and 2nd Laws
5. Application of Conservation Equations (Integral and Differential Forms) to Fluid Mechanical and Energy Conversion Devices
6. Static and Stagnation Properties
7. Propagation of and Property Variation Due to Disturbances (Mach, Shock, Compressions, and Expansions)
8. Quasi 1D analysis of compressible internal flows
9. Bernoulli equation, hydrostatics, streamlines
10. Physical characteristics and similarity parameters associated with continuum flow regimes (Subsonic, Transonic, Supersonic, Hypersonic, Steady, Unsteady, Viscous, Inviscid)

Students will gain a basic level understanding of:

11. Derivation of the Basic Conservation Equations for Thermodynamics and Fluid Mechanics

Students will gain an exposure level understanding of:

12. Relevant Applications to Aerospace Systems

TOPICAL OUTLINE:

Topic	Lecture Hours
I. Course Overview, Background and Review of Units	**1**
II. Basic Fluid and Thermodynamic Concepts	**4.5**
a. Continuum/macroscopic vs rarefied/microscopic viewpoints of fluids (and matter)	0.5
b. Properties of the velocity field: Eulerian/Lagrangian descriptions, streamlines, streaklines, pathlines	1
c. Systems (control mass vs. control volume), energy, work, heat transfer	1
d. Equilibrium, states, extensive/intensive thermodynamic properties (m, p, T, ρ, ν, U, …) and paths	1.5
e. Transport properties (e.g., fluid viscosity)	0.5
III. Thermodynamic Properties – State Equations	**5.5**
A. State postulate and p-*v*-T (EOS)	1
B. Ideal gases, generalized compressibility (and connection to microscopic motions)	2
C. Incompressible substances	0.5
D. Two-phase mixtures and real substances	2
IV. Conservation Equations	**25**
A. Derivation and application of mass conservation in integral and differential forms, and material derivatives	3
B. Reynolds Transport Theorem	1
C. Conservation of linear momentum	9
1. Derivation	
2. Hydrostatic examples: atmospheric pressure, manometers, buoyancy…	
3. Aerodynamic examples: lift and lift coefficient from flow redirection, and drag coefficient from wake profile	
4. Propulsion examples: thrust	
5. Bernoulli equation	
6. Reynolds number and Mach numbers as similarity parameters	
D. 1st Law - Conservation of Energy	6
1. Control mass form (integral and differential forms)	
2. Examples: constant volume and constant pressure heating, friction, latent heats	
3. Control volume analysis (integral and differential forms)	
4. Examples: energy conversion devices	
5. Stagnation and static temperature	
E. 2st Law - Conservation of Entropy	6
1. Characteristics of entropy and 2nd Law for isolated systems	
2. Reversible and irreversible processes: entropy production	
3. Development of 2nd Law for control mass and entropy transfer through	

Topic	Lecture Hours
heat transfer	
4. Entropy state relations: Gibbs equation	
5. Isentropic processes	
6. Stagnation and static pressure, relation to Bernoulli equation	
7. Control volume analysis - examples	
V. Compressible Flow	**20**
A. Wave propagation, speed of sound, Mach angle and Mach number, flow regimes	1.5
B. Isentropic compressible flows	4.5
1. Stagnation/static properties and Mach number	
2. Isentropic flow with area change	
3. Isentropic nozzle analysis and back pressure	
C. Shock waves	7
1. Formation	
2. Normal shocks and Mach number relations	
3. Examples (shocks in nozzles, moving shocks, starting problem, etc.)	
4. Oblique shocks and applications (e.g., supersonic engine inlets)	
D. Prandtl-Meyer expansions and compressions	2
1. Mach number relations and turn angles	
2. Examples	
E. Wave reflections (& connection to under- and over-expanded nozzles)	1
F. Application to lift and (wave) drag on simple airfoils	2
G. Introduction to flows with friction and heat transfer	2
Tests/Exams/Reviews	**4**
Total	**60**