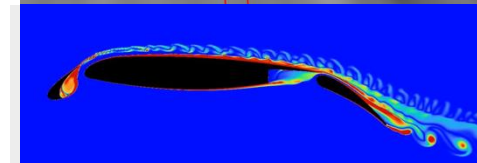
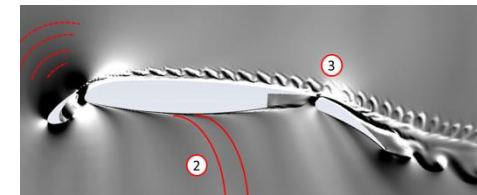
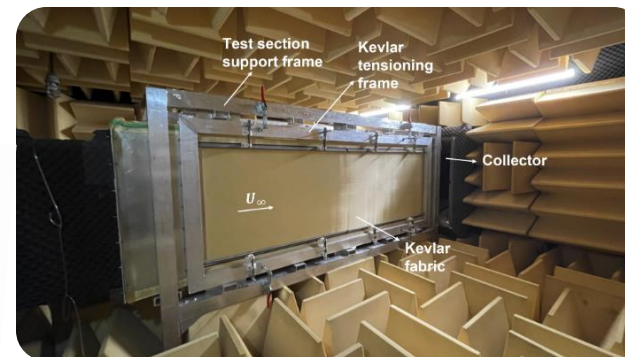
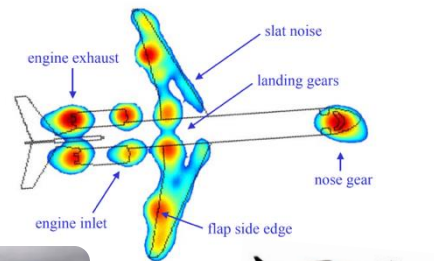
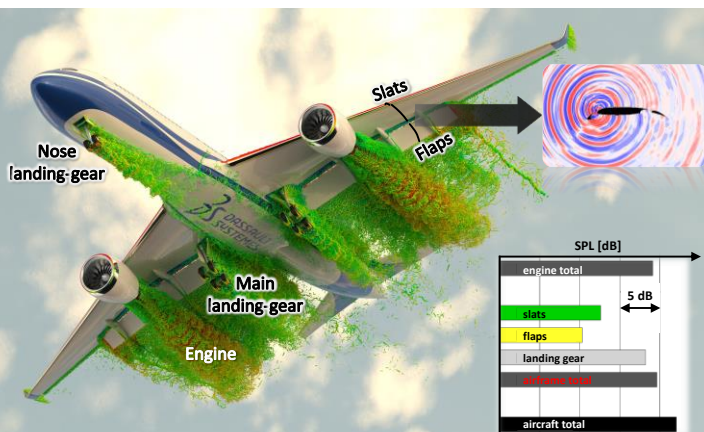
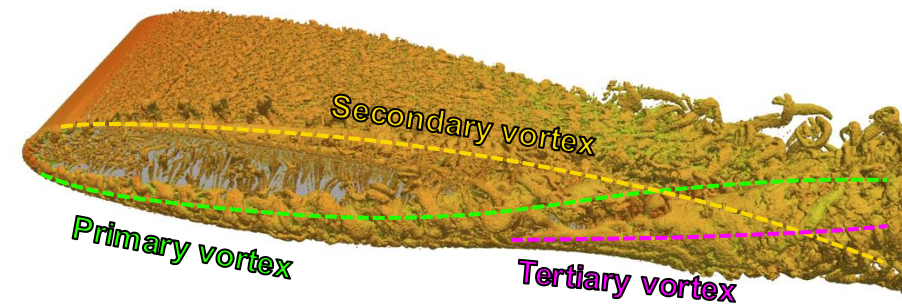
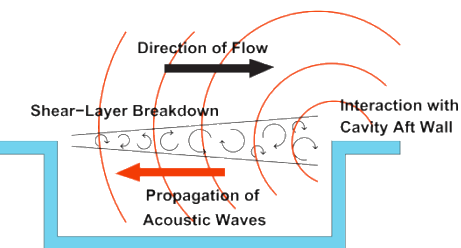


Aircraft Aeroacoustics

0860395

Dr. Hadar Ben-Gida

bengida@technion.ac.il



AA0860395 Course Overview

☐ Objective:

