Graduate Program in Acoustics

Overview Information For
Center for Acoustics and Vibration, 2017

prepared by

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Penn State Graduate Program in Acoustics
University Park, PA, USA
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Acknowledgements

Students
(this is what its all about)
What is the Graduate Program in Acoustics?

• The Graduate Program in Acoustics is:
  - Intercollege graduate degree program (IGDP), based in the College of Engineering
  - Administratively aligned with Dept. of Aerospace Engineering
  - Associated with the Applied Research Laboratory (ARL)

• History
  1965  Graduate Program established to provide the US Navy with an academic program in acoustics and its applications.
  1987  Distance Education established in partnership with ARL to further extend educational opportunities to students unable to pursue graduate school at University Park.
Acoustics Program Uniqueness

• Only U.S. institution awarding degrees in Acoustics
• Blending/Simulcasting almost all classes to both local and distance students
• Our distance education classes began (1987) before Penn State World Campus was established (1998). [We also enjoy a healthy relationship with World Campus.]
Philosophy

• Provide a broad education in acoustics fundamentals that will last a lifetime

• Provide this education for
  – residence students
  – working professionals
    o courses *a la carte*
    o pursue M. Eng. degree

• Blend residence and distance students when possible

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Penn State Graduate Program in Acoustics

- Over 55 in-residence graduate students in Acoustics
- Over 80 distance education students taking courses each semester
- Over 40 faculty members from across Penn State ARL, College of Engineering, etc.
- Degrees offered in Acoustics:
  - Master of Engineering
  - Master of Science (in-residence only)
  - Doctor of Philosophy (in-residence only)

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50+ years!

• In 2016 wrapped up the 50th year of targeted Acoustics Education.

• Long term commitment of
  – Penn State’s Graduate School,
  – Applied Research Laboratory, and
  – College of Engineering

• Over 650 graduates!

50th Anniversary Dinner,
Acoustical Society of America
May 20, 2015, Pittsburgh, PA
Acoustics Faculty Members

• Approximately 40 Members of the Graduate Faculty
  – Acoustics (5 + 1 in Dean’s office)
  – Aerospace Engineering (4)
  – Applied Research Laboratory (20)
  – Bioengineering (1)
  – Communication Disorders (1)
  – Geosciences (2)
  – Engineering Science and Mechanics (4)
  – Mechanical Engineering (3)
  – Recreation, Parks, & Tourism Management (1)

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Employment for Acoustics Students

Apple
APL Johns Hopkins
ARL Penn State
BBN
Boeing
Bose Corporation
Army Corps of Engineer’s Research Lab
Eminance Loudspeakers
EnSCO, Inc.
FDA
IBM
Ingersol Rand
Jet Propulsion Lab
Motorola
NASA Langley Research Center
Naval Surface Warfare Center
Northrup Grumman
Panasonic
Raytheon
US DOT Volpe Center
Verizon
Wyle

Brigham Young University
Central Washington University
Cheju National University (Korea)
Harvard Medical School
Illinois Institute of Technology
James Madison University
Kettering University
Lehigh University
McGill University
Silpakorn University (Thailand)
University of Arizona
University of Cincinnati
University of Hartford
University of Michigan
University of Nebraska
University of Rhode Island
University of Texas at Austin
Virginia Tech

Students also go to architectural acoustics/consulting firms . . .

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Acoustics Courses

- Fundamentals of Acoustics (ACS)
- Transducers
- Digital Signal Processing (DSP)
- Structural Acoustics
- Ocean Acoustics
- Data Measurement and Analysis
- Architectural Acoustics
- Outdoor Sound Propagation
- Noise Control Engineering
- Aerodynamically Induced Noise
- Spatial Sound and 3D Audio
- Nonlinear Acoustics (high amplitude sounds)

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Acoustics Curriculum at Penn State

Required courses for Penn State graduate degrees:

501 – elements of acoustics and vibrations
502 – elements of waves in fluids
505 – laboratory [Resident Ed., but not Dist. Ed.]
514 – transducers
515 – acoustics of fluids II
590 – colloquium
597 – signal analysis for acoustics and vibration I
597 – signal analysis for acoustics and vibration II
Elective courses, Fall 2017

• Outdoor Sound Propagation
  - Dr. Sparrow

• Applications of Aeroacoustics and Vibroacoustics
  - Dr. Russell

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## Updated Choices for Masters Students

<table>
<thead>
<tr>
<th>Student Preference</th>
<th>ACS Program Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Get masters degree in 1 year</td>
<td>New 1-year M.S. track in-residence</td>
</tr>
<tr>
<td>Get traditional masters degree with assistantship</td>
<td>Traditional 2-year M.S. track in-residence</td>
</tr>
<tr>
<td>Get masters degree at a distance</td>
<td>M.Eng. through distance in 3 - 5 years</td>
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New Option for M.S.

