ME 57200 Aerodynamic Design

Lecture #1: Syllabus, Basic Concepts in Aerodynamics

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About Me

General Information:

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- **B.S. in Aerospace Engineering**
  Beijing University of Aeronautics and Astronautics (BUAA)
- **M.S. in Aerospace Engineering**
  Beijing University of Aeronautics and Astronautics (BUAA)
- **Ph.D. in Aerospace Engineering**
  Iowa State University
- **Postdoc in Aerospace Engineering**
  Aircraft Icing Physics and Anti-/De-icing Technology Laboratory at ISU

About Me

General Information:

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Advanced Experimental Fluid Mechanics and Aerodynamics Laboratory:

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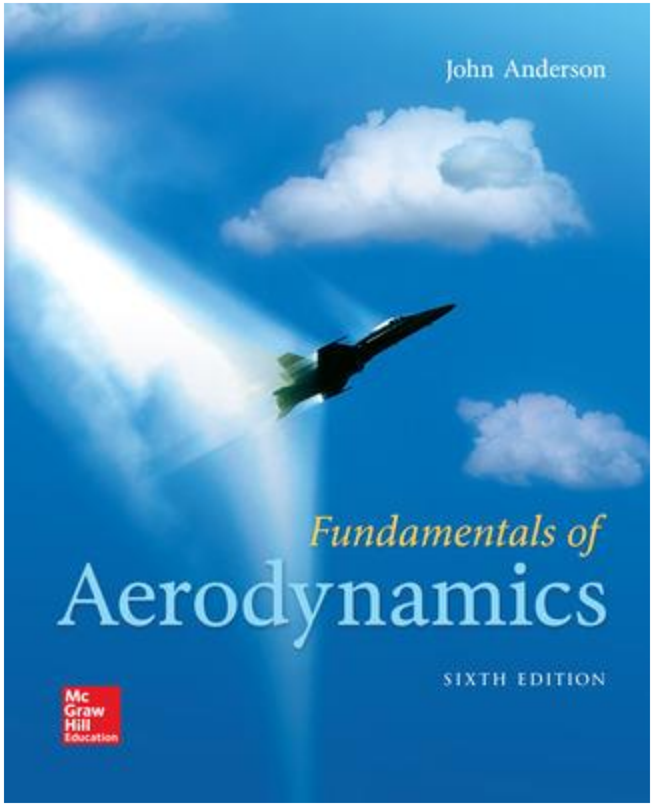
My research interests include bio-inspired aerodynamics, flow-structure interactions, supersonic/hypersonic aerodynamics, high-speed multiphase interactions driven by blast/shock, multiphase flow and heat transfer in additive manufacturing, aircraft icing physics and anti-/de-icing technologies, and unsteady multiphase flow in energy devices.

Syllabus

<u>Textbook:</u>

Title: Fundamentals of Aerodynamics
Author: John Anderson
Publisher: McGraw-Hill Education
Edition: 6
ISBN: 9781259129919



Syllabus

Grading Policy:

Grading Weighting	
In-class Quiz	10%
Homework	20%
Project	20%
Midterm Exam	20%
Final Exam	30%

Syllabus

<u>Academic Integrity:</u>

- Academic honesty is critical for success in this course. You are expected to understand what plagiarism is.
- Plagiarism is submitting the work of others as your own. Violations may include copying homework solutions from others with no evidence of independent thought and submitting the work of other students as your own. You must submit your own work.
- Penalties for repeated offenses may result in a failing grade for the course.

Syllabus

<u>Disabilities:</u>

- Students requesting accommodations based on a disability must be reported to The AccessAbility Center/Student Disability Services (AAC/SDS).
- Exam Accommodation Portal: https://central.ccny.cuny.edu/index.php

Aerodynamics

- What is Aerodynamics?
- Examples

- ➢ Aerodynamics is the way air moves around things.
- ➢ The rules of aerodynamics explain how an airplane is able to fly.
- ➢ Anything that moves through air reacts to aerodynamics.
  - A rocket blasting off the launch pad and a kite in the sky react to aerodynamics.
  - Aerodynamics even acts on cars, since air flows around cars.
  - ……

Aerodynamics

- Aerodynamics vs. Fluid Dynamics

Fluid dynamics is subdivided into three areas:

- Hydrodynamics – flow of liquids
- Gas dynamics – flow of gases
- <u>Aerodynamics – flow of air</u>

