TUNING FORK SOUND AND VIBRATION   Revision B

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Introduction

Tuning forks are used to tune musical instruments. They are also used for certain hearing tests. In addition, tuning forks are useful for science demonstrations.

A tuning fork is shown in Figure 1. Its mode shape is shown in Figure 2.

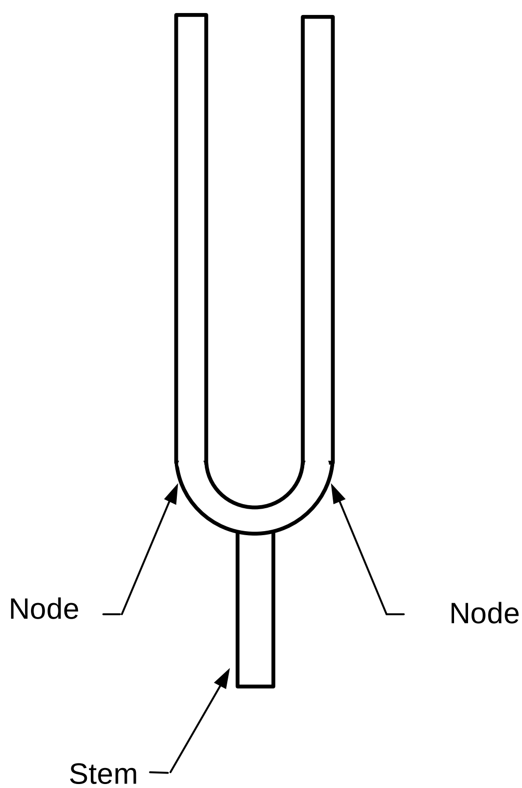

Figure 1. Tuning Fork Geometry

The node points are the points which remain stationary as the tuning fork is vibrating in its fundamental mode.

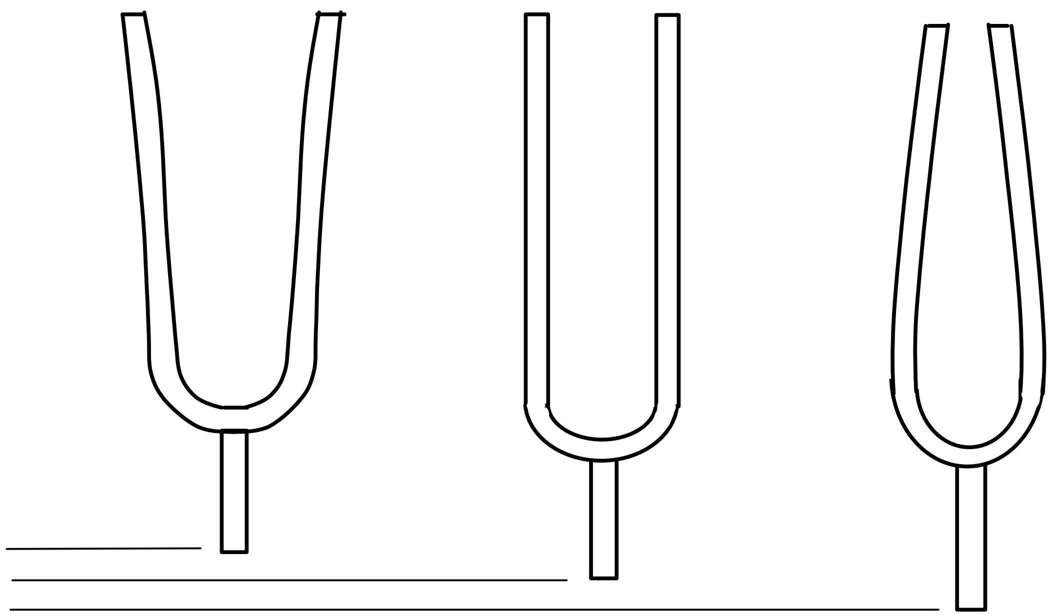

Figure 2. Tuning Fork Fundamental Vibration Mode, Exaggerated Displacement

The two prongs, or tines, vibrate 180 degrees out-of-phase with respect to one another.

