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The "2001" theme on the whistling tube

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This short paper describes an entertaining class demonstration that blends music and physics using the corrugated whistling toy tube.[1] First, students are given an introductory foundation to musical intervals and ear-training tricks so that they can recognize the intervals they hear. Then adjacent harmonics are played by whirling the corrugated toy pipe gradually faster and faster to identify the intervals. With very little practice, one can play the first four consecutive harmonics, which happen to be the beginning of the "2001: A Space Odyssey" theme song. A link to a YouTube video of this memorable class demonstration is provided.[2]

Background physics: Harmonics and pleasant intervals

This demonstration should be given after the students have learned about harmonics and approximate integer ratios for intervals in a musical scale. For the harmonics, they should know that the frequency of the *n*th harmonic is given by

$$f_n = nf_1.$$

The standard discussion of the harmonics for a string or open pipe leads to this basic frequency formula. Students should also know that string lengths with simple ratios provide for pleasing musical intervals,[3] either played simultaneously or consecutively. The observation of pleasant intervals dates back to Pythagoras when he compared lengths of strings producing consonant pairs of pitches. Today there are a variety of ways to obtain the closest whole-number ratios for the intervals of the major scale shown in Table I. Recent methods include variations of traditional plucking strings,[4] using pipes such as the boomwhacker toy tubes,[5] working with tuning forks,[6] or applying measurements with Fourier analysis.[7]

Table I. The major scale with closest integer frequency ratios.

Note	Do	Re	Mi	Fa	Sol	La	Ti	Do′
Closest Integer Ratio	1:1	9:8	5:4	4:3	3:2	5:3	15:8	2:1

Table II. Music intervals and common songs related to each.

Adjacent Interval	Frequency Ratio	Just Diatonic Musical Interval	Song
H1–H2	2:1	Octave (Do–Do′)	"Somewhere Over the Rainbow"
H2–H3	3:2	Fifth (Do–Sol)	"Twinkle, Twinkle, Little Star"
H3–H4	4:3	Fourth (Do–Fa)	"Here Comes the Bride"
H4–H5	5:4	Third (Do–Mi)	"Marines' Hymn"

Fig. 1. Students try their hand at producing music in a freeze frame from the author's Whistling Tube video. See the full video at *TPT Online*: http://dx.doi.org/10.1119/1.4947164 .

Relating adjacent harmonics to musical intervals

We relate the first few harmonics to musical intervals using $f_n = nf_1$ and Table I. We provide a basic lesson in ear training since the recognition of intervals by ear plays an important role in the physics demonstration. Everyone knows the major scale: Do, Re, Mi, Fa, Sol, La, Ti, Do′. The trick that enables students to recognize intervals is to relate intervals to common songs. Examples of common songs for our intervals are given in Table II.

One can use a real keyboard or Google "Internet keyboard" to readily pull up an online piano in class. Using the key of C is best, where the major scale consists of all white keys starting with the white key to the left of a pair of black keys. You or one of your students can play each of the intervals to check them against each song listed in Table II.

The first interval in Table II is the octave, and a tune that begins with an octave interval is "Somewhere Over the Rainbow" (from "The Wizard of Oz," 1939 movie). The 3:2 interval is the fifth, i.e., playing Do, then Sol. If you play the Do twice in succession and then Sol twice afterwards, you have the start of "Twinkle, Twinkle, Little Star." For H3 to H4 we have Richard Wagner's "Bridal Chorus" from the opera "Lohengrin," listed in Table II as "Here Comes the Bride." Finally, for the interval H4 to H5 we start the "Marines' Hymn." All of these musical pieces serve as very recognizable tunes for the intervals of interest.

The experiment: Music and science

It is now time to introduce the corrugated toy tube, which dates back to the early days of *TPT* as the corrugated singing pipe.[8] Historically the toy has gone by such names as the "whirl-a-tune,"[9] "whirl-a-sound," "Freeka," "the Hummer,"[8]

 DOI: 10.1119/1.4947164

and the “Voice of the Dragon.”[10] Either the instructor or a student plays the whirl-a-tune so all can hear the first two tones produced. The interval will be a fifth, which means H2 to H3. We skip H1, an observation reported in the literature long ago.[8] But now the students readily conclude this result from their own observation using their knowledge of music and physics. The music is necessary to recognize the interval and the musical observation indicates that the first harmonic has been skipped. If you gently tap the toy tube or blow across one end, you will excite the fundamental H1.[8] But when you twirl it, the singing tones begin with H2.

With care, you can proceed to compare H3 with H4. This musical interval is the fourth and the students will recognize “Here Comes the Bride.” Finally, playing H4 then H5 reveals the “Marines’ Hymn,” a third. Then comes the bonus. Playing H2-H3-H4-H5 in succession is the beginning of the “2001” movie theme.

Many students will recognize the theme (Richard Strauss’s “Also Sprach Zarathustra”) from the classic 1968 Stanley Kubrick movie “2001: A Space Odyssey.” With a little practice, you can play consecutively H2, H3, H4, and H5. Students love it. In the accompanying video[2] a student surprisingly twirls the theme in class at her first attempt, amazing everyone.

Conclusion

Our demonstration shows a deep connection between music and physics relating musical intervals to adjacent open-pipe harmonics. Furthermore, our little ear-training exercise in music plays an essential role in performing the experiment to determine the adjacent intervals from the whirling pipe. We observe that the four notes of the “2001” movie theme are harmonics H2 through H5 and we can play these on the whirling toy. This demonstration is rich in its interdisciplinarity involving music, physics, and mathematics. You can conclude with a contest to see who can reach the highest harmonic by counting them (2, 3, 4, …) as the tube is twirled faster and faster.

References

1. The 30-inch corrugated toy pipes are available as “whistling tubes” or “whistling plastic tube noisemakers.” However, note that some are made of sturdier quality, which can be recognized by those having substantial handles at one end.
2. Author’s YouTube video link: https://youtu.be/GLHV1qG4xdc.
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6. James Lincoln, “Ten things you should do with a tuning fork,” *Phys. Teach.* **51**, 176–181 (March 2013).
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8. Frank S. Crawford, “Singing corrugated pipes,” *Am. J. Phys.* **42**, 278–288 (April 1974). This reference is a nice early paper on the toy, which Crawford also says has been called “whirl-a-sound” and “Freeka.”
9. When I was in graduate school at the University of Maryland and Prof. Richard Berg’s teaching assistant in the early 1970s, he referred to the toy tube as a “whirl-a-tune.”
10. M. P. Silverman and G. M. Cushman, “Voice of the Dragon: The rotating corrugated resonator,” *Eur. J. of Phys.* **10**, 298–304 (Oct. 1989).