Aerodynamics

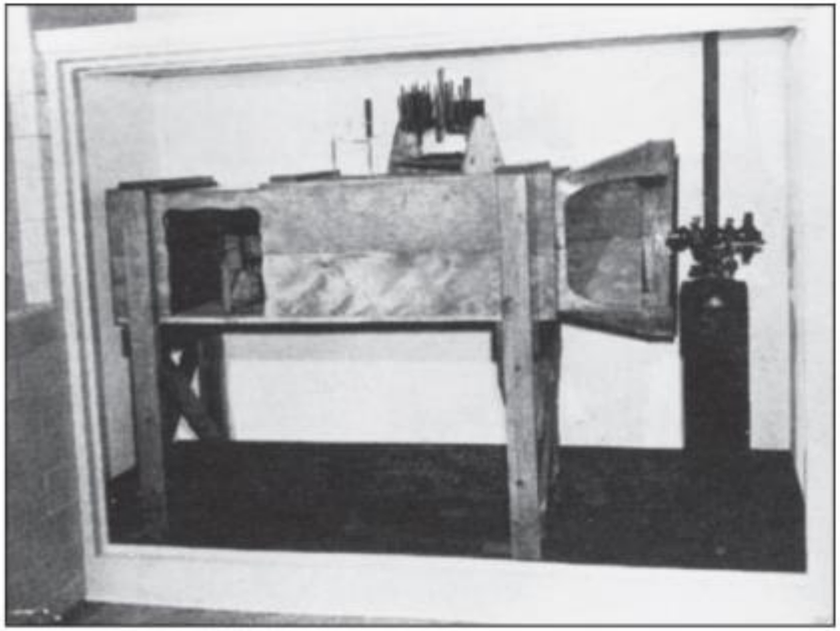
- Objectives of aerodynamics

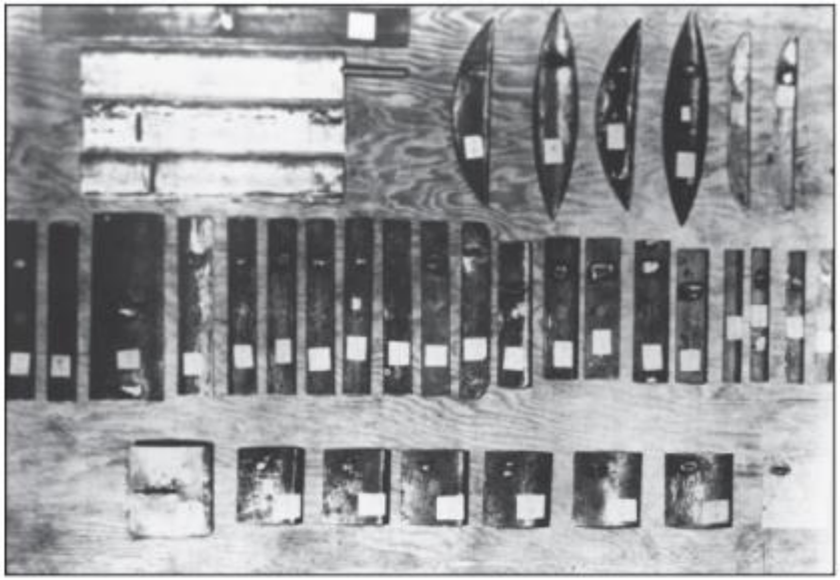
➢ Prediction of forces and moments (and heat transfer to) on bodies moving through air.
  - Aircraft design, buildings, wind turbines

➢ Determination of flows moving internally through ducts
  - Jet engines, wind tunnels, HVAC

Aerodynamics: Examples

Aerodynamics: Examples





Aerodynamics: Examples

Aerodynamics: Examples

Fundamental Aerodynamic Variables

- Pressure:

Normal force per unit area exerted on a surface due to the time rate of change of momentum of the gas molecules impacting on (or crossing) that surface.

- Usually defined at a point in the flow or a point on a surface.

$$dA = \text{elemental area}$$

$$dF = \text{force on one side of } dA \text{ due to pressure}$$

$$p = \lim \left(\frac{dF}{dA} \right) \quad dA \to 0$$

Fundamental Aerodynamic Variables

- Density:

The mass per unit volume.

$$dv = \text{elemental volume}$$

$$dm = \text{mass of fluid inside } dv$$

$$\rho = \lim \frac{dm}{dv} \quad dv \to 0$$

Fundamental Aerodynamic Variables

- Temperature:

Directly proportional to the average kinetic energy of the molecules of the fluid.

