NAME: ______________________________
(Last) (First) (Middle)

ME 41300 Noise Control
Spring 2010
Mid-Term Examination
Tuesday, March 2, 2010
Time: 6:30 pm – 8:30 pm

INSTRUCTIONS

Work on one side of each sheet only, with only one problem on a sheet.

Please turn off your cell phone and leave it in your backpack. Make sure all computers you brought are in your backpack. Your backpack is not to be opened during the examination.

There are a total of 4 (**FOUR**) questions in this examination paper: Question 1 and Question 4 is worthy of 25 points each, Question 2 is worthy of 30 points and Question 3 is worthy of 20 points.

Please remember that in order for you to obtain maximum credit for a problem, the solution must be clearly presented, i.e.,

- any assumptions used to arrive your solutions must be clearly stated,
- wherever appropriate, clearly labeled diagrams must be drawn.
- units must be clearly stated as part of the answer.

If the solution does not follow a logical thought process, it will be assumed in error.

When handing in the examination, please make sure that all sheets are in correct sequential order. If necessary, remove the staple and re-staple the sheets in order.

Unless stated otherwise, you may take the mean density and sound speed of air, water and hydrogen to be 1.21 kg m^{-3}, 340 m s^{-1} , 1000 kg m^{-3} and 1450 m s^{-1} , 0.08 kg m^{-3} and 1305 m s^{-1} respectively.

Question 1: ________ / 25

Question 2: ________ / 30

Question 3: ________ / 20

Question 4: ________ / 25

Total: ________________

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Question 1 (25 points)

(a) An accelerometer indicates that the acceleration of a body is sinusoidal at a frequency of 30 Hz with the maximum acceleration of 65 m s^{-2}. What are the amplitude of the displacement and the maximum velocity of the body?

(b) The algebraic sum of two harmonic motions x_1 and x_2 is given by

$$\begin{aligned} x &= x_1 + x_2 \\ &= A\cos(\omega t + \theta) \end{aligned}$$

where $x_1 = 2\sin(\omega t - \pi/3)$, $x_2 = -3\cos(\omega t + 3\pi/4)$ and ω is the angular speed of the harmonic motions. Draw x_1 and x_2 on a phasor diagram and represent them by complex notations. Hence, or otherwise, find the magnitude, A and the phase, θ of x.

(c) If the two parallel surfaces of a room are separated by 10 m, determine the lowest frequency for resonating standing waves that exist between the surfaces.

(d) The motion of a body can be approximated as sinusoidal. The instantaneous position, $x(t)$ of the body can be described in a form of

$$x(t) = X\sin(\omega t + \psi) ,$$

with a frequency of 50 Hz. The position and velocity of the body when $t = 0$ are 7 mm and 1.2 m s^{-1} respectively. Find the constants X, ω and ψ.

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Question 2 (30 points)

(a) You are asked to do a noise measurement in a workshop. Explain the concept of corrections for background noise levels when you want to estimate the noise levels radiated from a machine. State the assumption you have made in your analysis.

The sound pressure level due to the machine is 92 dB. If this machine operates when the workshop background SPL is 89 dB, what is the resultant SPL in the workshop?

(b) What is the maximum pressure in the sound wave generated by a rigid door slammed to stop impulsive from 'tip' speed of 10 m s^{-1}. What is the sound pressure level generated by the slamming door? (Hint: you consider the equation linking the acoustic pressure with the particle velocity for plane waves in this problem). You may take the reference sound pressure, p_{ref}, as 2×10^{-5} pa.

(c) Find the power output of a sound source which radiates uniformly into unobstructed space in air if the rms sound pressure at a distance of 5 m is 1 Pa. What is the sound power level of the sound source? You may take the reference sound power, w_{ref}, as 1×10^{-12} w.

(d) Suppose another sound source was placed about a hard ground and the measured rms sound pressure at a distance of 5 m is also 1 Pa. What are the sound power and the sound power level of this sound source? You may assume the same amount of sound energy is absorbed by the ground.

