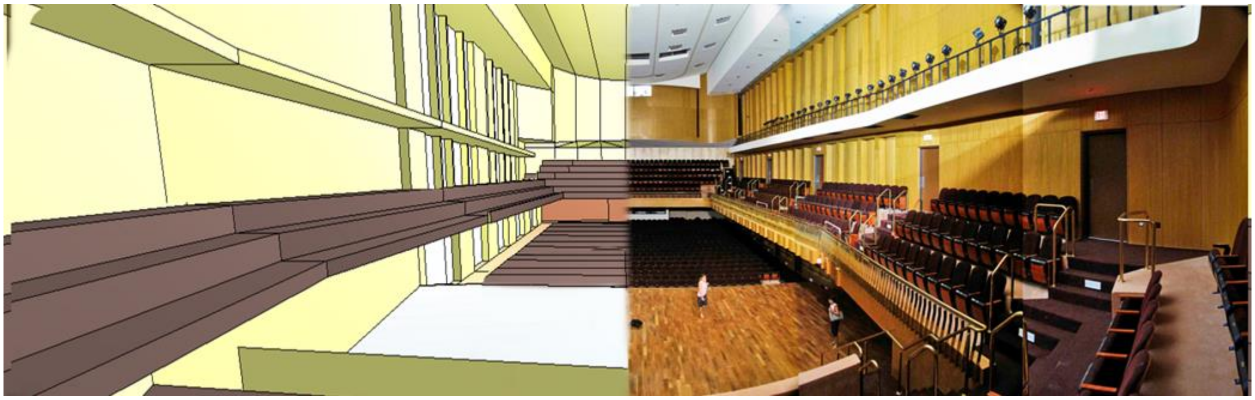
4.431 – Architectural Acoustics

Architectural acoustics entails architectural design, human perception, material properties, and building systems. This seminar will address how buildings respond and enhance our aural experiences, and how new technologies and analytical tools can assist designers to achieve their goals.



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Credits: 3-0-6 = 9 G. (Undergraduates also welcome.)

Prerequisites

All undergraduate and graduate students interested in architectural acoustics are welcome to join the class, though prior completion of 4401/4.461 (Architectural Building Systems) is recommended.

Class Meetings: Wednesdays, 11:00am to 2:00pm
Class meetings at MIT Room 36-372

Learning Objectives

This course is primarily a seminar to develop an understanding of the basic principles of architectural acoustics, how we hear and perceive sound both indoors and outdoors, and what are appropriate criteria for architecture and planning. The process will include how the properties of material absorb, transmit and reflect sound, how layout and design determine our acoustics environment, and how we can use modeling technologies to enhance the dissemination of design goals. Students who successfully complete the course will be able to evaluate and analyze the acoustical characteristics of spaces and designs, and will be able to use computational acoustics modeling and simulation as part of such analysis.

Course Description

The course is a seminar to develop a basic understanding of the principles of architectural acoustics: how we hear and perceive sound both indoors and outdoors, what are appropriate criteria for listening environments and privacy, and how architectural decisions of layout, materials, room shape, and design impact what we hear in and about a space. Topics include techniques for good hearing conditions, control of noise in buildings, privacy, mechanical equipment noise, electroacoustics, material properties (acoustic reflection, absorption, and diffusion), acoustics of critical listening spaces (like concert halls and studios), and acoustical design tools available to architects.

Integrated with this seminar will be a parallel study to understand the role of computer modeling as a tool to enhance the design process. This part of the course will delve into how computer programs can model the sound in a space. Students will have hands-on experience in creating these models, gaining through experience and reinforced during lecture an appreciation for their strengths and their shortcomings. As a culmination of the class, students will build acoustical models and develop auralizations (acoustical simulations) of an engaging space of their choosing, and will compare their simulations to acoustical measurements and real aural experience.

The course includes a series of lectures, problem sets, reading assignments, case studies, computer modeling exercises, field trips for listening and observations and presentations by students, with extensive opportunities for class participation throughout the course. Students will have opportunities to make measurements with sophisticated acoustical analyzers, attend field trips to performance spaces and other spaces of interest on and off MIT's campus, and create their own acoustical models and simulations. Students will be graded on the problem sets, assignments, and final project, and their contributions to class discussions. There will not be a final exam.

