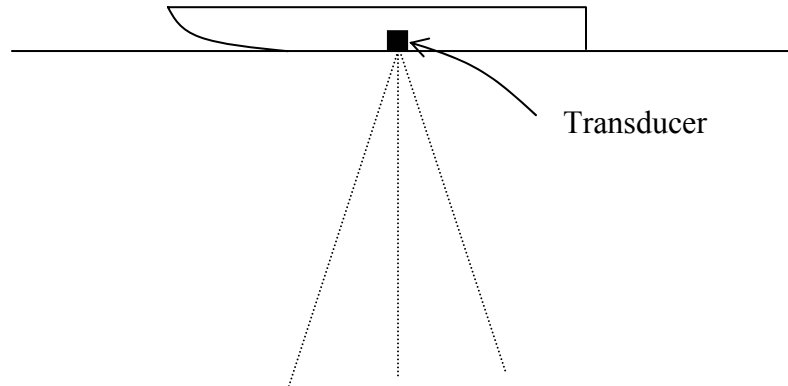


**ME413/513 Final Exam**

Instructions: 110 minutes to complete the exam. Open-book, open-notes. Perform computations on separate paper. Turn computations and exam in to instructor.

115 Total Points for Exam.

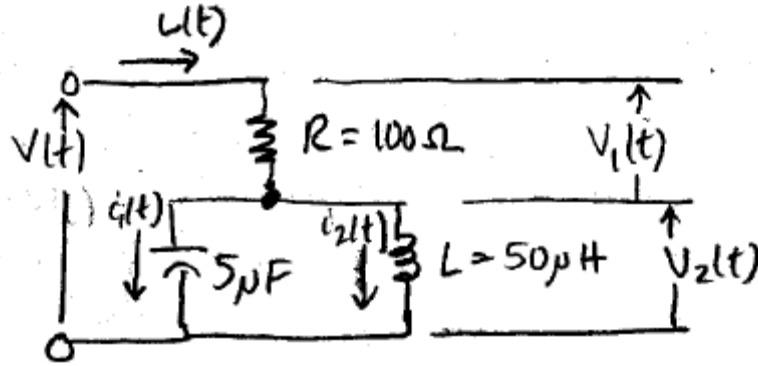
1. (30 Points) Consider the fish-finder sonar shown below



The system consists of a piezoelectric transducer mounted in the hull of a small boat. According to the manufacturer, the transducer is circular, 1 inch in diameter, and operates at a frequency of 200 kHz. To answer the questions below, you may approximate the boat hull by a planar rigid baffle.

- (5 Points) What size fish would be "visible" to the sonar?
- (5 Points) What is the distance to the farfield?
- (5 Points) What is the angular width of the major lobe?
- (5 Points) At 100 ft in depth, what is the diameter of the major lobe in feet?
- (10 Points) Suppose that an acoustic pressure amplitude of 30 Pa is required at a depth of 600 feet. What peak-to-peak displacement amplitude would be required of the transducer to achieve this pressure amplitude?

2. (30 Points) Consider the circuit shown below.



Voltage loop and current node equations give

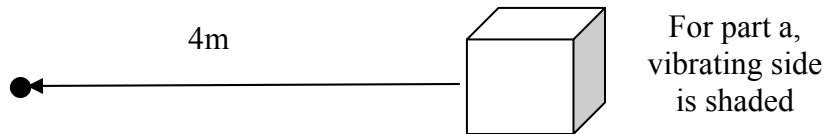
$$V(t) = V_1 + V_2,$$

$$i_1 + i_2 = i,$$

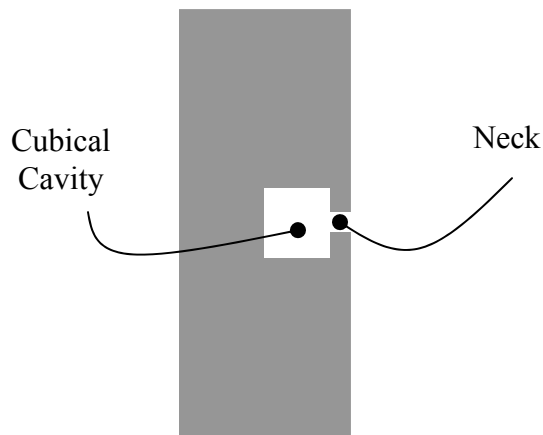
where  $i_1 = C \frac{dV_2}{dt}$ ,  $i_2 = \frac{1}{L} \int V_2 dt$ , and  $V_1 = Ri$ . Given that  $V(t) = 5 \cos(2\pi 9000t)$  volts,

- (15 Points) Compute  $V_2(t)$ .
- (15 Points) Compute the time-averaged power  $\Pi$  dissipated in the resistor  $R$ .

3. (20 Points) A cube-shaped object of side dimension  $3\text{in}=3*0.0254\text{m}$  radiates sound in air at a frequency of 200 Hz.



- a. (10 Points) If one side of the cube vibrates with a displacement amplitude of 5mm, what is the sound pressure amplitude in dB re  $20\mu\text{Pa}$  4m directly behind the vibrating side?
- b. (10 Points) If *two* sides of the cube vibrate *in-phase* with a displacement amplitude of 5mm, what is the time-averaged acoustic sound power output of the source?
4. (20 Points) A sound-absorbing material is fabricated by micro-machining small cavities in a material. The geometry of each cavity is shown below



The cavity volume is cubical in shape. The neck is circular in cross section,  $40\mu\text{m}$  in diameter, and  $10\mu\text{m}$  long. The theory is that the cavity will attenuate sound incident to the surface at frequencies near the resonant frequency of the micro-machined cavities. The propagation medium is air. (Note: viscous shear is to be neglected).

- a. (15 Points) Choose the side dimension of the cavity to remove incident sound at a frequency of 3000 Hz.
- b. (5 Points) Is the design consistent with the required assumptions? Support with numerical computations.

5. (15 Points) Consider a wave to be generated by a rigid  $yz$  plane, oscillating back and forth harmonically in the  $x$  direction. The propagation medium is air.
- a. (5 Points) What direction does the plane wave propagate in the half-space  $x > 0$ ?
  - b. (5 Points) If the frequency of oscillation is 1.2 kHz, what is the wavelength?
  - c. (5 Points) To cause a pressure amplitude of 10 Pa, what displacement amplitude is required of the moving boundary?