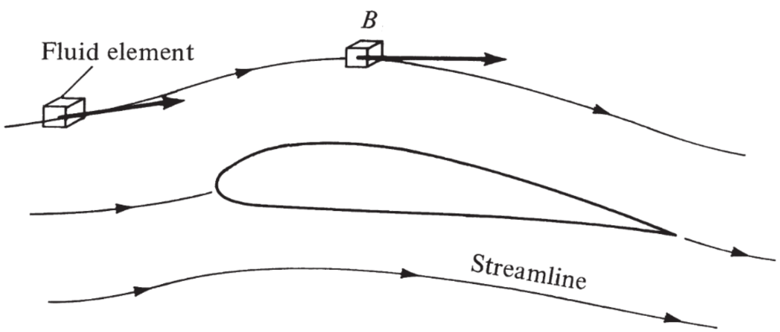
- An important role in high-speed aerodynamics

Fundamental Aerodynamic Variables

- Flow velocity:

An extremely important consideration in aerodynamics.

- Flow in motion
- A vector: has both magnitude and direction



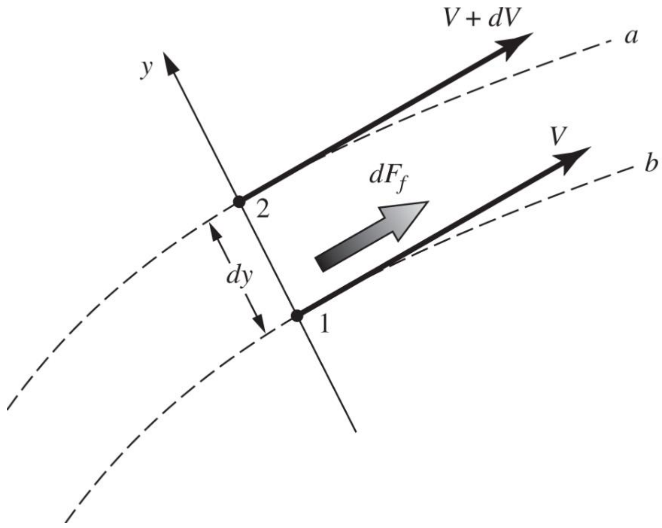
Fundamental Aerodynamic Variables

- Friction, shear stress, viscous flow:

Act tangentially along the flow direction.

- Play a role internally in a flow
- Related to velocity gradients

$$\tau = \mu \frac{dV}{dy}$$



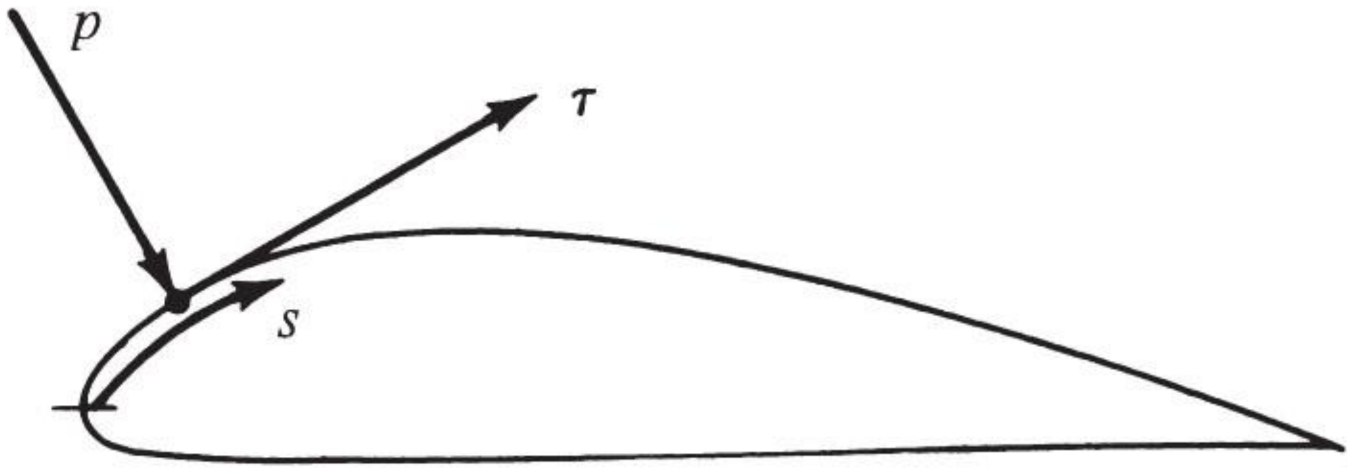
Aerodynamic Forces

- Types of forces acting on aircraft?

