Fall 2020 SHBT 200 | HST.714 | 9.016: Introduction to Sound, Speech, and Hearing Syllabus

Speech and hearing are fundamental to our ability to communicate, yet in the US alone millions of people suffer from some form of speech or hearing impairment. The goals of this course are to introduce students to the acoustics, anatomy, physiology, and mechanics related to speech and hearing and to build a foundational understanding of one of the most complex, interdisciplinary, and fascinating areas of bioengineering. Topics include acoustic theory of speech production, basic digital speech processing, control mechanisms of speech production and basic elements of speech and voice perception. These fundamental topics will be explored through applications and challenges involving acoustics, speech recognition, and speech disorders, which are especially relevant given the ubiquity of recording and playback devices such as smartphones and home assistants. On the hearing side, topics include acoustics and mechanics of the outer ear, middle ear, and cochlea, how pathologies affect their function, and methods for clinical diagnosis. Surgical treatments and medical devices such as hearing aids, bone conduction devices, and implants will also be covered.

Lecture Schedule: Wednesdays, Fridays 9:00 - 10:30 am Eastern
Recitation: Mondays 9:00 - 10:00 am Eastern
Office Hours: By appointment over Zoom

Lecture Room: https://harvard.zoom.us/j/97398901465
Recitation Room: https://harvard.zoom.us/j/99825167769?pwd=OHNCZnc0d0pNQlRBRU5KSnRCMng0Zz09

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Grading Policy
Problem Sets - 40%
Quizzes - 40%
Final Project - 20%

Breakdown of Students' Weekly Commitment to the Course:
Pre-lecture
- 2x 1 hour asynchronous
  - e.g. videos, class notes, lecture slides
- 2x 1 hour reading assignments

Lecture block
- 2x 45 min lecture
- 2x 30 mins interactive session to reinforce lesson plan

Post-lecture
- 1 hour recitation
- 4½ hours on problem sets

Schedule is on the following pages
Updated September 28, 2020

Date			Description	Required material before class (medium, time)	Optional material	Pset/Quiz Dates
Wed Sept 2	L1	HHN SP, SSG,	Course Introduction HHN – Intro to course mechanics SP – Intro to hearing SSG – Intro to speech	Sound Localization Where is sound coming from? by Dr. Cliff (video, 5 min) Sound Propagation by Interactive Biology Episode 37 (video, first 2 mins) Auditory Transduction by Brandon Pletsch (7 mins) Frequency Analysis by the cochlea by A.J. Hudspeth (1 min) Read: The speech chain Chap 1 - 2	Organ of Corti (video, 6 mins)	
Th Sept 3 10:30am - 11:30am	R1	GA, JG	Recitation: Zoom Features, PSets, Quizzes, and Projects			
Fri Sept 4	L2	SP	Physics of Sound ● Propagation of sound ● Quantification of sound (Units, Scalar vs vector) ● Frequency, wavelength, dB	- What is a Wave? - Comparing circular and sinusoidal motion - Wave motion in space and time - Superposition of two waves (webpages from Dan Russell's Acoustics website, 45 min) Read: JO Pickles "An introduction to the physiology of hearing" Ch. 1, sections 1.1-1.3	Simple Harmonic Motion (4.1 - 4.3) (website with videos)	
Mon Sept 7			Holiday: Labor Day			
Wed Sept 9	L3	SP	Time & Frequency Analysis ● Fourier transforms ● Fourier Series	Fourier Transform: A visual introduction (video, 20 min) But what is a Fourier Series? (video, 25 min)	The history of the FFT (10-15 min read)	PS #1 out