A tuning fork has numerous natural frequencies. Many of the frequencies are excited when the tuning fork is struck. The higher natural frequencies, however, quickly decay. Thus, the tuning fork experiences sustained sinusoidal vibration at its fundamental frequency.

An important point is that the stem participates in the fundamental mode shape. The stem tip thus represents an antinode. The acoustic radiation efficiency of the tuning fork is greatly enhanced by touching its stem to a surface of a large area such as a table.

The mode shapes calculated from a finite element model of a tuning fork are shown in Appendix A.

<u>Experiment</u>

An interesting science experiment is to place a vibrating tuning fork near the end of an open-open pipe. The pipe will amplify the radiated sound from the tuning fork if the pipe's acoustic fundamental frequency coincides with the tuning fork's fundamental frequency. The pipe's length should chosen accordingly.

For example, a common tuning fork frequency is 440 Hz, which corresponds to an A4 musical note. An open-open pipe with a length of 15.3 inches (38.8 cm) has a 440 Hz acoustic natural frequency. This assumes that the diameter is very small relative to the length.

In reality, the diameter increases the "effective length" of the pipe. Thus a slightly shorter piper is required. Again consider a 440 Hz tone. Assume that the tuning fork acts as a piston. Also assume that the open end is unflanged. The length would be 14.8 inches (37.6 cm) for a diameter of 0.75 inches (1.9 cm).

The natural frequencies for pipes with constant cross-section are given in Table 1.

Table 1. Natural Frequencies of Pressure Oscillation

Configuration	Frequency (Hz)
Open-Open	$f_n = \frac{n}{2}\frac{c}{L}$
Closed-Open	$f_n = \left(\frac{2n-1}{4}\right)\frac{c}{L}$
Closed-Closed	$f_n = \frac{n}{2}\frac{c}{L}$
Driven by piston at one end. Open at other end. Large flange at open end.	$f_n = \frac{n}{2}\frac{c}{\left[L + \frac{8a}{3\pi}\right]}$
Driven by piston at one end. Open at other end. Unflanged.	$f_n = \frac{n}{2}\frac{c}{[L + 0.6a]}$

where

n = 1, 2, 3, ….
c is the speed of sound.
L is the length.
a is the radius.

Note that the open-open and closed-closed pipes have the same formula.

Speed of Sound

The speed of sound in air for a temperature of 70 °F (21 °C) is

$$c = 1130 \text{ ft/sec}$$

$$c = 344 \text{ m/sec}$$

APPENDIX A

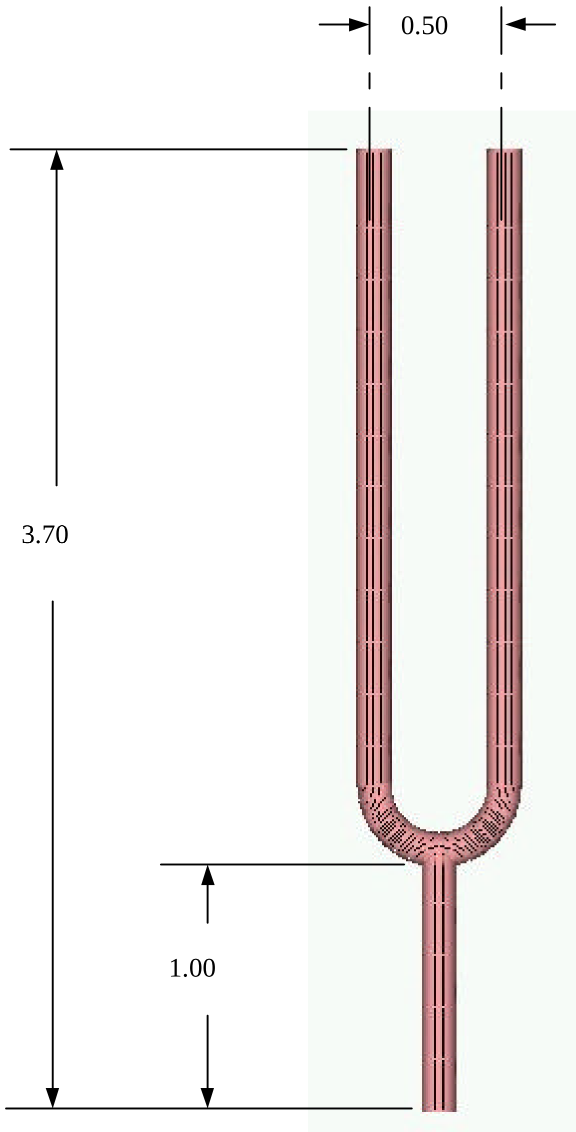

Figure A-1. Tuning Fork, Designed for A4 Note, Frequency = 440 Hz

Dimension in inches.

