

**UNIVERSITY OF NOTRE DAME
DEPARTMENT OF AEROSPACE AND MECHANICAL ENGINEERING**

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Unsteady Aerodynamics & Aeroacoustics

Topical Outline

Steady and Unsteady Flows

- Bluff and Streamlined Bodies
- Separated and Attached Flows
- Incompressible, Subsonic, Transonic and Supersonic Flows
- Characteristics of Unsteady Flows
- Relations to Aeroacoustics and Aeroelasticity

Equations of Motion of Unsteady Flows

- The Equation of Continuity
- Kinematics of the Flow Field
- The Momentum and Energy Equations
- Boundary Conditions on a Solid Surface in Motion
- Kinetic Energy
- Virtual Mass
- Pressure Equation in Moving Frame
- Forces on Moving Bodies
- 2D and 3D Bodies Moving in Unbounded Fluid
- Irrotational Motion
- Sources and Vortices - Vortex Sheet - Vortex Street
- Large Structure Rotational Motion

Linear Unsteady Aerodynamics

- Some Mathematical Tools
- The Splitting Theorem : Acoustic, Rotational and Entropic Modes
- The Wagner Problem
- The Theodorsen Problem
- The Sears Problem
- The Indicial Method
- Effect of Compressibility - The Possio Equation

The Linear Cascade: Solidity, Stagger, Interblade phase angle

Unsteady Aerodynamics Of Nonuniform Flows

Large Structure Nonuniform Flows
The Rapid Distortion Approximation
Mathematical and Numerical Methods
Oscillating Airfoils
Airfoil in a Gust
Effects of Loading
Effects of Compressibility

Unsteady Aerodynamics of Separated Flows

Topology of the Flow at Various Reynolds Numbers
Unsteady Separation
Aerodynamic Hysteresis
Mathematical and Numerical Methods
Receptivity

Acoustics in Moving Media

The Convective Wave Equation
Elementary Solutions: Sources, Dipoles, Quadrupoles
Acoustic Intensity and Energy
Sound from a Moving Source at Subsonic and Supersonic Speeds
Sound from a Fluctuating Force
Sound from Turbulence
Effect of Solid Boundaries

Aerodynamic Sound - Lighthill's Acoustic Analogy

Free-Space Solutions
Jet Noise
Effect of solid Boundaries
Ffowcs Williams- Hawkins Equation
Effects of Uniform Flows
Application to Fan and Compressor Noise

Aerodynamic Sound as the Far Field of Unsteady Flows

Sound from a Thin Airfoil in a Gust
Numerical Methods

Far Field Boundary Conditions – The Kirchhoff Method
Sound from a Thin Airfoil in a Gust
Effects of nonuniform Flows

Tonal and Broadband Interaction Noise

Turbulence Spectral Structure
Modal Decomposition
Lipmann and von Karman Models
Sound from an Airfoil in a Turbulent Flow

Turbomachinery Noise

The Linear Cascade Model
The Annular Cascade Model
Coupling with the Duct Acoustics
Tonal Noise
Broadband Noise
Isotropic and Anisotropic Turbulence
Rotor Noise

Aeroelasticity

Static and Dynamic Phenomena
Divergence
Bending and Torsional Modes of a Structure
Flutter
Forced Vibration
Buffeting
Cascade Effects
Application to Turbomachinery