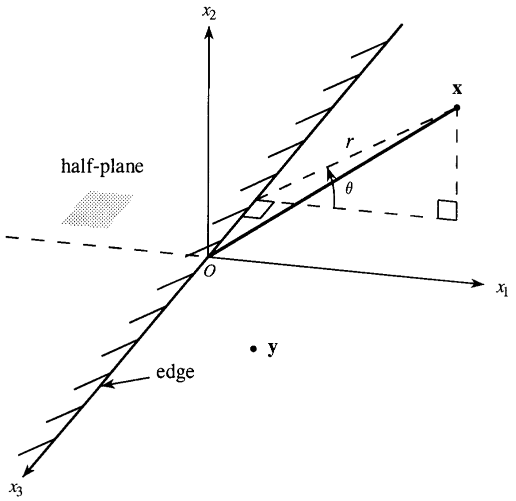
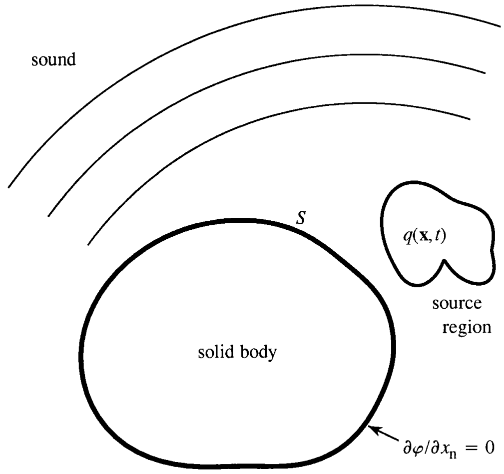




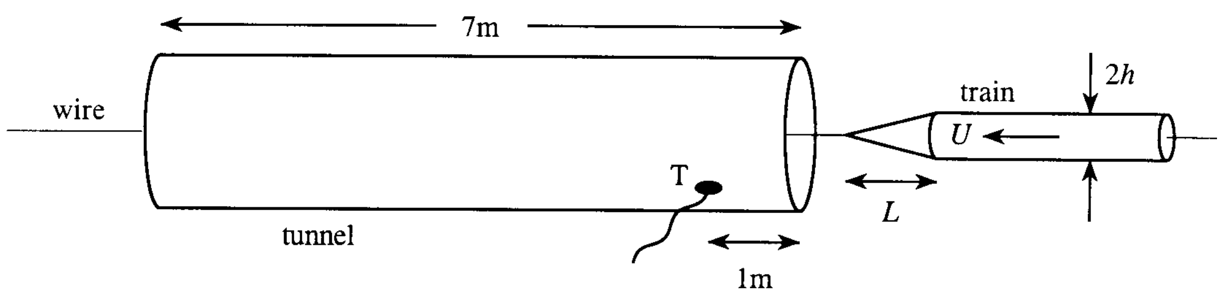
ME720: Acoustics II

Acoustic noise and accompanying structural vibrations are a major environmental problem for all types of mechanised transport, household and industrial appliances, heating and air conditioning systems, etc, ... This course will consolidate and draw together your knowledge and understandings of acoustics and fluid mechanics. It begins with a review of background acoustic theory, which forms a stand-alone introduction to acoustics. Acoustic problems are analysed by various approaches involving Green's functions, Fourier analysis and diffraction theory. The 'compact Green's function' will be developed to predict sound generation by vibrating surfaces and by mean-flow surface interactions. This and related methods are designed to provide an intuitive understanding of the underlying physics, and each student will undertake a project involving a numerical analysis of an acoustic or fluid-acoustic-interaction problem.

Prerequisites: Multivariate Calculus; some knowledge of fluid mechanics, acoustics or continuum mechanics useful, but not essential. Open to seniors with instructor approval.

