Title
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Publication Date
1973-03-01

Submitted to The American Journal of Physics.
Notes and Discussions

LBL-1708
Preprint

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March 1973

Prepared for the U.S. Atomic Energy Commission
under Contract W-7405-ENG-48

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LBL-1708

Which Octave Do You Whistle Dixie In?*

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March 1973

I invite the reader to perform the following short experiment. Whistle a comfortable note. Then decrease the pitch in a downward glissando until you reach the lowest note you can whistle. Next sing a comfortable note and glissando upwards to the highest note you can produce. (If you are a man go into falsetto and strain upwards until you can squeak no higher.) Now ask yourself, which sounds higher in pitch, the lowest whistled or the highest sung note? Use only your intuitive feeling for pitch. Reach a conviction before reading further.

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One afternoon about a year ago I was sitting at one of the Carrels at the Lawrence Hall of Science at Berkeley, whistling and singing into a microphone connected to an oscilloscope. I tried whistling the lowest possible note and singing the highest possible note. I would have bet anyone $5 that my lowest whistled note was at least an octave lower than my highest falsetto singing note. I would have lost! The oscilloscope showed plainly what my ear refused to believe; my whistling and singing range have no overlap; my highest falsetto note is lower than the lowest note I can whistle. It is as if the effort to whistle low as contrasted with the effort to sing high convinces me that the lowest whistled note is far below the highest sung note. Indeed, if I sing a note in my comfortable range and then whistle that note to the most comfortable octave, my feelings of comfort lead me to feel that the two notes are roughly the same pitch. Actually, my comfortably whistled note is three octaves above my comfortably sung note!

A few weeks ago while teaching Physics 4C at Berkeley I hit upon a simple way to arrive at the absolute pitch of my vocal and whistling range without the use of an oscilloscope. Instead of an oscilloscope I use a 3-ft long tube. (I prefer golf tubes. They cost about 20¢, are 1¼-in. diameter, 3-ft long, and plastic. They have less damping than do cardboard mailing tubes.) I will describe the experiment for my voice.[1]

First I tap the tube on my head or blow across one end. This excites the lowest mode, where the tube length is one-half a wavelength. Call f_1 the frequency of that mode. Then I sing a note that is comfortably in my range and has a frequency f that is some (unknown) octave of f_1:

$$f = nf_1, \quad n = \tfrac{1}{4}?,\ \tfrac{1}{2}?,\ 1?,\ 2?\ 4?,\ 8?\ 16?$$

While singing this note I put the tube close to my mouth, being careful to leave a small space between the end of the tube and my mouth, so that that end of the tube remains an "open" end. Then I vary the pitch slightly up and down near nf_1 to see whether I am at a resonance. For my voice, with the lowest octave of a 3-ft tube that I can sing, I am not at a resonance. In the most comfortable octave I can sing, which is an octave higher, I hit my first resonance. (It is obvious when you hit a resonance. You can hear it, and also feel it in your throat.) This already tells me that my lowest octave has $n=\frac{1}{2}$ (not a resonance) and my most comfortable octave has n=1. As a check I continue singing an upwards glissando searching for the next resonance. It occurs an octave higher, thus at n=2. Going into a high falsetto I can barely squeak up to another resonance a major fifth above the n=2 resonance, at n=3. Thus my highest falsetto has

$$f_{max}(\text{voice}) \approx 3\ f_1,$$

where f_1 is the lowest mode of the three-foot open-ended tube. (The absolute pitch of f_1 is F#, 185 Hz.)

Next I do the same thing while whistling. (An important technical point: I find that I cannot whistle at all while blowing air outwards with the tube next to my mouth; but I can easily whistle while sucking air inwards.) I tap the tube to hear f_1, then whistle a comfortable octave of f_1, $f = nf_1$; the integer n is unknown. Then I whistle an upwards glissando starting at nf_1 and listening for resonances. The resonances are quite sharp. In fact, it is nearly impossible to whistle a smooth glissando; the pitch gets "pulled" into whichever resonance is nearest. When I start with my comfortable octave I find that the neighboring resonances form a whole tone scale, as in "do, re, me". That tells me that my comfortable octave is the 8th harmonic of f_1, as follows: If n is my comfortable octave of f_1, then $(n+1)f_1$ is the next resonance. If n were equal to 1, the next resonance would be n=2, an octave higher. For n=2 the next resonance is at n=3, a major fifth higher. For n=4 an upwards glissando will produce 4, 5, 6, which is a major triad ("do, me, so"). For n=8 I get 8, 9, 10, which is "do, re, me". For n=16 I would get a chromatic (half tone) scale.

Let us examine the last two possibilities (n=8 and n=16) more carefully. The comfortable octave nf_1 and the next resonance produced by the upwards glissando, $(n+1)f_1$, have the ratio

$$(n+1)/n = 1 + (1/n) = 1.125 \quad \text{for } n = 8 \qquad (1)$$
$$= 1.0625 \text{ for } n = 16.$$

In a well-tempered scale an octave is divided into 12 equal pitch ratios called half tones. A half tone (smallest interval on piano keyboard) has the pitch ratio

$$2^{1/12} = 1.059. \qquad (2)$$

A "chromatic" scale consists in going from one note to the next a half tone higher, then to the next, etc. A whole tone (two half tones) has the ratio

$$2^{2/12} = 1.12. \qquad (3)$$

Comparing (1), (2), and (3), we see that for n=8 we get neighboring resonances that sound like a whole tone scale, while for n=16 we get a chromatic scale.

Now that I know my most comfortable octave of f_1 is $8f_1$, I can find my whistling range by going up or down, keeping track of octaves. I find my lowest whistled note is about $3f_1$. (I also hear the resonances, 8, 7, 6, 5, 4 as I glissando down!)

Thus I find with a 3-ft tube what I found earlier using an oscilloscope: my lowest whistled note and my highest falsetto note are both about $3f_1$. My whistling and singing ranges do not overlap.

I invite the reader to find a three-foot tube and find out whether her singing and whistling ranges overlap.

As a final experiment I joined two 3-ft tubes together with masking tape to make a 6-ft tube. Its lowest mode is an octave below that of the 3-ft tube. When I whistle my most comfortable octave of the tube into it, and then attempt to glissando upwards or downwards in search of resonances, I hear no glissando at all but only a beautiful chromatic scale.

Footnotes and References.

*This work was supported by the U.S. Atomic Energy Commission.

1. I have not seen this experiment described elsewhere, but the principles are so simple and well known that it has undoubtedly been practised and described by many physics teachers. It's probably somewhere in Lord Raleigh's writings, as is everything.

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