Name: ______________________________

ME 513Q --- Engineering Acoustics

Final Exam – Fall 2007 --- 12/13/2007

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, it is said to be ____ .

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

(v) In the development of the wave equation for an ideal fluid, the fluid is assumed to have no ______________________________ and to undergo ___________________________ compression.

(vi) When a plane wave in air hits the surface of a very deep layer of water at normal incidence, 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) A “Level” has the units of _____________________________________ .

(ix) A small axial fan 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) Does a point monopole possess a “velocity nearfield”?

(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 an open-ended tube occurs when the tube is approximately what fraction of a wavelength long?

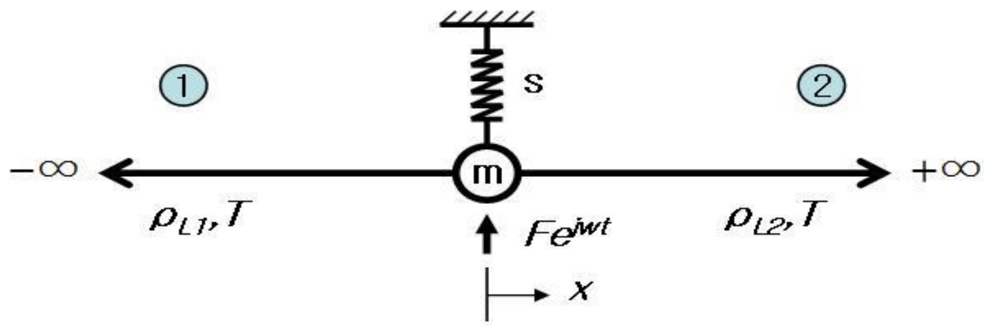
(xiv) For a uniform piston that is large compared to wavelength and which is mounted in an infinite baffle, sketch the complete characteristics of the on-axis sound pressure magnitude as a function of distance from the center of the piston.

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

Problem 2.

An undamped single-degree-of-freedom system consisting of a mass, *m*, and a stiffness, *s*, is attached to two semi-infinite tensioned strings as shown in the sketch below.

(i) Give the appropriate assumed solutions for the waves in strings 1 and 2, and define as appropriate the quantities appearing in these expressions.
(ii) Draw the free-body-diagram at $x = 0$.
(iii) Give in equation form the boundary *conditions* that applies at $x = 0$.
(iv) By applying the boundary conditions solve for the transverse displacement of both string segments
(v) Calculate the input mechanical impedance experienced by the force.



Problem 3.

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.

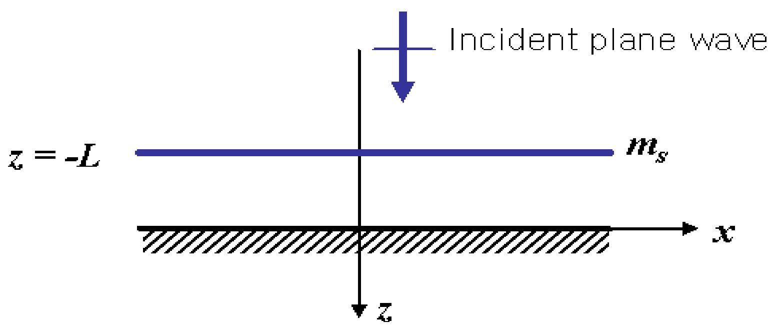
(ii) By using the linearized Euler equation, derive an expression for the particle velocity in the region between the rigid backing and the membrane.

(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 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 $\pi/2$: 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 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 circular rigid piston in a rigid baffle radiates into air at 100 Hz. The radius of the piston is 0.01 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 such a 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.

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?