Aerodynamic Forces

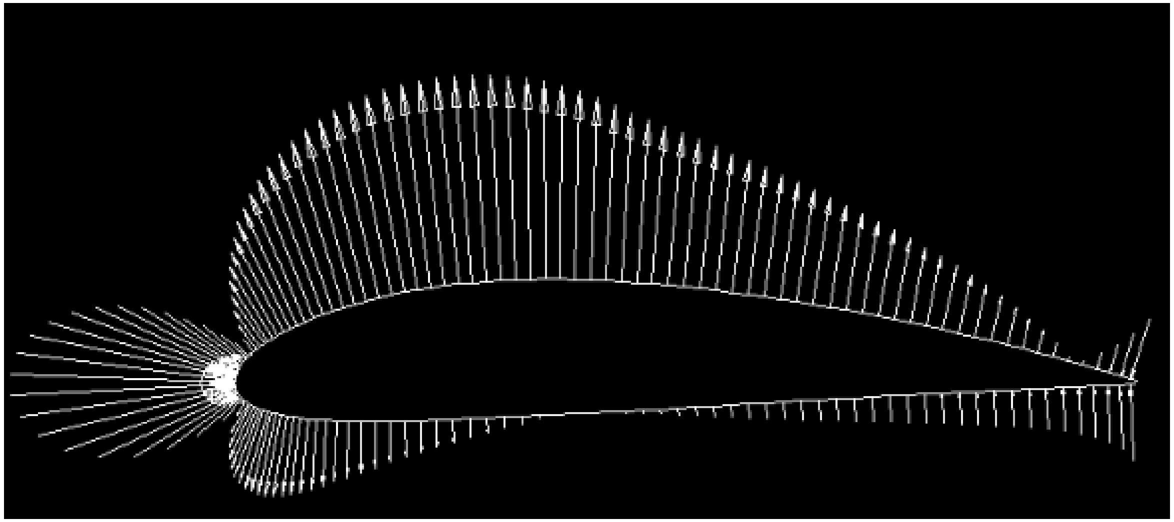
- Types of forces acting on aircraft?
  - Pressure distribution over the surface
    - Acts normal to the surface
  - Shear stress distribution over the surface
    - Acts tangential to the surface
  - No matter how complex the body shape may be, the aerodynamic forces and moments on the body are due to the above two basic sources.

Aerodynamic Forces

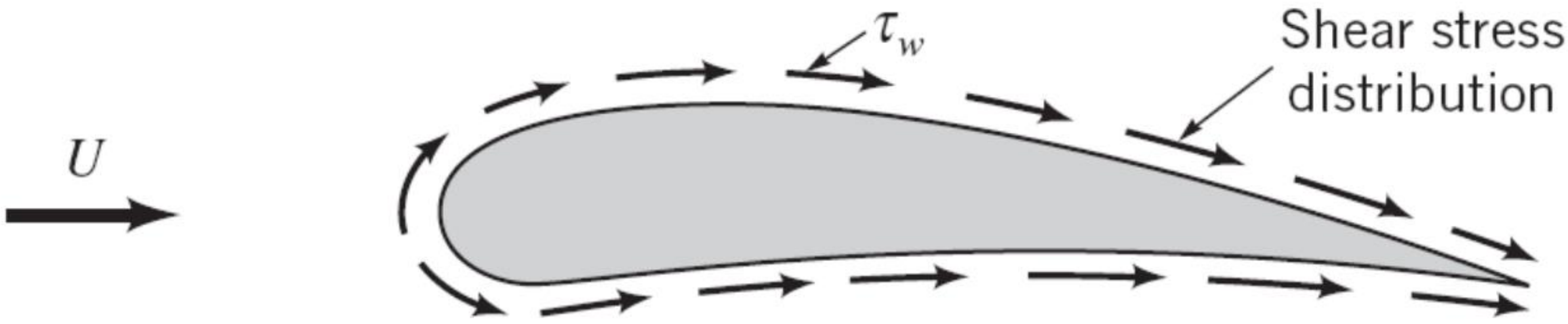


$p = p(s)$ = surface pressure distribution
$\tau = \tau(s)$ = surface shear stress distribution