				Read: JO Pickles "An introduction to the physiology of hearing" Ch. 1, sections 1.4-1.6 Read: Geisler "From Sound to Synapse" Appendix A - Fourier Theory		
Fri Sept 11	L4	SP	Wave Propagation in Tubes ● Wave equation ● Magnitude/phase over space/time for standing/traveling waves ● Closed/open tubes	- Phase between pressure and particle velocity for plane waves - Standing longitudinal sound waves (webpages from Dan Russell's Acoustics website, 1 hr)	Conical resonances (website) Read: Hearing the transformation of conical to closed pipe resonances Michael J Ruiz 2017 Phys. Educ. 52 035012 Reflections from Impedance & Standing Waves (website)	
Mon Sept 14	R2	GA	Recitation			
Wed Sept 16	L5	SP, SSG	Tubes (cont.) - multitubes ● Resonant freqs, freq response ● Tubes, resonance Boundary conditions ● Multi-tubes	A better description of resonance (video, 13 min) Read: Geisler "From Sound to Synapse" Appendix B - Tube Resonance	Read: Waveguide physical modeling of vocal tract acoustics (2006) Helmholtz resonance (website)	PS #1 DUE PS #2 out
Th Sept 17						Quiz #1 out
Fri Sept 18	L6	SP	Sound Localization ● Room acoustics ● Head, outer ear, ear canal ● ITD, ILD, HF hearing ● Head size ● Sound diffraction ● Pinna localization	- Driving room modes and source location - Reverberation time in a small room (webpages from Dan Russell's Acoustics website, 30 min) Read: Heffner, H., and Heffner (**2008**). "High-frequency hearing," in *Audition*, edited by P. Dallos, and D. Oertel (Elsevier, San Diego), pp. 55-60.	Virtual Barber Shop (video, 5 min) *wear headphones* Read: Hoffman, Van Riswick, & Van Opstal (1998) Relearning sound localization with new ears pp. 417-420	Quiz #1 DUE

Mon Sept 21	R3	GA	Recitation			
Wed Sept 23	L7	HHN	Sound Transmission ● Anatomy & physiology of the ear ● Transformer – lever and area ratios	EPL 3D Viewer (interactive models, 30 min) *Must download models. Not compatible with some OSs. If your models work, please share your screen with others Horn Amplification: Impedance Matching (video, 9 min) Read: Geisler Ch.3 External Ear pp. 23-36 Read: Geisler Ch.4 Middle Ear pp. 37-54 Read: JO Pickles "An introduction to the physiology of hearing" Ch. 2, pp. 11-24	Hear New York City in 3D Audio (video, 7 min) *wear headphones*	PS #2 DUE PS #3 out
Th Sept 24						PS #1 corrections DUE Quiz #2 out
Fri Sept 25	L8	HHN	Lumped element and circuit representations ● Lumped elements ● Impedance ● Circuit models	- Simple Harmonic Oscillator (webpage from Dan Russell's Acoustics website, 10 min) Harmonic Oscillation (video, first 42 min) Read: SHBT Acoustics Bootcamp Notes		Quiz #2 DUE
Mon Sep 28	R4	GA	Recitation			
Mon Sep 28 (11 am EDT)	L+	Guest Mason	Comparative structure function of the middle ear			

We Sep 30	L9	HHN	Acoustic Circuit modeling ● Cont. Lumped Element Circuits - Helmholtz ● Lumped transmission model, wave eqn ● Circuit Modeling of the Middle Ear ● Pathologies	Read: Mason (2013) Flexibility within the middle ears of vertebrates Read: The Middle Ear (4.1, 4.2)	Read: Mason (2016) Structure and function of the mammalian middle ear Read: Zwislocki (1962) Analysis of the MIddle-Ear Function. Part 1: Input Impedance	PS #3 DUE PS #4 out
Th Oct 1						PS #2 corrections DUE Quiz #3 out
Fri Oct 2	L10	HHN	● Cont. Circuit Model of the Middle Ear ● Circuit Modeling of the Inner ear ● Pathologies	Read: The Middle Ear (4.3, 4.4)	How Speakers Work (video, 6 min)	Project topic DUE Quiz #3 DUE
Mon Oct 5	R5	GA	Recitation			
Wed Oct 7	L11	SP	Evolution of the ME ● Isometry Eardrum and ossicles ● Ear drum (shape, orientation, composition, etc) FE modeling	Classes of Levers (video, 2 mins): Read: Puria (2020). "Middle Ear Biomechanics: Smooth Sailing', Acoustics Today Magazine 16, 3 (pp 27-34)	Read: Hemila et al., 1995 Read: Fay et al. 2006	PS #4 DUE PS #5 out
Th Oct 8						PS #3 corrections DUE Quiz #4 out
Fri Oct 9	L12	SP	Traveling wave and tuning in the cochlea ● Traveling wave ● FE modeling	Read: Bekesy, G. von (1956). "Simplified model to demonstrate the energy flow and formation of traveling waves similar to those found in the cochlea", PNAS 42 pp 930-944	Read: Puria and Steele (2008) Mechano-Acoustical Transformations	Quiz #4 DUE