- Provide students with a comprehensive understanding of the physical principles of aeroacoustic phenomena relevant to aircraft systems
- The student will learn to apply acoustic analogies, as well as analytical and empirical methods, to predict and analyze the noise characteristics of aircraft systems

☐ Prerequisites:

- Compressible flow (84312)

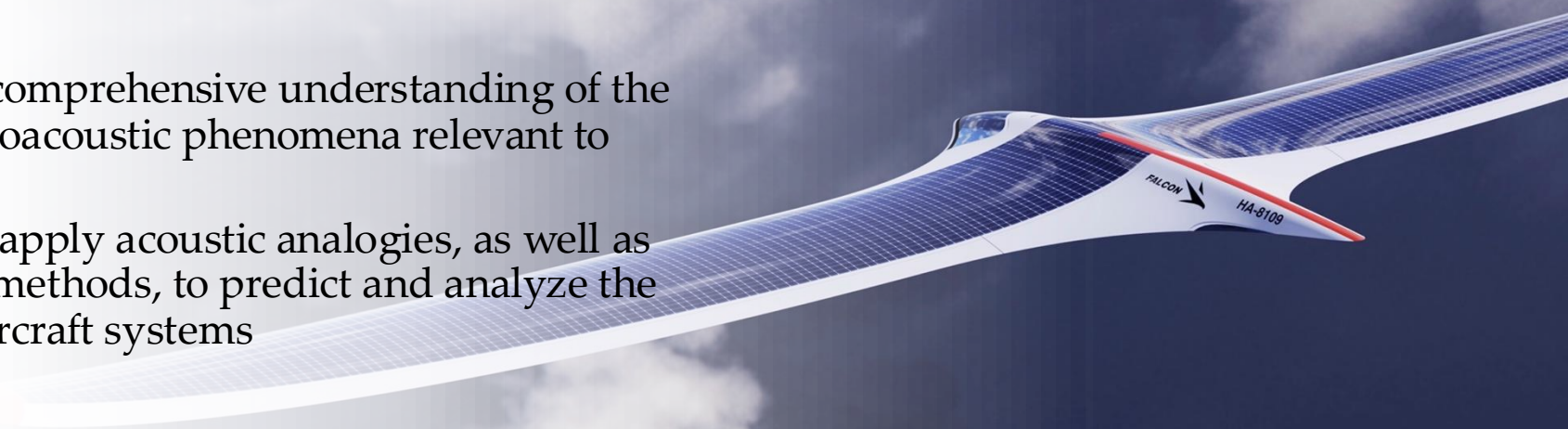
☐ Weekly hours:

- 3 lecture hours, Tue 14:30-17:30, Lady Davis, Room 371

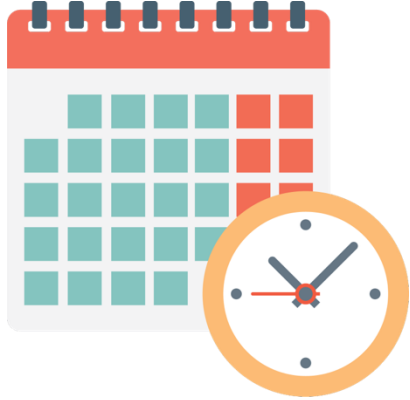
☐ 3 academic credits

☐ Office hours: Tue, before class (upon request)

☐ TA: Ohad Katri



Schedule



**Lecture time is 14:30-17:30,
at Room 371**

Sun	Mon	Tue	Wed	Thu
26/10	27/10	28/10	29/10 Semester starts!	30/10
2/11	3/11 Itzhak Rabin Mem. Day	4/11 Lecture 1	5/11	6/11
9/11	10/11	11/11 Lecture 2	12/11	13/11
16/11	17/11	18/11 Lecture 3	19/11	20/11
23/11	24/11	25/11 Lecture 4	26/11	27/11
30/11	1/12	2/12 Lecture 5	3/12	4/12
7/12	8/12	9/12 Lecture 6	10/12	11/12
14/12 Hanukkah	15/12 Hanukkah	16/12 Lecture 7 Hanukkah	17/12 Hanukkah	18/12 Hanukkah
21/12 Hanukkah	22/12 Hanukkah	23/12 Lecture 8	24/12 Christmas Eve.	25/12 Christmas
28/12	29/12	30/12 Lecture 9 Tenth of Tevet	31/12	1/1/2026
4/1	5/1	6/1 Lecture 10	7/1	8/1
11/1 SciTech Forum	12/1 SciTech Forum	13/1 SciTech Forum	14/1 SciTech Forum	15/1 SciTech Forum
18/1	19/1	20/1 Lecture 11	21/1	22/1
25/1	26/1	27/1 Lecture 12	28/1	29/1 Semester ends!