Material: Steel Rod, 1/8 inch diameter

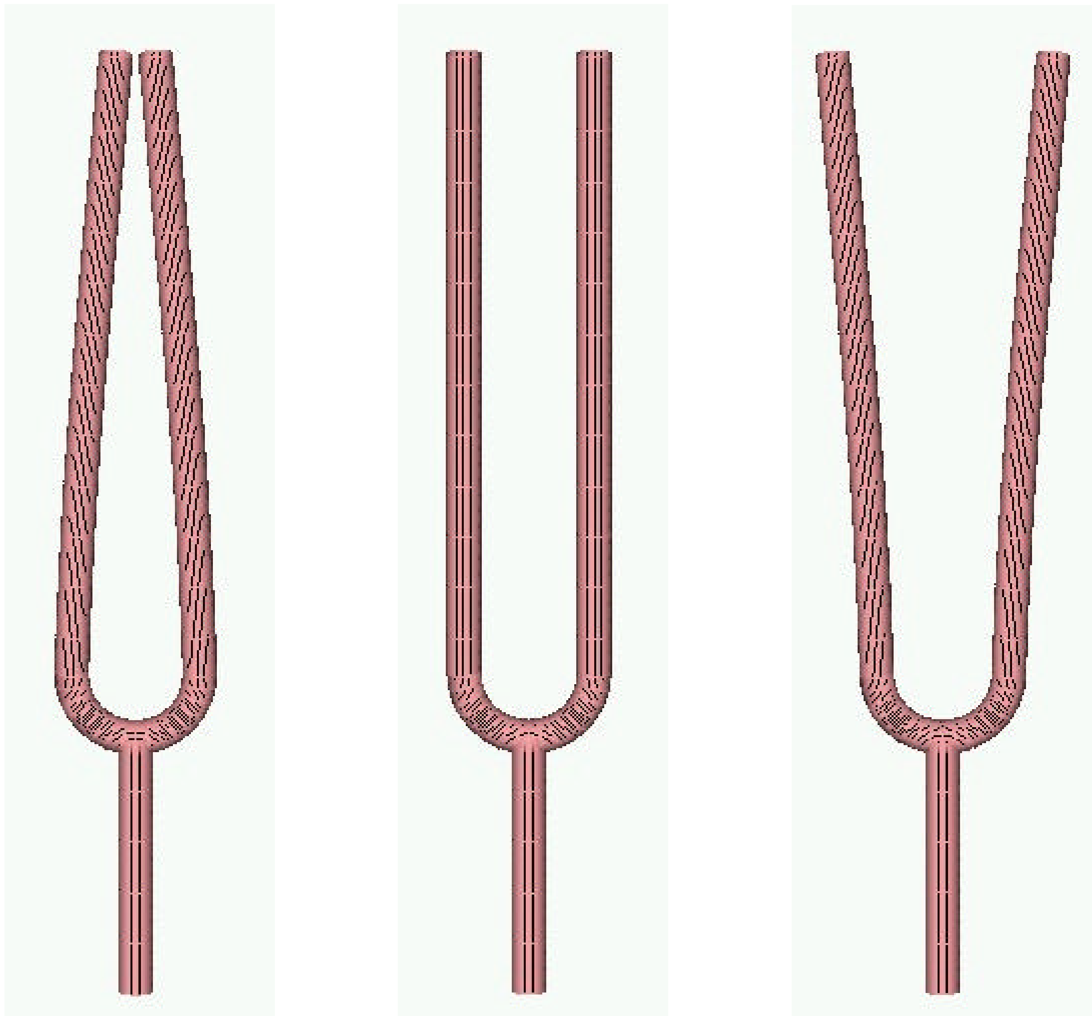

Figure A-2. Tuning Fork, First Mode, Frequency = 440 Hz

The two tines undergo an in-plane bending mode, 180 degrees out-of-phase with one another. The stem also participates in this mode, but its displacement is so relatively small that it is not apparent in the figures.