1-year resident Master of Science in Acoustics (no thesis)

• New, additional program to Penn State
• Many U.S. schools are going to similar non-thesis M.S. degrees
• Approved in May 2015
  - Began Fall 2016
  - 30 credits of courses (13 in Fall, 13 in Spring, 4 in Summer)
• Finish a scholarly paper in the summer
  - Part of research experience for M.S
  - Advisor is assigned so student can start early
• Advantage: 1-year in and out
• Other considerations:
  - Pay your own way, no assistantships
  - Very busy in that 1 year

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Delivery via Distance Education


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What a distance education student sees

6.11 Sound Power For Realistic Noise Sources

**Fan Noise**

**Centrifugal Fans**

- Airfoil blades – used in large HVAC systems (relatively clean air)
- Backward curved blades (BCB) – general ventilation and _____, higher efficiency, fan speed must be higher for given flow rate, usually 8 to 16 blades
- Radial blades (FCB) – _____ handling systems, industrial applications where sand, wood chips, small particles present in air, usually 6 to 12 blades
- Forward curved blades (FCB) – lower fan efficiency, used for low pressure rise, low speed (domestic furnaces, packaged home A/C units), usually 36 to 64 blades

**Axial Fans**

(Student asking questions in chat area. Also can use microphone.)
Acoustics Information Contacts

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Backup Slides
Example Courses for 1-year M.S. track

Fall courses: (13 cr.)
- ACS 501 (3 cr.) Elements of Acoustical Vibrations
- ACS 502 (3 cr.) Elements of Waves and Acoustics
- ACS 513 (3 cr.) Digital Signal Processing
- ACS 594 (1 cr.) Research Topics
- 1 elective (3 cr.) such as ACS 516, ACS 519, or other electives

Spring courses: (13 cr.)
- ACS 515 (3 cr.) Acoustics in Fluid Media
- ACS 505 (2 cr.) Experimental Techniques in Acoustics
- ACS 590 (1 cr.) Colloquium
- ACS 594 (1 cr.) Research Topics
- ACS 514 (3 cr.) Electroacoustic Transducers
- 1 elective (3 cr.) such as Outdoor Sound Propagation

Summer courses: (4 cr.)
- 1 elective (3 cr.) such as E MCH/ACS 521, Stress Waves in Solids
- ACS 580 (1 cr.) Contemporary Research Topics in Acoustics

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New Course: ACS 580

- Title: Contemporary Research Topics in Acoustics
- Approved Summer 2015
- Culminating research experience for 1-year M.S. track
- Contemporary research activities in acoustics: major research thrusts, including current research methodologies and their limitations
- Expose students to analytical, experimental, and simulation-based research approaches in acoustics
- Case studies considered and guest speakers describe challenges in their own research efforts
- Complete scholarly paper, begun earlier in the year

Scholarly Paper

- Format similar to M.Eng. paper, but must be research-based and short
- Each student assigned an advisor paid to oversee their paper
- Begin topic selection and outlining in Fall ACS 594 class
- Completed outline and begin writing in Spring ACS 594 class
- Completed writing in Summer ACS 580 class
- If don’t finish in summer, allowed to finish up afterward (beyond the 1 year)
- After completed, papers made available on scholarsphere.psu.edu

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Distance Education Classes Leading to M. Eng. Degree

1987 – began acoustics distance education via satellite links with Navy labs and industry

1992 – added PictureTel video conferencing delivery in addition to satellite

1994 – added videotape distribution for many students

1997 – satellite discontinued

2002 – added videostreaming delivery over internet to PictureTel

2003 – ended PictureTel

2006 – blended classes; videostreaming only; no VHS

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Current Status of DE Delivery (1)

• Students have opportunity to see lectures live with residence students (blended) or archived (on demand)

• Students participate in live chat room or use microphone to ask questions during lectures

• Web discussion forums for students and media download between classes

• Live office hours / recitation sections

• Dropboxes for homeworks and proctors for tests

Thanks to Miguel Horta and Andrew Orr for providing the following screen shots:
Current Status of DE Delivery (2)

• Use Adobe Connect (Macromedia Breeze) software
  - Need high-speed internet (no dialup)

• Use Smartboards for writing on board/screen

• Use student video producers to ensure quality
Current Status of DE Delivery (3)

Signals and Transforms

- Continuous-Time Function:
  \[ X_c(t) \]
  - Continuous function
  - Sampled at \( f_s = 1/T \)

- Discrete-Time Function:
  \[ x[n] = x[nT] \]
  - Discrete sequence

Fourier Transform

- \( X(j\Omega) = X(s)|_{s=j\Omega} \)
  - Continuous function of frequency

Discrete-Time Fourier Transform

- \( X(e^{j\omega}) = \sum_{n=-\infty}^{\infty} x[n] e^{-j\omega n} \)
  - Continuous function of frequency
  - Periodic with period \( 2\pi \) rad/sample
  - Defined on unit circle in complex plane

Z-Transform

- \( X(z) \)
  - Continuous function of complex variable \( z \)
  - Defined for all \( z \in \text{ROC} \)

Z-transform evaluated on unit circle: \( X(z)|_{z=e^{j\omega}} \)
Current Status of DE Delivery (4)

(Students asking questions in chat area)
ANC Requirements Depend On Sound Field

- Duct is essentially 1-dimensional; sound propagates as plane waves
  - ANC relatively simple to implement

- In Enclosures and rooms, sound field is dominated by normal modes
  - Amplitudes vary throughout the space
  - Excitation Frequencies may be shared by several different modes, especially at high-frequencies
  - ANC requires multiple sensors and sources, effective only at low-frequencies

- In free-field, sound radiates with spherical spreading
  - Amplitude change with distance from source makes near-field cancellation limited
  - In far-field, cancellation can be achieved, but very directionally dependent
  - Many sensors and sources required for extensive sound reduction
Proud of Our Graduates

• Acoustics Education Nationwide!

Robert Celmer
Univ. of Hartford

Lily Wang
Univ. of Nebraska

Rendell Torres
Rensselaer Poly.

Tim Leishman, Kent Gee
Scott Sommerfeldt
Brigham Young Univ.

Tom Weber
New Hampshire

Penn State Acoustics Program

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