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Question 3 (20 points)

(a) Explain the differences between low pass, high pass and band pass filters.

(b) What are the lower band and upper band frequency of the one-third octave band with the center frequency of 4000 Hz? What is the corresponding bandwidth of this one-third octave band?

(c) Explain the difference between white noise and pink noise sources.

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Question 4 (25 points)
The acoustic impedance of sound absorption materials can be determined by means of an impedance tube. A sample of the material is placed at one end of a long tube and a loud speaker is placed at the other end of the tube. A pure tone acoustic signal is sent from the loud speaker and the sound pressure is measured along the tube from the surface of the sample. Explain (with diagrams) the principle for determining the acoustic impedance of the sound absorption materials. You are **NOT** required to derive the formula.

A 200 Hz plane wave in air is normally incident on an absorptive panel. The resulting standing wave has a *standing wave ratio* of 10 and the node closest to the panel of 0.5 m measured from it. Find the normalized impedance of the absorptive panel.

You may use the relevant formulas shown in the following page.

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Theory of the impedance tube

$$\frac{e^{-ikL} + \hat{R}e^{ikL}}{e^{-ikL} - \hat{R}e^{ikL}} = \frac{\hat{Z}_s}{\rho_0 c_0} = \hat{\zeta}_s$$

$$\hat{R} = \frac{\hat{B}}{\hat{A}} = \frac{\hat{\zeta}_s - 1}{\hat{\zeta}_s + 1} e^{-2ikL}$$

Let $\hat{R}_s = \dfrac{\hat{\zeta}_s - 1}{\hat{\zeta}_s + 1}$

$$\left(\hat{R}_s = \left|\hat{R}_s\right| e^{i\delta_s}\right)$$

Then, $\hat{\zeta}_s = \dfrac{\hat{Z}_s}{\rho_0 c_0} = \dfrac{1+\hat{R}_s}{1-\hat{R}_s}$

$$\left(p^2\right)_{av} = \frac{1}{2}\left|\hat{p}\right|^2 = \frac{1}{2}\left|\hat{A}\right|^2 \left|1+\hat{R}_s e^{-2iky}\right|^2 = \frac{1}{2}\left|\hat{A}\right|^2 \left[1+\left|\hat{R}_s\right|^2 + 2\left|\hat{R}_s\right|\cos\left(\delta_s - 2ky\right)\right]$$

1) Standing wave ratio: $s = \dfrac{p_{rms,max}}{p_{rms,min}} = \dfrac{u_{rms,max}}{u_{rms,min}}$

2) Location of any node or anti-node: $\left|\hat{R}_s\right| = \dfrac{s-1}{s+1}$

$$\delta_s = 2ky_{max,1} + 2m\pi \qquad m = 0,1,2,3,\ldots$$

$$= 2ky_{min,1} + (2n+1)\pi \qquad n = 0,1,2,3,\ldots$$

where $k = \omega/c$

The symbols used in above equations have their usual meanings.

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Purdue University
ME 413 - NOISE CONTROL
SPRING 2010 – Mid term Exam (Indicative Answers)

Question 1

(a)

Maximum Displacement = $A \cong 1.83$ mm

Maximum Velocity = 0.345 m s^{-1}

(b)

$\hat{x} = \hat{x}_1 + \hat{x}_2 = 0.38927 - 3.12132i = 3.1455e^{-i(1.446)}$

i.e. $x = \text{Re}\left[3.1455e^{i(\omega t - 1.446)}\right]$

(c) 17 Hz

(d)

$\omega = 314.159$ rad s^{-1}

$X = 7\times10^{-3}/\sin\psi = 8$ mm

$\psi \approx 61.38^0 = 1.07^c$

Question 2

(a)

Total noise level = 93.8 dB

(b)

SPL = 166 dB

(c)

Not covered in the course materials yet

(d)

Not covered in the course materials yet

Question 3

Not covered in the course materials yet

Question 4

$$\varsigma_s = \frac{1+\hat{R}_s}{1-\hat{R}_s} = 1.204 + 3.069i$$