EE 480 Exam #1 NAME: ________________________________.

October 5, 2004 50 Minutes 30 points total OPEN BOOK and NOTES (but no consultants!)

3 problems, 3 pages

SHOW YOUR WORK: Correct answer with no work shown may not receive credit.
Wrong answer with work shown will receive partial credit.

Unless otherwise stated, assume propagation in air, 1 atm, 20°C, c = 343 m/sec $\rho_0 c$ = 415 Pa · sec/m

(1) A harmonic plane wave is propagating through air at 1 atm, 20° C, with a frequency of 200 Hz. A standard sound level meter <u>with 'A'-weighting filter</u> reports 85 dB SPL re 20μPa.

(a) (3 pts.) Determine the *RMS pressure* <u>and</u> the *pressure amplitude* for this wave.

From handout graph (NOTE that handout needs correction!): 85dBA @ 200 Hz is 105dB linear

$$P_e = 20\,\mu\text{Pa}\cdot 10^{105/20} = 3.5566\text{ Pa}$$

$$P = \sqrt{2}\,P_e = 5.0297\text{ Pa}$$

(b) (2 pts.) What would the meter report if a 'C'-weighting filter was used instead of the 'A'-weighting filter?

From handout graph (NOTE that handout needs correction!): 85dBA @ 200 Hz is 105dBC

(c) (3 pts.) Determine the wavelength.

$$\lambda = \frac{c}{f} = \frac{343\text{ m/sec}}{200\text{ /sec}} = 1.715\text{ m}$$

(d) (2 pts.) If the temperature increased to 40° C, what would the wavelength be?

$$c_{40} = c_0\sqrt{1+T/273} = 331.6\sqrt{1+40/273} = 355.06\text{ m/sec}$$

$$\lambda_{40} = \frac{c_{40}}{f} = \frac{355.06\text{m/sec}}{200\text{/sec}} = 1.775\text{ m}$$

(2) A small source (ka<<1) of spherical waves radiates into air at 150 Hz.

(a) (3 pts.) At **what distance** from the source will the pressure and particle speed be 45° out of phase?

Relationship between pressure and particle speed is the *acoustic impedance*.

$$\tan\theta = \frac{1}{kr}$$

$$\text{If } \theta = \frac{\pi}{4}, \tan\theta = 1, \text{ so}$$

$$\rightarrow r = \frac{1}{k} = \frac{c}{\omega} = \frac{343}{2\pi 150} = 0.36 \text{ m}$$

(b) (3 pts.) What is the numerical value of the complex **specific acoustic impedance** at the distance determined in (a)?

At this distance, *kr*=1, so

$$\tilde{z} = \rho_0 c \frac{(kr)^2}{1+(kr)^2} + j\rho_0 c \frac{kr}{1+(kr)^2} = \frac{\rho_0 c}{2} + j\frac{\rho_0 c}{2} = 207.5 + j207.5 \text{ Pa}\cdot\text{s/m}$$

(c) (4 pts.) The pressure amplitude is found to be 0.05 Pa at a distance of 30 cm from the source. What is the **particle speed amplitude (U)** and **particle displacement amplitude** at this distance?

$$k = \frac{\omega}{c} = 2.7477 \text{ /m}$$

$$kr = 0.8243$$

$$\cos\theta = \frac{kr}{\sqrt{1+(kr)^2}} = 0.6361$$

$$U = \frac{P}{\rho_0 c \cos\theta} = 1.89\times10^{-4} \text{ m/sec}$$

$$\text{Displacement Amplitude} = \frac{U}{\omega} = 2\times10^{-7} \text{ m}$$

(3) It is necessary to obtain at least a 1 centimeter displacement amplitude in a simple mechanical loudspeaker system with the following parameters:

R_m = mechanical resistance = 2 N·s/m
m = mass = 10 grams (0.01 kg)
f(t) = applied force = 40 cos(2π·100t) N

What is the **required stiffness** for which the steady-state displacement amplitude will be at least 1 centimeter?

Displacement amplitude (steady state) of driven oscillator: $\frac{F}{\omega Z_m} \geq 0.01\,\mathrm{m}$

$F = 40\ \mathrm{N}$

$\omega = 2\pi \cdot 100\ \mathrm{rad/sec}$

$\Rightarrow \mathrm{Z_m} \leq 6.3662\ \mathrm{N \cdot sec/m}$

$$\mathrm{Z_m} = \sqrt{R_m^2 + \left(\omega m - \frac{s}{\omega}\right)^2}$$

$$s = \omega\left(\omega m \pm \sqrt{Z_m^2 - R_m^2}\right)$$

$$\Rightarrow 150.4 \leq \mathrm{s} \leq 7745\ \mathrm{N/m}$$