Name: ______________________________

ME 513 --- Engineering Acoustics

Final Exam – Fall 2009 --- 12/16/2009

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) What are the characteristics of a stiffness-like impedance?

(iii) When a SDOF system is driven by an external force at its natural frequency, the system is said to be ____ .

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

(v) What is the acoustical "inverse square law"?

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

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

(viii) When a plane wave in air hits the surface of a very deep layer of water at normal incidence, the transmitted pressure magnitude is approximately ___________________ that of the incident pressure magnitude.

(ix) 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.

(x) When can a reflecting surface be modeled as being "locally reacting"?

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

(xii) 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.

(xiii) 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 __________________ .

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

(xv) Acoustic loading of a loudspeaker usually causes the natural frequency of the loudspeaker to be ___________________________________ compared to the value it would have in a vacuum.

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, defining quantities as necessary.
(ii) Draw a free body diagram of the forces acting at the end of the string at $x = L$.
(iii) Give the boundary conditions at both ends of the string in equation form.
(iv) 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.
(v) Sketch both sides of the characteristic equation as a function of kL, and show how the natural frequencies could be located graphically.
(vi) Give an approximate expression for the allowed values of $(kL)_n$ when n is large.

Problem 3.

The spatial variation for the first non-planar mode in a two-dimensional hard-walled channel of width L is:

$$p(x,y) = A_1 \cos\left(\frac{\pi y}{L}\right) e^{-jk_1 x}$$

$$where: k_1 = \left[k^2 - \left(\frac{\pi}{L}\right)^2\right]^{\frac{1}{2}}$$

and $k = \omega/c$, c is the ambient sound speed and A_1.is complex.

(i) Derive the vector particle velocity field by using the linearized momentum equation.

(ii) Calculate the vector intensity field in the channel, and show, in particular, that the y-component of the intensity is equal to zero.

(iii) Explain, based on your results, why the x-component of the intensity is also equal to zero when $k^2 < (\pi/L)^2$.

Problem 4.

A thin, limp membrane having mass per unit area m_s is positioned a distance L above a rigid surface as shown in the sketch below. A plane wave strikes the membrane at normal incidence.

(i) Give the appropriate assumed solutions form for the sound field in the region between the membrane and the rigid backing.

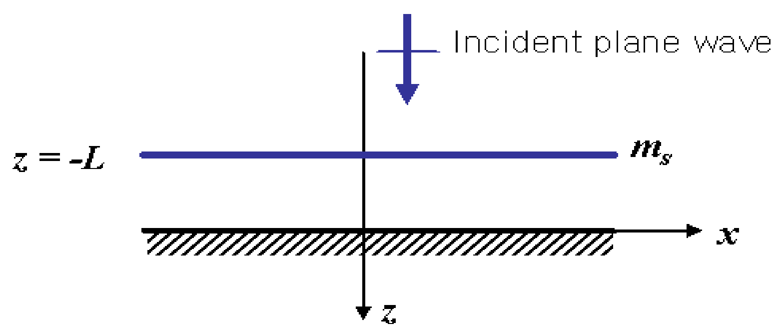
(ii) By using the linearized Euler equation, derive an expression for the particle velocity in the region between the rigid backing and the membrane.

(iii) Apply the appropriate boundary condition at the rigid backing surface, and give a solution for the sound field between the rigid backing and the membrane in terms of a trigonometric function.

(iv) Calculate the normal specific acoustic impedance, z_b, on the positive-z-facing side of the membrane: i.e., at $z = -L^+$.

(v) Calculate the total normal specific acoustic impedance, z_t of the membrane *plus* the backing airspace: i.e., find the impedance on the negative-z-facing side of the membrane at $z = -L^-$.

(vi) For the case $kL << 1$, find an approximate expression for the resonance frequency of this system.



Problem 5.

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 in some other direction.

So, imagine that the phase, φ, of the first of the two monopoles that make up the dipole is set to $\pi/2$: i.e., the sound field radiated by the first monopole is $(A/r_1)e^{-jkr_1}e^{j\pi/2}$.

By following an approach similar to that used in class 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. Give the approximations used to arrive at the solution.

Problem 6.

A circular rigid piston in a rigid baffle radiates into air at 100 Hz. The radius of the piston is 0.05 m.

(i) Calculate the *displacement* amplitude of the piston required to produce a sound pressure level of 90 dB re 20 μPa at a distance 2 m in front of the piston. Make use of whatever simplifying assumptions you feel appropriate under these conditions (but justify your assumptions). Comment on why a relatively large displacement amplitude is required in this case.

(ii) By using the appropriate form of the radiation impedance, calculate the sound power radiated by the piston.