# Worksheet #8

PHYS 4C: Waves and Thermodynamics

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# 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).

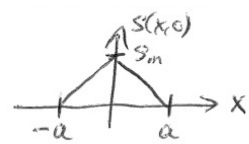
a. Based on this information, what is the bulk modulus of steel?

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 $\Delta p_m$ 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.

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

### 1.2 Solution (b)

First, using the equations of $f(x)$, 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)?