Day & Time: Tues and Thurs 6-8pm, Spring 2012

Instructor: Michael Howe, Room EMA 218, mshowe@bu.edu



ENG ME 720 Acoustics II

Instructor:

M. S. Howe
EMA 218
mshowe@bu.edu

This course develops the theory of acoustics and provides the student with a mature approach beyond that found in a first course in acoustics or fluid mechanics.

Outline syllabus:

Mathematical preliminaries. Equations of motion; acoustics as a branch of fluid mechanics. Sound waves and sources of sound in one, two and three dimensions. Scattering of sound by rigid and elastic bodies. Diffraction by sharp edges and apertures. General solution of the wave equation using Green's functions and compact Green's functions; retarded potentials; energy flux. Sound produced by vibrating bodies and by flow-structure interactions; noise. Radiation from open-ended ducts; end-correction.

Prerequisites:

Working knowledge of multivariate calculus; some familiarity with fluid mechanics, acoustics or continuum mechanics will be useful, but not essential. Open to properly qualified seniors with instructor permission.

Textbooks:

Students of fluid mechanics and acoustics should aim to build a library of classic texts. These are usually considered to be 'too difficult' for the average graduate, and most textbooks in use in American universities are simplifications that present interpretations and often misguided simplifications of the originals. Many valuable classics are now out of print, but are often available from libraries and online sources.

The engineering text *Mathematical Methods for Mechanical Sciences* (MMMS) can be downloaded from the ME 720 Website.

Course grading:

- Class participation (20%) (Students will be asked to discuss and make class presentations of selected homework problems.)
- One take-home examination (40%)
- One Project (40%)

Students are expected to:

- Exhibit a level of mathematical maturity roughly equivalent that derived from an advanced undergraduate course on 'Engineering Mathematics' (Review material will be found in MMMS).
- Independently study and attempt to solve problems in the recommended texts. Some of these will be set as homework problems and used in class discussions.

Recommended texts:

Blackstock, D. T. *Fundamentals of Physical Acoustics*, Wiley, 2000.

Howe, M. S. *Theory of Vortex Sound*, Cambridge University Press, 2003.

Howe, M. S. *Hydrodynamics and Sound*, Cambridge University Press, 2006

Lighthill, James 1978 *Waves in Fluids*. Cambridge University Press.

Noble, B. 1958 *Methods based on the Wiener-Hopf Technique*. London: Pergamon Press.

Other books related to acoustics:

Rayleigh, Lord 1945 *Theory of Sound*, Volumes 1 and 2. New York: Dover.

Howe, M. S. *Acoustics of Fluid-Structure Interactions*, Cambridge University Press, 1998

Pierce, A. D. 1989 *Acoustics, An introduction to its principles and applications*. American Institute of Physics.

Baker, B. B. and Copson, E. T. 1969 *The Mathematical Theory of Huygens' Principle*, Second edition. Oxford University Press.

Crighton, D. G. Dowling, A. P., Ffowcs Williams, J. E., Heckl, M. and Leppington, F. G. 1992 *Modern methods in analytical acoustics* (Lecture Notes). Springer-Verlag: London.

Dowling, A. P. and Ffowcs Williams, J. E. 1983 *Sound and sources of sound*. Ellis Horwood (ISBN 0-85312-400-0).

Goldstein, M. E. 1976 *Aeroacoustics*. New York: McGraw-Hill.

Classics:

Batchelor, G. K. 1967 *An Introduction to Fluid Dynamics,* Cambridge University Press.

Birkhoff, G. 1955 *Hydrodynamics – a study in logic, fact and similitude.* Dover publications (republication of edition published by Princeton University Press, 1950)

Birkhoff, G. and Zarantonello 1957 *Jets, wakes and cavities.* New York, Academic Press.

Durand, W. F. 1934. (editor) *Aerodynamic Theory*, 6 volumes. See especially volumes II and III. Second hand only.

Gurevich, M. I. 1965 *Theory of jets in ideal fluids.* New York, Academic Press.

