Worksheet #8

PHYS 4C: Waves and Thermodynamics

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October 20, 2025

1 Problem 1

The speed of sound in steel is 5941 m/s. Steel has a density of around 7900 kg/m^3 (depends somewhat on the alloy content).

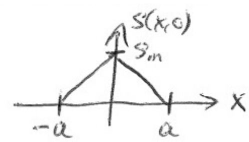
a. Based on this information, what is the bulk modulus of steel?

b. A steel rod of cross-sectional area A is placed on the x-axis. The following sound pulse is sent through the steel rod in the +x direction:

$f(x) = s(x, 0) = s_m(1 - |x|/a)$, if $|x| < a$.

$f(x) = s(x, 0) = 0$, if $|x| \geq a$.

Determine the total energy of this pulse.



Sound pulse graph

c. Now suppose a sinusoidal sound wave with frequency 440 Hz is sent through steel with a sound level of 100 dB. Calculate s_m and Δp_m for this sound wave.

1.1 Solution (a)

The bulk modulus is used as part of an equation for the velocity.

$$v = \sqrt{\frac{B}{\rho}} \tag{1}$$

This can be solved for the bulk modulus.

$$B = \rho v^2 \tag{2}$$

We know all the values necessary, so we can solve this equation.

$$B = (7900\,\text{kg/m}^3)(5941\,\text{m/s})^2 = \boxed{2.788 \times 10^{11}\,\text{kg/m}\cdot\text{s}^2} \tag{3}$$

1.2 Solution (b)

We know the speed of the sound in the steel.

1.3 Solution (c)

We know the sound level. This can be used to calculate the intensity.

$$\beta = 100\,\mathrm{dB} = (10\,\mathrm{dB})\,\log_{10}\frac{I}{I_0} \tag{4}$$

$$10 = \log_{10}\frac{I}{I_0} \tag{5}$$

$$10^{10} = \frac{I}{10^{-12}\,\mathrm{W/m^2}} \tag{6}$$

$$10^{10} * 10^{-12} = 10^{-2}\,\mathrm{W/m^2} = I \tag{7}$$

Next, we

2 Problem 2

A half-open organ pipe is tuned to A(440) (i.e., the fundamental frequency is 440 Hz). Air has a density of 1.21 kg/mol and a speed of sound of 343 m/s at 20°C.

a. What is the length of the pipe?

b. What is the maximum kinetic energy density (per unit volume) at the open end of the pipe if $s_m = 2.0\,\mu\mathrm{m}$? At the closed end?

c. If the ambient temperature were raised from 20°C to 40°C, what would be the new fundamental frequency of the pipe (ignore changes in the length of the pipe due to the temperature change)?