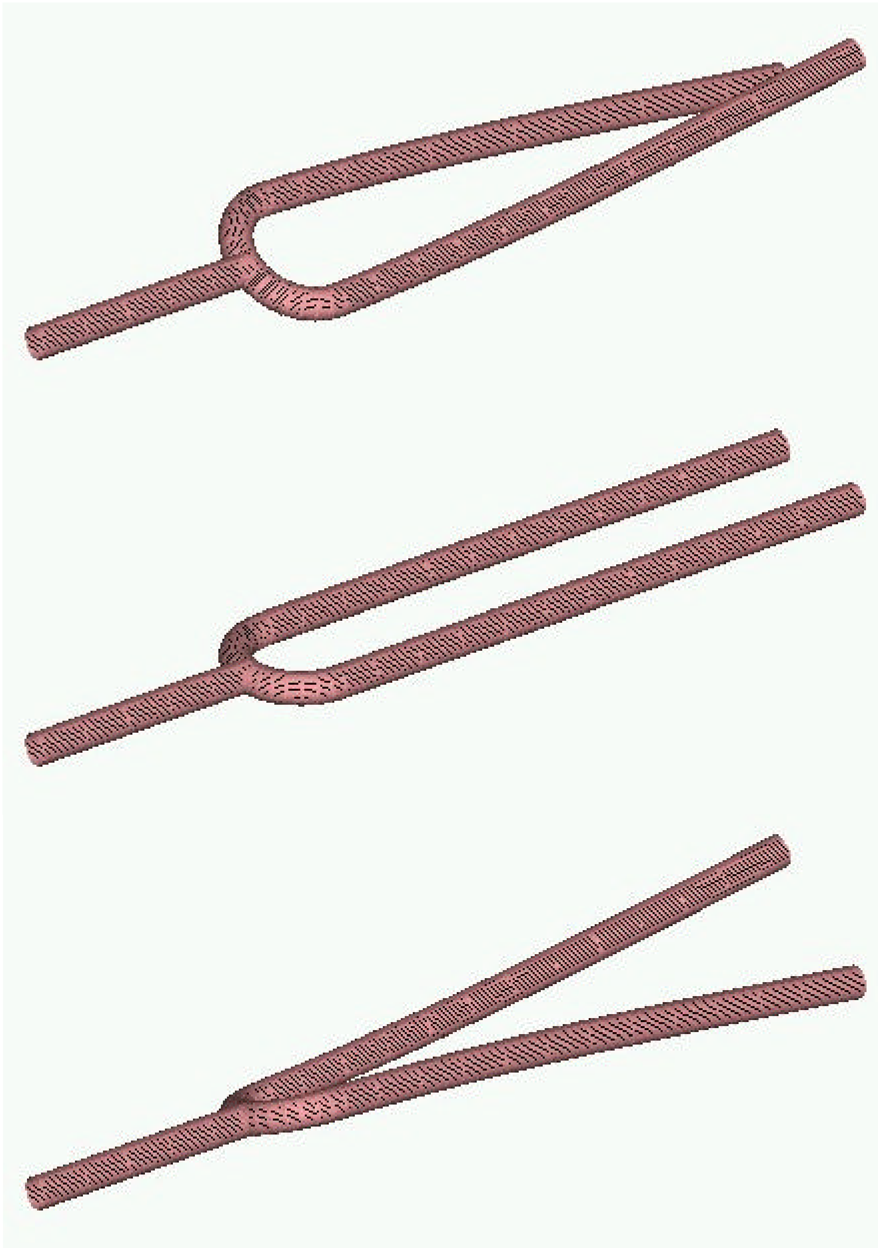

Figure A-3. Tuning Fork Second Mode, Frequency = 693 Hz

The two tines undergo an out-of-plane bending mode, 180 degrees out-of-phase with one another. In addition, the U-shaped section experiences twist about the stem.