Name: __________________

ME 513Q

Final Exam – Fall 2006 --- 12/13/2006

Note: To help you complete this exam, you may refer to your class notes, your homework, solutions provided to you and other material distributed as part of the course, and the text (Kinsler, Frey, Coppens and Sanders) or to any other acoustics text

- Problem 1: ____________/30
- Problem 2: ____________/20
- Problem 3: ____________/20
- Problem 4: ____________/20
- Problem 5: ____________/20
- Problem 6: ____________/20

Problem 1.

(i) What is sound?

(ii) Does the sound speed depend on ambient atmospheric pressure (given that the temperature is constant)?

(iii) What is the acoustical “inverse square law”?

(iv) Why was the reference intensity chosen to be 1×10^{-12} W/m^2?

(v) At the interface between two ideal fluids, which component of the acoustic particle velocity is not continuous across the interface? Why?

(vi) When a plane wave in air hits the surface of a very deep layer of water at normal incidenece, the transmitted pressure magnitude is ___________________ than that of the incident wave while the transmitted intensity is ____________________ than that of the incident wave.

(vii) When considering sound transmission through a limp barrier, doubling either the ______________________ or the ________________________ causes the transmission loss of the barrier to increase by 6 dB.

(viii) When can a reflecting surface be modeled as being “locally reacting”?

(ix) An unbaffled loudspeaker can be modeled as a __________________________ .

(x) When a point monopole is placed at the junction of three rigid, perpendicular surfaces, __________________ image sources are required to satisfy the hard wall boundary conditions.

(xi) Consider a piston of area S and oscillatory velocity U in a rigid baffle. When the piston radius is very small compared to a wavelength, the piston source may be modeled as a _______________________ in free space having source strength __________________ .

(xii) In a public address system, why is it normal to use many high frequency drivers, and a relatively small number of low frequency drivers?

(xiii) The first plane wave resonance of a open-ended tube occurs when the tube is approximately what fraction of a wavelength long?

(xiv) A duct terminates in an unflanged opening. The acoustic particle velocity in the tube is approximately a ____________________ at the opening.

(xv) Acoustic loading of a loudspeaker usually causes the natural frequency of the loudspeaker to be ______________________________ .

Problem 2.

A uniformly tensioned string of finite length (tension T and mass per unit length ρ_s) is attached to a rigid support at $x = 0$, and at $x = L$ it is transversely constrained by a spring of stiffness s.

(i) Give the general complex harmonic form for the transverse displacement of the string.
(ii) Give the boundary conditions at both ends of the string.
(iii) By applying the boundary conditions, derive the transcendental characteristic equation (written in terms of kL, where k is the wave number for transverse wave motion on the string) that could be solved to give the natural frequencies of the system.
(iv) Sketch both sides of the characteristic equation as a function of kL, and show how the natural frequencies could be located graphically.

Problem 3.

When sound transmits into a fluid region at an angle greater than the critical angle, its spatial variation has the form

$$\tilde{p}(x, y) = Ae^{-\gamma x}e^{-jk_y y}$$

where x is normal to the interface, y is parallel with the interface, and γ and k_y are both real constants.

(i) Calculate the vector particle velocity field that corresponds to the given sound pressure field.

(ii) Calculate the vector intensity field for this sound field and thus prove that there is no energy flow normal to the fluid interface at incidence angles greater than the critical angle.

Problem 4.

A dipole can be considered to consist of two monopoles of equal strength operating 180 deg. out-of-phase with each other. The sound field radiated by the dipole is zero on the plane defined by $\theta = \pi/2$, where θ is the polar angle measured from the dipole axis. However, it may be desirable that the sound field be zero on some other plane.

So, imagine that the phase, φ, of the first of the two monopoles that make up the dipole is set to $\pi/4$: i.e., the sound field radiated by the first monopole is $(A/r_1)e^{-jkr_1}e^{j\pi/4}$.

By following an approach similar to that used to derive the farfield of a dipole, find an expression for the polar angle at which the radiated sound pressure is zero in this case.

Problem 5.

A loudspeaker is placed at one end of a duct of constant cross-sectional area S that is terminated at $x = L$ by a massless piston connected to a pure stiffness reactance as shown (note that you may assume that there is a vacuum outside the tube: i.e., there is no acoustic loading applied to the exterior of either the massless piston or the loudspeaker diaphragm). The loudspeaker diaphragm has a mass m, and its suspension has been designed to provide negligible stiffness and damping. The delivery of a voltage to the loudspeaker voice coil causes an oscillatory force to be applied to the diaphragm as shown below.

(i) Give an expression for the termination impedance, Z_{mL}, provided by the combination of the massless piston and the spring.

(ii) Give an expression for the acoustic loading, Z_{m0}, acting on the loudspeaker in this case. Give the result in terms of kL and the ratio of the termination stiffness to the stiffness of the air in the duct: i.e., the ratio $b = s_t/(S\rho_0 c^2/L)$.

(iii) Give a simplified expression for Z_{m0} that is valid when $kL << 1$.

(iv) Also under the condition $kL << 1$, give an expression for the total impedance experienced by the force acting on the loudspeaker diaphragm.

(v) Show that when $kL << 1$, the natural frequency of the acoustically-loaded loudspeaker diaphragm is:

$$\omega = \sqrt{\frac{s_t}{(1+b)}\frac{1}{m}}$$

Problem 6. (20 points):

Part A (10 points)

i. When the energy acoustics approach to room acoustics is adopted, it must be assumed that the sound field is ___________________________ .

ii. At steady-state conditions, the rate at which energy is input to a space by an acoustic source is equal to:

iii. In a "normal" room, the Energy Acoustics approach cannot be used to calculate the details of the sound decay in the first 50 ms after a sound source is turned off because:

iv. The reverberation time is usually frequency-dependent because:

v. A layer of porous material is usually a more effective absorber at _______________ frequencies than at _________________________ frequencies.

Part B (10 points)

A room is 10 m in length, 8 m wide and 3 m in height. The ceiling is covered by tiles having an absorption coefficient of 0.5 and the floor is covered by a carpet having an absorption coefficient of 0.25. The absorption at the walls may be considered negligible.

(i) What is the average Sabine absorption coefficient of the space?

(ii) What is the reverberation time in this space?

(iii) Given a source having a sound power of 1 W, what is the reverberant sound pressure level in the space?

(iv) If the ceiling absorption is increased to 0.8, by how much is the reverberant sound pressure level in the space reduced?