Pressure Distribution around Airfoil

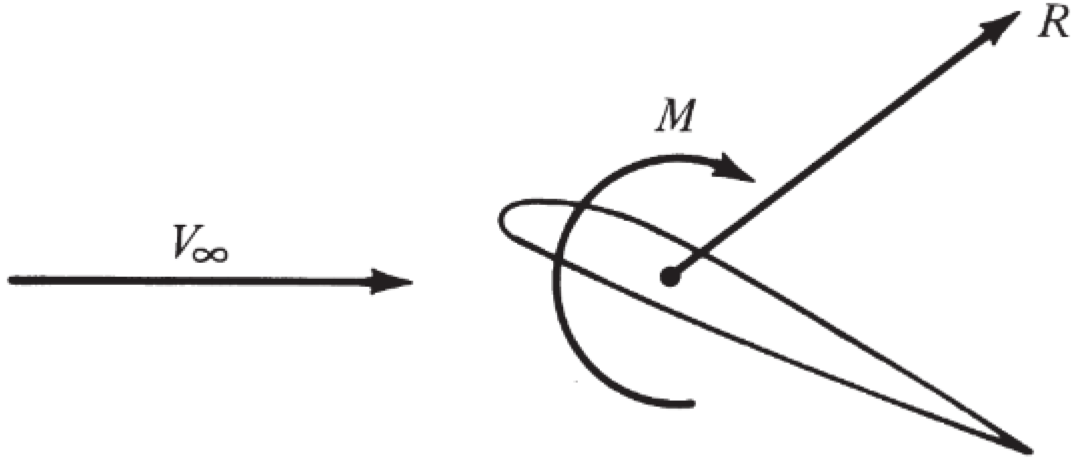


Shear Stress around Airfoil

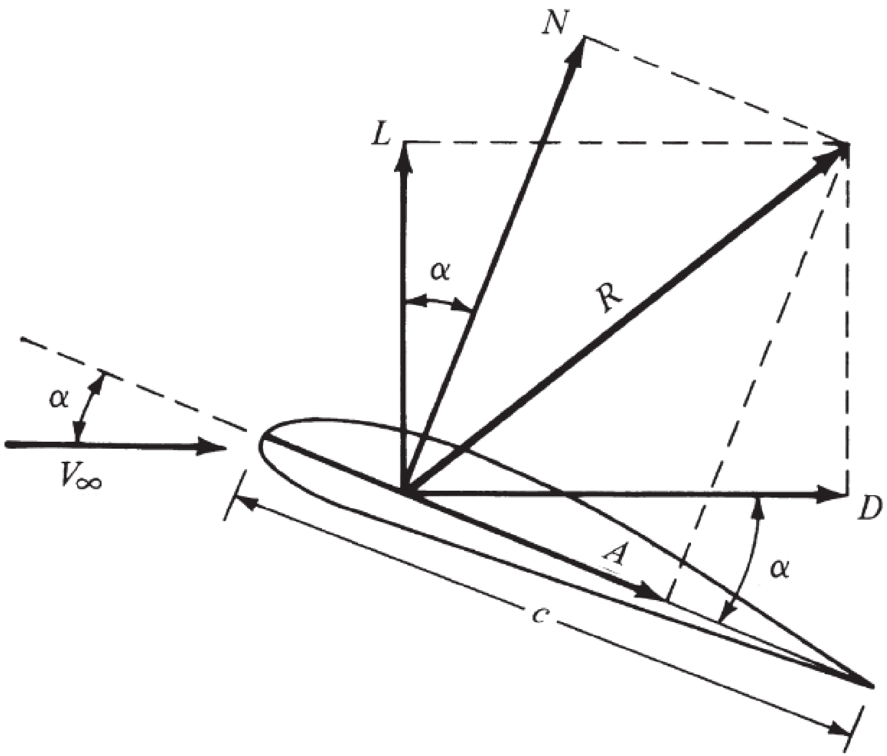


Aerodynamic Forces

- The net effect of the pressure and shear stress integrated over the body surface is a resultant aerodynamic force R and moment M on the body



Aerodynamic Forces



$L \equiv$ lift $\equiv$ component of R perpendicular to V_∞

$D \equiv$ drag $\equiv$ component of R parallel to V_∞

$N \equiv$ normal force $\equiv$ component of R perpendicular to c

$A \equiv$ axial force $\equiv$ component of R parallel to c

Vectored Thrust

Vectored Thrust

It can give an advantage of low-speed, plus high angle-of-attack maneuverability, compared to conventional-thrust aircraft.

FASTYI

In-Class Quiz