Course Syllabus

- ❑ **Ch. 1** – *Introduction to Aircraft Aeroacoustics*
- ❑ **Ch. 2** – *Linear Acoustics*
- ❑ **Ch. 3** – *Acoustic Analogies (Lighthill, Curle, FW-H)*
- ❑ **Ch. 4** – *Unsteady Loading*
- ❑ **Ch. 5** – *Airfoil Self-Noise*
- ❑ **Ch. 6** – *Propeller and Rotor Noise*
- ❑ If time permits:
 - Aeroacoustics of high-lift devices, wingtip,...
 - Cavity noise

Final Grading

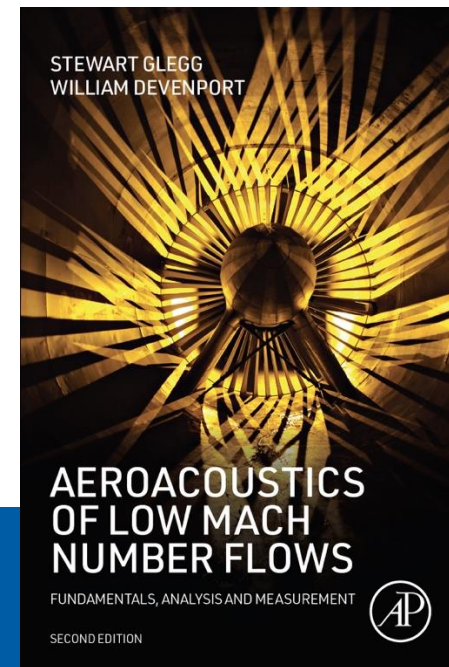
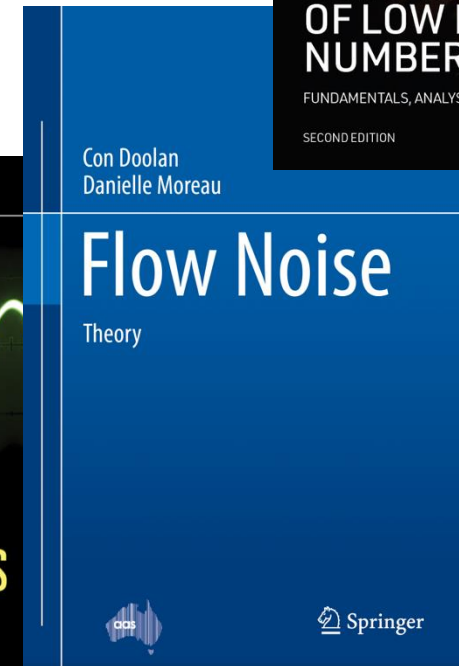
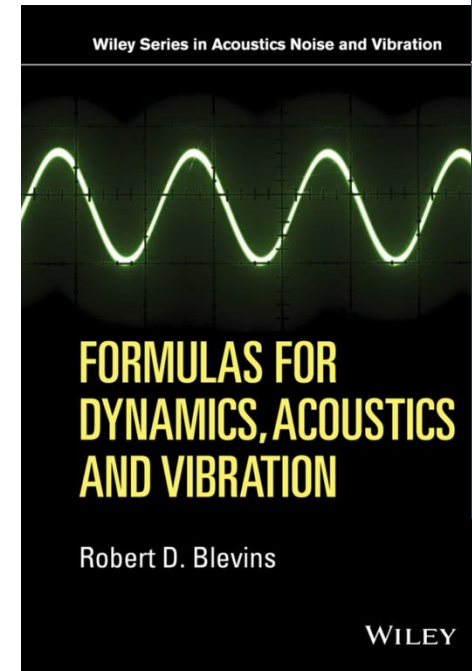


□ 3 HW assignments: 70% (23%, 23%, 24%)

