MODULE DESCRIPTION FORM

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

ME530 AERO-ACOUSTICS

Module Registrar: Dr M Z Afsar mohammed.afsar@strath.ac.uk	Taught To (Course): Cohorts for whom class is optional	
Other Lecturers Involved:	**Credit Weighting: 10 (ECTS 5)**	**Semester: 1**
Optional class	**Academic Level: 5**	**Suitable for Exchange: Y**

Required prerequisites

Note: It is the responsibility of ALL students to ensure that they satisfy the prerequisite knowledge for this module BEFORE adding as part of curriculum selection. If unsure, please contact the Module Registrar or discuss with your Programme/Year Adviser of Studies.

Technical pre-requisites:
Knowledge of fluid mechanical theory:
- derivation of the Navier-Stokes equations in compressible and incompressible flows;
- meaning of fluid mechanical terms such as viscosity, flow Reynolds number and vorticity;
- qualitative understanding of turbulence in fluids

Good programming skills:
Knowledge of basic programming principles:
- manipulation of scalar, vectors and matrices variables;
- use of operators, expressions and statements (including conditional statements);
- algorithms, structured programming logic and flow diagrams;
- computer arithmetic and errors.

Ability to develop and implement effective algorithms (MATLAB is the officially supported language/environment for this module, but the assignments and courseworks can be done in any programming language).

Mathematical methods:
Linear algebra, vectors & matrices.

Numerical Methods:
Solution of linear and nonlinear equations; differentiation and integration; numerical quadrature; interpolation.

Module Format and Delivery (HOURS i.e. 1 credit = 10hrs of study):

Lecture	Tutorial	Laboratory	Groupwork	External	Online	Project	Assignments	Private Study	**Total**
20	20						20	40	100

Educational Aim

This class gives students the necessary training in theoretical and computational techniques used in modern Aero-acoustics. It builds upon the students' previous exposure to the Navier-Stokes equations and shows how formal solutions can be sought for acoustic pressure for isolated flows and flows installed in machinery. The computational element provides students with experience in data processing for Aero-acoustics.

Learning Outcomes

A general objective of the class will be to introduce the methods of aero-acoustic analysis to determine the far-field sound given a near field region of turbulence. The role of solid surfaces in sound generation process will also be examined.

On completion of the module the student is expected to be able to:

LO1 Understand what sound is and its governing equations

LO2 Analyse the three-dimensional wave equation to determine the basic mathematical properties of sound in a stationary and moving medium

LO3 Apply aero-acoustic and diffraction theory to determine the acoustic spectrum formula for free/installed flow problems and use the resulting formulae to carry out basic analytical acoustic calculations

LO4 To be able to use basic data processing techniques in computational aero-acoustics to determine the far-field sound: both numerical methods and Fourier analysis of sound spectrum

Syllabus

Acoustics of moving media: the wave equation; elementary sound source distributions; moving sources; ray theory; sound waves at interfaces; sound created by moving/vibrating wall; waves in a duct.

Aerodynamic sound: Lighthill's acoustic analogy; Lilley analogy; Powell/Howe analogy; Goldstein's generalized analogy. Lighthill's dimensional scalings; effect of source motion.

Effect of solid boundaries: Reciprocity and Kirchhoff's theorem; the Ffowcs-Williams Hawking's equation; generalized acoustic analogy with solid surface effects.

Scattering and distortion of sound: Rapid-distortion theory; trailing edge noise and the vorticity interaction problem. Brief look into non-linear acoustics

Computational aeroacoustics: Order of accuracy of numerical scheme, characteristic form of Navier-Stokes equations, nonreflective boundary conditions.

Fourier analysis: Understanding Fourier analysis, discrete data and Fast Fourier Transform, Correlation and auto-correlation functions, calculation of Power Spectral Density

Acoustic analogy: define source regions to apply acoustic analogies, implementation of relevant terms from FWH analogy for representative simulation data, implementation of relevant terms in FWH/Lighthill's analogy for a representative analytical source.