					(pp 180-188, passive cochlea; pp 166-180 if you want a review of the middle ear)	
Mon Oct 12			Holiday: Indigenous Peoples' Day			
Tu Oct 13 10:30am - 11:30am	R6	GA	Recitation			
Wed Oct 14	L13	SP	Cochlear Amplification	Read: JO Pickles "An introduction to the physiology of hearing" Ch. 3	Read: Puria and Steele (2008) Mechano-Acoustical Transformations (pp 188-193)	PS #5 DUE PS #6 out
Th Oct 15						PS #4 corrections DUE Quiz #5 out
Fri Oct 16	L14	HH N	Alternative pathways to hearing ● Round Window Stim ● Bone conduction	Bone Conduction Hearing Aids (video, 5 min) Read: Stenfelt, S. (**2013**). "Bone Conduction and the Middle Ear," in *The Middle Ear: Science, Otosurgery, and Technology*, edited by S. Puria, R. R. Fay, and A. N. Popper	Read: Guan et al. 2020	Project topic details DUE Quiz #5 DUE
Mon Oct 19	R7	GA	Recitation			
Wed Oct 21	L15	SSG	Digital signal processing ● Representing sound in other domains ● Sampling, Filtering ● Separating source and filter	A/D and D/A (video, 23 mins) Signal Processing (video 13 mins) Aliasing demonstration (video, 7 mins) Read: Keith Johnson (Acoustic and Auditory phonetics): pp. 19 - 45 Read: Springer Handbook of Speech Processing (2008) pp. 161-180	Read: Discrete cosine transform - Wikipedia Read: MP3 - Wikipedia	PS #6 DUE PS #7 out

Th Oct 22						PS #5 corrections DUE Quiz #6 out
Fri Oct 23	L16	SSG	Speech perception ● Infant perception timeline ● Categorical perception ● Speaker variation	Read: Springer Handbook of Speech Processing (2008) pp. 61-81 (4.1.1, 4.1.2, 4.2.1, 4.2.3, 4.2.4, 4.3.1, 4.3.2) Language development The Emergence of Speech Sounds in Children (website, 30 minutes) Visual Manipulations of Acoustic Input (video, 3 minutes) McGurk effect (video, 3.25 minutes) Read: Response advantage for identification of speech sounds Classic review of categorical perception: Pisoni (1979) On the Perception of Speech Sounds as Biologically Significant Signals	Yanni or Laurel? As Explained by SHBT students! (video, 3 minutes) Read: Springer Handbook of Speech Processing (2008) pp. 27-56 Read: Magnotti, J. F., & Beauchamp, M. S. (2017). A causal inference model explains perception of the McGurk effect and other incongruent audiovisual speech. *PLoS computational biology*, *13*(2), e1005229. Read: https://www.jneurosci.org/content/38/27/6076	Quiz #6 DUE
Mon Oct 26	R8	JG, GA	Recitation			
Wed Oct 28	L17	SSG	Speech acoustics ● Phonetics: units of sound ● Acoustic properties and relations to vocal tract shapes	Read: Springer Handbook of Speech Processing (2008) pp. 7-24 Read: Keith Johnson (Acoustic and Auditory phonetics): pp. 102 -168	Wernicke's Aphasia (video, 2 minutes) Broca's Aphasia (video, 4 minutes) Read: Barbier, G., Perrier, P., Payan, Y.,	PS #7 DUE PS #8 out

