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.

Credits: 3-0-6 = 9 G. (Undergraduates 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 5-415

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 studio without medical excuse supported by a doctor’s note or verifiable 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**)

<table>
<thead>
<tr>
<th>Date</th>
<th>Topics</th>
<th>Activities</th>
<th>Homework</th>
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<tbody>
<tr>
<td>2/5/2020</td>
<td>Procedures, schedule; <strong>Basics</strong>: Sound waves, decibels, logarithms, frequency; inverse square law</td>
<td>Introductions; class discussion</td>
<td>Hmwk 1: Mapparium, readings, problem set</td>
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<tr>
<td>2/12/2020</td>
<td><strong>Perception v. measurement</strong>: A-weighting and Leq; power/pressure; Human hearing</td>
<td>Sound level meter measurement lab</td>
<td>Hmwk 2: Measurement analysis</td>
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<td>2/19/2020</td>
<td><strong>Materials</strong>: Absorptive (fibrous, membrane, Helmholtz); Reflective and diffusive material</td>
<td>Material samples</td>
<td>HW#3: materials</td>
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<td>2/27/2020</td>
<td><strong>Room acoustics</strong> and absorption/reflection/diffusion; reverberation, speech acoustics; <strong>Small rooms</strong>: room modes and Schroeder Frequency</td>
<td>MIT tour; Walk-away test</td>
<td>HW#4: Room acoustics (RT, NRC) and small rooms (modes, ( f_s ))</td>
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<td>3/11/2020</td>
<td><strong>Transmission</strong>: TL, NR, composite TL, common constructions, STC, doors/windows, flanking, privacy, impact isolation</td>
<td>Practice Rooms visit, &quot;noise box&quot; demo, sound isolation product samples, tapping machine</td>
<td>HW#5: TL</td>
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<tr>
<td>3/18/2020</td>
<td><strong>Noise Control</strong>: HVAC noise, vibration isolation; and acoustics &amp; sustainability</td>
<td>Lecture</td>
<td>HW#6: noise control</td>
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<td>3/25/2020</td>
<td><strong>MIT SPRING VACATION</strong></td>
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<td>4/1/2020</td>
<td><strong>Performance space acoustics</strong> - room acoustics parameters; loudness, quiet, RT, clarity, spaciousness</td>
<td>Killian Hall – tour, performance evaluation</td>
<td>HW#7: performance space evaluation</td>
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<td>4/8/2020</td>
<td><strong>Modeling</strong> - geometric acoustics, ISM and raytrace,</td>
<td>Introduce final</td>
<td>Install modeling software</td>
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### 4.431 Architectural Acoustics – Syllabus

#### Department of Architecture

**Spring 2020: ACOUSTICS: Markham**

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Notes</th>
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<tbody>
<tr>
<td>4/15/2020</td>
<td>Acoustics modeling <strong>software</strong>, and <strong>Auralization</strong>. Anechoic sound, IR, convolution, HRTF, playback</td>
<td>tutorial workshop; Auralization demos.</td>
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<tr>
<td>4/22/2020</td>
<td>Final project check-ins; <strong>performance space acoustics part two</strong></td>
<td>Final project check-in</td>
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<tr>
<td>4/29/2020</td>
<td><strong>Case studies</strong> from professional practice.</td>
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<tr>
<td>May 6, 2020</td>
<td><strong>Final Presentations</strong> of course projects</td>
<td>Final Project Presentation</td>
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**Instructor:** Ben Markham  
*Director, Architectural Acoustics*  
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Cambridge, MA 02138  
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**Academic Integrity**
MIT’s expectations and policies regarding academic integrity should be read carefully and adhered to diligently: [http://integrity.mit.edu](http://integrity.mit.edu)

Assignments are individual. Students may work together on problem sets and are encouraged to discuss assignments together, but in no circumstances should one student be in possession of another’s homework.

**Student Performance Criteria (NAAB)**
B8. Environmental Systems (Acoustics)

**From the Writing Center:**
The MIT Writing and Communication Center offers free one-on-one professional advice from communication experts. The WCC is staffed completely by MIT lecturers. All have advanced degrees. All are experienced college classroom teachers of communication. All are published scholars and writers. WCC lecturers have a combined 130 years’ worth of teaching here at MIT (ranging from 1 to 26 years). We work with undergraduates, graduate students, post-docs, faculty, and staff. The WCC helps everyone strategize about all types of academic and professional writing as well as oral presentations and slide design. No matter what department or discipline you are in, the WCC helps you think your way more deeply into your topic, and helps you see new implications in your data, research, and ideas. The WCC also helps with non-
native speaker issues, from writing and grammar to pronunciation and conversation practice. To make an appointment, go to 
https://mit.mywconline.com and register with our online scheduler. The WCC is at E18-233, 50 Ames Street.