Assessment of Learning Outcomes

LO1 Understand what sound is and its governing equations

C1 Students should demonstrate ability to work out basic solutions to the three-dimensional wave equation to analyse the classical acoustics problem of sound generated in moving media

LO2 Analyse the three-dimensional wave equation to determine the basic mathematical properties of sound in a stationary and moving medium

C1 Students will comprehend the role of mean flow shear in the wave propagation as the distinguishing feature of various acoustic analogy approaches and be able to determine the basic solution in each case using a Green's function

LO3 Apply aero-acoustic and diffraction theory to determine the acoustic spectrum formula for free/installed flow problems and use the resulting formulae to carry out basic analytical acoustic calculations

C1 Students will have a thorough appreciation of the role of solid surfaces in creating an efficient sound source and various techniques to determine the sound in free and installed jet flows

LO4 To be able to use basic data processing techniques in computational aero-acoustics to determine the far-field sound: both numerical methods and Fourier analysis of sound spectrum

C1 Students will gain a basic understanding in the various methods used in computational aero-acoustics to determine the sound radiated in complex problems involving solid boundaries that require solution of Ffowcs-Williams Hawkings equation

The standards set for each criterion per Module Learning Outcome to achieve a pass grade are indicated on the assessment sheet for all assessment.

Principles of Assessment and Feedback

(within Assessment and Feedback Policy at: https://www.strath.ac.uk/professionalservices/staff/policies/academic/)

Students are encouraged to collaborate in the calculations and models provided in the tutorial exercise and demonstration calculations provided during the course.

Informal feedback will be provided at regular tutorial sessions primarily through verbal discussion with individuals or groups on tutorial exercises attempted in advance by students.

Guidance to the solution of certain tutorial questions will be discussed in lectures/tutorial sessions.

Formal, summative feedback will be provided by the return of examination marks to students after assessment (note:- exam scripts will not be returned to students and no collective discussion of exam performance will be facilitated). Individual feedback on the exam may be arranged if appropriate.

Immediate feedback will be provided following the on-line assessment.

Assessment Method(s) Including Percentage Breakdown and Duration of Exams *(individual weightings)*

Examination				Coursework		Practical		Project	
Number	Month(s)	Duration	***Weighting***	Number	***Weighting***	Number	***Weighting***	Number	***Weighting***
1	Dec	2 hrs	70%	2	30% (20%+10%)				
* LO1, LO2, LO3, LO4				* LO1, LO2, LO3, LO4		*		*	

* ***L/Os:*** *Indicate which Learning Outcomes (L01, L02, etc) are to be assessed by exam/coursework/practical/project as required.*

Coursework / Submission deadlines (*academic weeks*):

A computational coursework requiring submission of report will be given in week 7 counting as 20% of the final mark. An assessed example paper will be given in week 9 counting as 10% of the final mark.
The coursework will involve determination of the sound radiated in a flow/surface interaction problem by modifying an existing Ffowcs-Williams Hawkings code. The results will then be interpreted using theoretical and computational aero-acoustic principles taught during lectures.

Resit Assessment Procedures:

2hr examination in August diet.

PLEASE NOTE:
Students must gain a summative mark of 50% to pass the module. Students who fail the module at the first attempt will be re-assessed during the August diet. This re-assessment will consist entirely of examination. No marks from any previous attempts will be transferred to a new resit attempt.

Recommended Reading

*****Purchase recommended** ****Highly recommended reading** ***For reference**

*** Physical Acoustics --- Allan Pierce
** Acoustics of Fluid-Structure Interaction – Michael Howe
** Computational Aeroacoustics: A Wave Number Approach – C. K. W. Tam

Additional Student Feedback
(Please specify details of when additional feedback will be provided)

Date	Time	Room No
Each Thursday	3:00pm – 4:00pm	Check timetable webpages for details

Session: : 2021/22

Approved:

Course Director Signature: E Henderson

Date of Last Modifications: 08/09/2021

(Updated July 2021-MAE)

MODULE TIMETABLE

Module Code:	**ME 530**	**Module Title:**	**Aero-acoustics**

Brief Description of Assessment:

30% coursework and 70% summative examination.

Assessment Timing

Indicated on the table below are the start/submission dates for each assignment/project and the timing of each exam/assessment. Dropdowns may be left blank. Add extra notes below the dropdowns where relevant.

Please note: Timings can and will change, this should only be used as a guide.

Semester One	W&D Wk	WK1	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9	WK10	WK11	Exam Period
	None	None	None	None	None	Course work Set	None	Course work Submit	Course work Set	Course work Submit	None	None	Exam

Semester Two	C&D Wk	WK1	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9	WK10	WK11	Exam Period
	Choose an item. Choose an item.	Choose an item. Choose an item.	Choose an item. Choose an item.	Choose an item. Choose an item.	Choose an item. Choose an item.	Choose an item. Choose an item.	Choose an item. Choose an item.	Choose an item. Choose an item.	Choose an item. Choose an item.	Choose an item. Choose an item.	Choose an item. Choose an item.	Choose an item. Choose an item.	Choose an item.