				American English Consonants (video, 6 minutes) American English Vowels (video, 5 minutes) Non-English Phonemes (video, 9 minutes) What is Required to Produce Speech? (video, 3 minutes) Study: "44 Phonemes" Worksheet (25 minutes)	Tiede, M. K., Gerber, S., Perkell, J. S., & Ménard, L. (2020). What anticipatory coarticulation in children tells us about speech motor control maturity. *Plos one*, *15*(4), e0231484.	
Th Oct 29						PS #6 corrections DUE Quiz #7 out
Fri Oct 30	L18	SSG	Speech acoustics *(continued)*			Project Lit Review DUE Quiz #7 DUE
Mon Nov 2	R9	JG	Recitation			
Wed Nov 4	L19	SSG	Sensorimotor integration ● Interactions between production and perception ● Perturbation studies	Read: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3361736/ Read: Goldiamond, I., & Hawkins, W. F. (1958). Vexierversuch: The log relationship between word-frequency and recognition obtained in the absence of stimulus words. *Journal of Experimental Psychology*, *56*(6), 457.	Palatal Manipulations (website, 20 minutes) Read: Schuller, B. W., Friedmann, F., & Eyben, F. (2014, May). The Munich Biovoice Corpus: Effects of Physical Exercising, Heart Rate, and Skin Conductance on Human Speech Production. In *LREC* (pp. 1506-1510).	PS #8 DUE PS #9 out

Th Nov 5						PS #7 corrections DUE Quiz #8 out
Fri Nov 6	L20	SSG	Speech processing ● Extracting information from speech signals ● Non-linguistic and linguistic content ● Identity	Read: Springer Handbook of Speech Processing (2008) pp. 725-739 (36.1, 36.2) Read: GeMAPS paper	Read: Choi, J. Y., Hu, E. R., & Perrachione, T. K. (2018). Varying acoustic-phonemic ambiguity reveals that talker normalization is obligatory in speech processing. *Attention, Perception, & Psychophysics*, *80*(3), 784-797.	Quiz #8 DUE
Mon Nov 9	R10	JG	Recitation			
Wed Nov 11			Holiday: Veterans Day			
Thu Nov 12						PS #9 DUE PS #10 out PS #8 corrections DUE Quiz #9 out
Fri Nov 13	L21	TQ	Voice ● Voice quality ● Clinical pathologies that can impact vocal quality	Vocal Tract Manipulations (interactive website, 15 minutes) Phonation and Glottal States (video, 9 minutes) Apraxia of Speech Pt. 1 (video, 3 minutes) Apraxia of Speech Pt. 2 (video, 10 minutes)		Project Specific Aims page (Draft) DUE Quiz #9 DUE

				Read: Springer Handbook of Speech Processing (2008) pp. 83-96		
Mon Nov 16	R11	JG	Recitation			
Wed Nov 18	L22	SSH	Prosody ● Timing, intensity, pitch variation ● Accent ● Enhancements	Suprasegmental Information (video, 12 minutes) Prosody of American English (video, 8 minutes) Read: Read: Springer Handbook of Speech Processing (2008) pp. 471-485	Read: Springer Handbook of Speech Processing (2008) pp. 181-207	PS #10 DUE
Th Nov 19						PS #9 corrections DUE Quiz #10 out
Fri Nov 20	L23	SSG	Voice Technologies ● Voice assistants (e.g., Siri, Alexa) ● Assistive devices: Electro-larynx ● Speech enhancement	Adult Electrolarynx (video, 2 minutes) Child Electrolarynx (video, 4 minutes) Read: Nasirian, F., Ahmadian, M., & Lee, O. K. D. (2017). AI-based voice assistant systems: Evaluating from the interaction and trust perspectives. Read: Springer Handbook of Speech Processing (2008) pp. 539-554	TedXCuny: Speech is More than Words (video, 16 minutes) Press Article on Google Euphonia (5 minutes)	Quiz #10 DUE
Mon Nov 23			Holiday: Thanksgiving			
Wed Nov 25			Holiday: Thanksgiving			
Fri Nov 27			Holiday: Thanksgiving			
Mon Nov 30	R12	JG	Recitation			
Wed Dec 2	L24	SP	Auditory Technologies	Between Sound and Silence (video, 12 minutes)		

