ME 515

# Vibrations of Complex Systems

Fall 2009, Mon-Wed 8-10 am, Room 202, Photonics Building

***Overview:*** The course as given this year differs considerably from that in previous years, because of the inclusion of lectures on the quantum mechanical aspects of vibrations, on electromechanical vibrations, and on vibrations of very small scale (microscale and nanoscale) structures. There is less emphasis on random vibrations, statistical energy analysis, fuzzy structures, and nonlinear vibrations.

***Prerequisites:*** Knowledge of mathematics, physics, dynamics, fluid and solid mechanics at the level of mastery of required courses in a standard mechanical engineering curriculum. ME 515 is typically taken only by graduate students. Undergraduates are encouraged to take instead the senior elective: ME 414, Mechanical Vibration.

***Textbooks:*** Ginsberg: Mechanical and Structural Vibrations (required). Crandall et al: Dynamics of Mechanical and Electromechanical Systems (reference). Pippard: Physics of Vibration (reference).

***Course requirements:*** Regular and punctual attendance at lectures. Weekly homework assignments, which will be graded. Homework problems will frequently require numerical calculation using a computer and standard software, such as Octave, MatLab, or Mathematica. (Octave is the free open source counterpart of MatLab.) There will be two open book quizzes (Sept. 30 and Oct. 26) and a final exam.

***Topics (tentative, and by week)***

1. Elementary models of vibration. Lumped parameters. Vibrating string. Electric circuits. Cyclical motions.
2. Harmonic oscillator equation. Matrix formulation. Natural modes. Sturm-Liouville eigenvalue problems. Orthogonality. Superposition. Rigid body idealizations.
3. Initial value problems. Lagrange's equations. Hamilton's principle. Piezoelectricity. Electromechanical oscillations.
4. Schroedinger.s equation. Quantum-mechanical oscillator. Electro-mechanical vibrations.
5. Rayleigh's principle. Rayleigh-Ritz method. Perturbation techniques. Impedance. Helmhotz resonators.
6. Reciprocity. Models for forces. Flow-induced vibrations. Rotating machinery. Born-Oppenheimer approximation. Molecular vibrations. Boltzmann distribution.
7. Corrugated roads. Damping models. Anelasticity. Dashpots. Voigt model. Zener model. Relaxation. Complex number description of forced vibrations.
8. Rayleigh dissipation funnction. Lagrange-Rayleigh equations. Light damping approximation. Quality fractor and fraction of critical damping. Power flow in forced vibration. Spectral density. Tuned vibration absorber.
9. Continuum models of vibrations. Rods, beams, and plates. Surface energy effects. Microphones, accelerometers, and transducers.
10. Cavity oscillations. Sloshing vibrations. Ocean wave energy conversion devices . Photons and phonons. Einstein theory of specific heat.
11. Vibrational relaxation. Attenuation of cavity oscillations. Radiation damping. Bubble oscillations. Resonance scattering.
12. Interacting oscillators. Equipartition principle. Quantum-mechanical Hamiltonians. BCS theory of superconductivity. Statistical energy analysis.

***About the instructor:*** Allan D. Pierce is currently Professor of Mechanical Engineering at Boston University, and is also an Adjunct Scientist at the Woods Hole Oceanographic Institution and the Editor-in-Chief of the Acoustical Society of America(ASA). He is a past recipient of the Per Bruel Gold Medal of the American Society of Mechanical Engineers, the Gold Medal of the Acoustical Foundation of India, the ASA Silver Medal in Physical Acoustics, the Rossing Prize in Acoustics Education, and the ASA Gold Medal. Before coming to Boston University to take on the position of Department Chair (1993), he was holder of the Leonhard Chair in Engineering at Penn State, and before that he was Regents' Professor at Georgia Tech. He is a Life Fellow ot the ASME and a Registered Professional Engineer.