Required Work, Reading Assignments, Grading, and Exams

There will be lectures, field trips, in-class demonstrations, and extensive opportunities for class participation. Readings, required most weeks, will be from material to be provided by the instructor or on reserve in Rotch Library. There will be weekly homework problem sets, computer modeling exercises, or field reports, and one major final project incorporating acoustical modeling and analysis which will be due, along with a presentation in class, on the final days of class. Students will be graded on the weekly assignments (totaling 60%), the final project (25%), and their contributions to class discussions (15%). Everyone in the class is expected to participate in the class discussions most weeks.

The definition of grades will follow Institute guidelines (as follows):

A Exceptionally good performance demonstrating a superior understanding of the subject matter, a foundation of extensive knowledge, and a skillful use of concepts and/or materials.

B Good performance demonstrating capacity to use the appropriate concepts, a good understanding of the subject matter, and an ability to handle the problems and materials encountered in the subject.

C Adequate performance demonstrating an adequate understanding of the subject matter, an ability to handle relatively simple problems, and adequate preparation for moving on to more advanced work in the field.

D Minimally acceptable performance demonstrating at least partial familiarity with the subject matter and some capacity to deal with relatively simple problems, but also demonstrating deficiencies serious enough to make it inadvisable to proceed further in the field without additional work.

F Failed. This grade also signifies that the student must repeat the subject to receive credit.

Absence Policy

Please contact the instructor if you will be absent from class. Students are expected to make up homework and class exercises in a timely basis. Greater than two absences from class without medical excuse or personal emergency could result in a failing grade for the class.

Textbooks

Readings will be supplied by the instructor weekly; there is no required textbook. An excellent, but optional, reference textbook is *Architectural Acoustics* by Marshall Long, 2nd Edition, published by Academic Press.

Course Topics

Introduction to Sound and Perception
Properties of materials: absorption, reflection, transmission
Noise control
Acoustics of performance spaces, workplaces, education spaces, and other acoustically sensitive environments
Computer Modeling and Auralization

Schedule/Outline (*subject to revision as discussed in class*)

Date	Topics	Activities	Homework
2/2/2022	Procedures, schedule; **Basics:** Sound waves, decibels, logarithms, frequency; inverse square law	Introductions; class discussion	HW#1: Mapparium, readings, problem set
2/9/2022	**Perception v. measurement**: A-weighting and Leq; power/pressure; Human hearing	Sound level meter measurement lab	HW#2: Measurement analysis
2/16/2022	**Materials:** Absorptive (fibrous, membrane, Helmholz); Reflective and diffusive material	Material samples	HW#3: materials
2/23/2022	**Room acoustics** and absorption/reflection/diffusion; reverberation, speech acoustics	MIT tour; Walk-away test	HW#4: Room acoustics (RT, NRC)
3/2/2022	**Small rooms**: room modes and Schroeder Frequency **Room acoustics measurement.**	Measurement lab – impulse response measurement. Reverberation time and other metrics.	HW#5: small rooms (modes, f_s). Measurement.
3/9/2022	**Transmission**: TL, NR, composite TL, common constructions, STC, doors/windows, flanking, privacy, impact isolation	Practice Rooms visit, "noise box" demo, sound isolation product samples, tapping machine	HW#6: Sound isolation
3/16/2022	**Noise Control**: HVAC noise, vibration isolation; and acoustics & **sustainability**	Lecture	HW#7: noise control
3/23/2022	**MIT SPRING VACATION**		
3/30/2022	**Performance space acoustics** - room acoustics parameters; loudness, quiet, RT, clarity, spaciousness	Killian Hall – tour, performance evaluation	HW#8: performance space evaluation

4/6/2022	**Modeling** - geometric acoustics, ISM and raytrace, wave acoustics, physical and computer models	Introduce final	Install modeling software
4/13/2022	Acoustics modeling **software,** and **Auralization**. Anechoic sound, IR, convolution, HRTF, playback	tutorial workshop; Auralization demos.	HW#9: modeling basics
4/20/2022	Final project check-ins; **performance space acoustics part two**		Final project check-in
4/27/2022	**Case studies** from professional practice.		
5/4/2022	**Final Presentations** of course projects		Final Project Presentation

Academic Integrity

Massachusetts Institute of Technology students are here because of their demonstrated intellectual ability and because of their potential to make a significant contribution to human thought and knowledge. At MIT, students will be given unusual opportunities to do research and undertake scholarship that will advance knowledge in different fields of study. Students will also face many challenges. It is important for MIT students to become familiar with the Institute's policies regarding academic integrity, which is available at *Academic Integrity at MIT: A Handbook for Students.*

Student Performance Criteria (NAAB)

B8. Environmental Systems (Acoustics)