- Each HW assignment is due within 4 weeks (after being published)
- Require MATLAB/Python or any other suitable programming language
- Each HW assignment is to be submitted via *Moodle* (.zip file containing the **report + codes**)
- Each HW assignment includes **bonus points** (+20/30) **applicable only to the specific HW**
 - Final course grade can be up to 100
- Assignments:
 - **HW1** (23%) – Fundamentals in aeroacoustics (deadline: 02/12/2025)
 - **HW2** (23%) – Aircraft noise analysis (deadline: 30/12/2025)
 - **HW3** (24%) – Rotor noise prediction (deadline: 27/01/2026)
 - **Optional - HW4** – Airframe noise (deadline: 26/02/2026)
 - Can replace one HW assignment with the lowest grade (MAGEN)

Reference Material

- ❑ S. Glegg and W. Devenport. *"Aeroacoustics of Low-Mach Number Flows"*. 2nd Edition, Elsevier Academic Press, 2024.
- ❑ C. Doolan and D. Moreau. *"Flow Noise"*, Springer 2022.
- ❑ R. D. Blevins, *"Formulas for Dynamics, Acoustics and Vibration"*. John Wiley & Sons, 2016



Chapter 1

Introduction to aircraft aeroacoustics

Sound and noise



Aircraft Aeroacoustics



Sound or noise?

Aircraft approach



Space shuttle launch



Jet noise



Helicopter



Drones



Sonic boom



Defintions

□ Acoustics

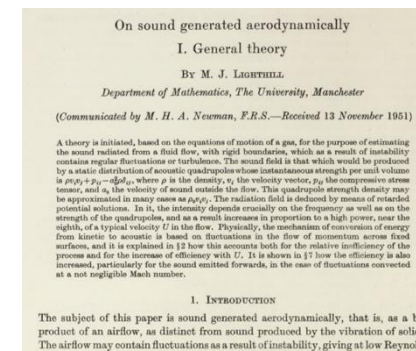
- Scientific study of **sound** generation, propagation, and reception
- **Noise** is any unwanted or undesirable sound that is heard by a person, referred to as an observer in acoustics terminology

□ Aeroacoustics

- The study of **noise generation by air flows (flow-induced sound)**, and the way in which aerodynamic systems can be designed to minimize noise
- Subject born from Lighthill's paper on his theory of aerodynamic sound (1952) – “Lighthill's Acoustic Analogy”



Sir James Lighthill
(23 January 1924 – 17 July 1998)
A British applied mathematician



Simple example

□ Flow around a cylinder

- Low Mach number
- Formation of von Kármán vortex street
- Tonal sound can be generated at the vortex shedding frequency
 - Vortices generate an unsteady force on the cylinder surface, generating a dipole sound source, also known as the Aeolian tone
- $St \sim 0.2$ over a large range of Re numbers

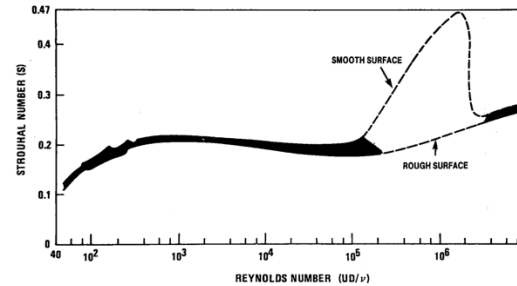


Fig. 3-3 Strouhal number-Reynolds number relationship for circular cylinders (Lienhard, 1966; Achenbach and Heinecke, 1981). $St \approx 0.21 (1 - 21/Re)$ for $40 < Re < 200$ (Roshko, 1955).