Goldstein, S. 1960 *Lectures on fluid mechanics.* Interscience: New York. (out of print)

Lamb, Horace 1932 *Hydrodynamics* (6th. ed.). Cambridge University Press. (Also available from Dover; paperback version reprinted as a *Cambridge Classic* by Cambridge University Press, 1993). All serious students should have this!

Landau, L. D. and E. M. Lifshitz 1987 *Fluid Mechanics* (Second edition). Oxford: Pergamon.

Lighthill, J. 1986 *An Informal Introduction to Theoretical Fluid Mechanics.* Oxford: Clarendon.

Milne-Thomson, L. M. 1968 *Theoretical Hydrodynamics* (5th. edition). London: Macmillan. (Also available from Dover)

Prandtl, L. 1952 *Essentials of Fluid Dynamics.* London, Blackie and Sons. (out of print)

Sedov, L. I. 1965 *Two dimensional problems in hydrodynamics and aerodynamics.* New York: John Wiley.

For a review of elementary fluid mechanics:

Acheson, D. J. 1990 *Elementary Fluid Dynamics.* Oxford: Clarendon Press.

Rough course syllabus:

Lecture 1: T, 17 Jan
Preliminary math review

Lecture 2: R, 19 Jan
Equations of motion
Equation of linear acoustics

Lecture 3: T, 24 Jan
Sound produced by a pulsating sphere
Sound produced by an impulsive point source
Free space Green's function

Lecture 4: R, 26 Jan
Retarded potential
Monopoles, dipoles and quadrupoles
Acoustic energy flux

Lecture 5: T, 31 Jan
Calculation of the acoustic far field
Multipole expansion
Examples
Problems 1

Lecture 6: R, 2 Feb
Volume and surface integrals
Kirchhoff's formula
Radiation from a noncompact surface

Lecture 7: T, 7 Feb
The Helmholtz equation
The reciprocal theorem

Lecture 8: R, 9 Feb
Problems 2
The influence of solid boundaries
Time-harmonic compact Green's function
Kirchhoff vector

Lecture 9: T, 14 Feb
Compact Green's function for a rigid sphere
Compact Green's function for cylindrical bodies

Lecture 10: R, 16 Feb
Symmetric compact Green's function
Radiation from a vibrating body
Sphere, panel, disk
Problems 3

Lecture 11: R, 23 Feb
Diffraction radiation
Green's function summary and special cases
Method of descent

Lecture 12: T, 28 Feb
Vorticity and the kinetic energy of incompressible flow
The vorticity equation

Lecture 13: R, 1 Mar
The Biot-Savart law
Surface force expressed in terms of vorticity

Lecture 14: T, 6 Mar
The complex potential
Motion of a line vortex

Lecture 15: R, 8 Mar
Generalized Kirchhoff formula
Rayleigh scattering

Lecture 16: T, 20 Mar
Vortex sound
Lighthill's theory
Problems 4

Lecture 17: R, 22 Mar
Vortex-surface interaction noise
Examples

Lecture 18: T, 27 Mar
The baffled piston

Lecture 19: R, 29 Mar
Radiation from an open end
Rayleigh's method for low frequency sound
Physical significance of the end correction

Lecture 20: T, 3 Apr
Radiation into a semi-infinite duct
Compact Green's function

Lecture 21: R, 5 Apr
Wave generation by a train entering a tunnel

Lecture 22: T, 10 Apr
Problems 5

Lecture 23: R, 12 Apr
Sound transmission by a compact aperture
Sources near a circular aperture

Lecture 24: T, 17 Apr
Kirchhoff diffraction theory
Circular aperture and disk
Babinet's principle

Lecture 25: R, 19 Apr
Diffraction of sound by a half-plane
Wiener-Hopf theory

Lecture 26: T, 24 Apr
Far field calculated by stationary phase

Lecture 27: R, 26 Apr
Review

Lecture 28: R, 1 May
Review