			• Acoustic Hearing Aids • Middle Ear Hearing Aids • Cochlear Implants • Auditory Brainstem Implants	Hearing Loss Simulator (play, 20 minutes) Read: Springer Handbook of Speech Processing (2008) pp. 903-926		
Fri Dec 4			Presentations			PS #10 corrections due
Mon Dec 7			No Class			
Wed Dec 9			Presentations			Project Specific Aims page (Final) DUE

For MIT students

All work in this course is governed by the academic integrity policies: https://integrity.mit.edu/
Information about academic accommodations: https://studentlife.mit.edu/sds/students/procedures-requesting-academic-accommodations
Student resources: https://resources.mit.edu/

For Harvard students

Academic Integrity
All work in this course is governed by the academic integrity policies of GSAS (https://gsas.harvard.edu/codes-conduct/academic-integrity) and HMS (https://mastersstudenthandbook.hms.harvard.edu/409-academic-dishonesty-and-plagiarism). It is the students' responsibility to be aware of these policies and to ensure that their work adheres to them both in detail and in spirit. Unless otherwise specified by the instructor, the assumption is that all work submitted must reflect the student's own effort and understanding. Students are expected to clearly distinguish their own ideas and knowledge from information derived from other sources, including from collaboration with other people. If you have a question about how best to complete an assignment in light of these policies, ask the instructor for clarification.

Reasonable Accommodations
As an institution that values diversity and inclusion, our goal is to create learning environments that are usable, equitable, inclusive and welcoming. Harvard University complies with federal legislation for individuals with disabilities and offers reasonable accommodations to qualified students with documented disabilities and temporary impairments. To make a request for reasonable accommodations in a course, students must first connect with their local disability office. The primary point of contact for GSAS students is the Accessible Education Office (www.aeo.fas.harvard.edu). The

HMS Director of Disability Services, Timothy Rogers (timothy_rogers@hms.harvard.edu) is another potential source of accommodation information for PhD students and is the primary contact for MD and master's students.

Accommodations are determined through an interactive process and are not retroactive. Therefore, students should contact their local disability office as soon as possible, preferably at least two weeks before accommodations are needed in a course. Students are strongly encouraged to discuss their access needs with their instructors; however, instructors cannot independently institute individual accommodations without prior approval from the disability office. Student privacy surrounding disability status is recognized under FERPA. Information about accommodations is shared on a need-to-know basis, and with only those individuals involved in instituting the accommodation.

Academic and other Support Services

We value your well-being and recognize that as a graduate student you are asked to balance a variety of responsibilities and potential stressors: in class, in lab, and in life. If you are struggling with experiences either in- or outside of class, there are resources available to help. Jackie Yun, the GSAS Director of Student Services (617-495-5005) is available to assist students navigating academic or personal difficulties and to connect students to university resources. HILS PhD students have access to free academic tutoring which can be arranged through the DMS office. A variety of academic support services are also available to GSAS students through the Bureau of Study Counsel (https://bsc.harvard.edu/) and the Center for Writing and Communicating Ideas (https://gsas.harvard.edu/center-writing-and-communicating-ideas).

All students have access to Counseling and Mental Health Services (CAMHS) available in Longwood, Cambridge or remotely via webcam or phone. The use of CAMHS is included in the student health fee, regardless of insurance, at no additional cost. More information is available at https://camhs.huhs.harvard.edu or by calling the main office at 617-495-2042. Urgent care can be reached 24/7 at 617-495-5711.