Reynolds
number

Mach
number

$$Re = \frac{\rho U_{\infty} D}{\mu} = 69,000 U_{\infty} c$$

$$M = \frac{U_{\infty}}{c} = 0.003 U_{\infty}$$

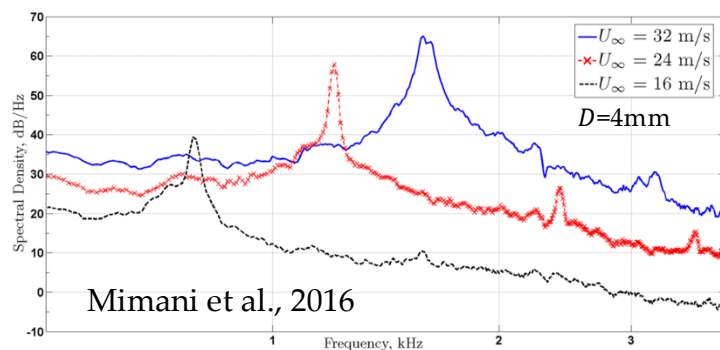
Strouhal
number

$$St = \frac{fD}{U_{\infty}}$$

⇓

Shedding
frequency

$$f = \frac{St U_{\infty}}{D}$$



LBM, $Re=100$, $St=0.17$

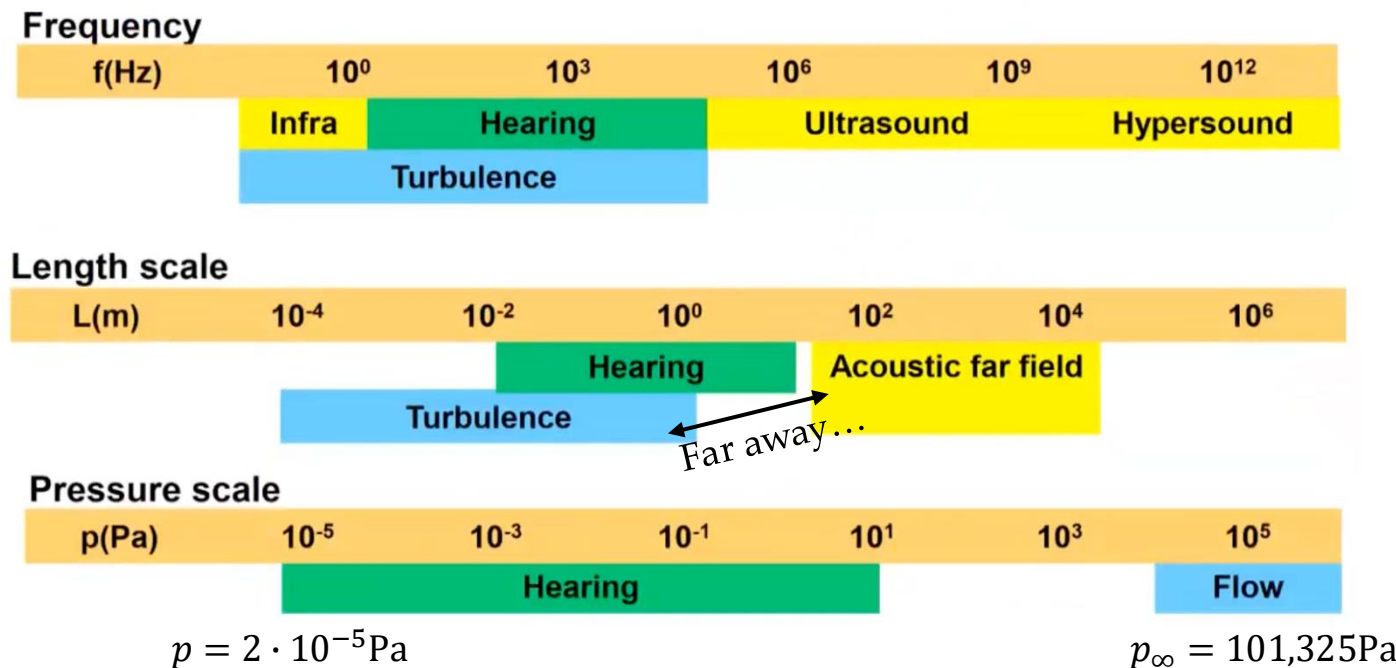


Standard atmosphere – sea level (SL)

density:	$\rho_{SL} = 1.225 \text{ kg/m}^3$
pressure:	$p_{SL} = 1.0132 \times 10^5 \text{ Pa}$
temperature:	$T_{SL} = 288.15 \text{ K}$
speed of sound:	$c_{SL} = 340.3 \text{ m/s}$
viscosity:	$\mu_{SL} = 1.79 \times 10^{-5} \text{ kg/m-s}$

Scientific Challenge

- ❑ The design of low-noise aircraft systems needs good knowledge of aeroacoustics
- ❑ Reduction of development time can be obtained by using common rules-of-thumb, relatively simple theories, and computational aeroacoustic (CAA) simulation
- ❑ Main challenge – disparity of *length* and *energy* scales



Acoustic wavelength $\lambda = \frac{c_0}{f}$

Frequency (Hz)	1	10	100	1000	10,000
Wavelength (ft)	1128	112.8	11.28	1.128	0.1128 (1.3 in.)
Wavelength (m)	343	34.3	3.43	0.343	0.0343 (34.3 mm)