

BUT I AM STANDING!

REFLECTIONS ON RESONANCE & STANDING WAVES

In the last issue, we amused ourselves by coaxing a musical note from a wine glass. Now, out of fairness to our readers that do not drink wine, we progress to the next logical item in our musical quest — a beer bottle. The sound produced by blowing over the top of a beer bottle, though not as delicate and sophisticated as the ethereal sound made by rubbing the rim of a wine glass, is no less musical and no less acoustically sophisticated.

To make a note by blowing air over the mouth of a bottle it must be just the right amount of air and at just the right angle. Flute players call this just-right-pucker the “embouchure.” When the embouchure is executed

correctly, the air will flow past the leading edge of the opening and be cut in half as it meets the far edge of the hole. Actually the air is going mostly into the hole and, in the case of our beer bottle, only so much air can go in. Forcing this extra plug of air into the bottle compresses the air inside which then begins to press back. The pressure pushes the plug of air back out of the bottle deflecting the embouchure air away from the hole. You can visualize the plug of air now traveling

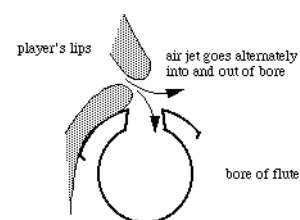


Figure 2. Flute

sucked back into the bottle, the embouchure air is now deflected back into the bottle and this process will repeat as long as we keep blowing. The rate or frequency of this back-and-forth air flow is what defines the pitch that we hear coming from the bottle. And it is not just any pitch. The pitch is pre-determined by the length and size of the air cavity in the bottle, which determines how long it will take to compress and expand this body of air, and that determines the frequency of vibration. This is known as the **resonant frequency** of the bottle. In your high school physics class this scenario was called Simple Harmonic Motion (SHM) and was usually represented by a weight (mass) attached to a spring. In our bottle example, the plug of air is the weight and the air within the bottle is the spring. SHM also defines the math behind pendulums and other regularly re-occurring and vibrating systems. The ancients actually referred to the motion of the planets as the “harmony of the spheres”.

Another way to visualize the concept of resonance is to think of it as a **reflected wave**. A puff of air at the mouth of the bottle makes a wave

that travels down the length of the bottle. When it hits the bottom, it is reflected back from whence it came. But as it travels back, it meets and interacts with the new waves still coming into the bottle from the opposite direction. As we learned from our examination of beat-notes (see page-4 of vol.4 no.1 in the Archives at www.folkworks.org), sound waves interact in various ways that can either combine or cancel out their energies. Nothing special happens in our bottle until the frequency of the incoming wave matches the

resonant frequency of the bottle. At that magical moment, the wave pulse takes just long enough to travel the length of the bottle so that the reflected

wave returns exactly (180 degrees) out of phase. When two waves are of the same frequency and amplitude and are traveling in opposite directions and out of phase by 180 degrees they will combine to form what is called a **standing wave**. The first animated example on Professor Fred Skiff's page at www.physics.uiowa.edu/~umallik/adventure/sound-skiff.htm is a wonderful demonstration of how a reflected wave folds back upon itself to produce a standing wave.

Standing or **stationary waves** are characterized by static locations called nodes whose amplitude remains at zero. Mid-way between the nodes are points of maximum movement called anti-nodes where the amplitude alternates between maximum and minimum doing a kind of wagging up and down. The third animation at www.kettering.edu/~drussell/Demos/superposition/superposition.html, a web page by Dan Russel, Ph.D., is an excellent visualization of nodes and anti-nodes on a standing wave.

What actually happens is that various frequencies can be introduced into a resonating system and they will amplify and cancel each other without producing any practical results until there is a match with the system's resonant frequency. At that point, the waves line up in such a way as to most efficiently combine their energies, and the amplitude or volume generated jumps up greatly. This is basically an amplifier and musical instruments are essentially resonators used to amplify musical notes. This same concept exists in the world of electronics as a tuned circuit. A radio antenna receives all incoming frequencies and then sends them on to a tuned circuit. Most frequencies pass inefficiently through the circuit and fade away, but frequencies that match the resonant frequency of the circuit get a great boost in amplitude and—tah dah—you have just tuned in a radio station.

Before you are tempted to make the observation that, “There is more energy coming out of this system than is going in,” and, “Isn't that essentially perpetual motion?” and, “Doesn't that go against the conservation of energy laws?” let me point out that we have all experienced a form of Simple Harmonic Motion when we pushed a child on a swing. The idea is that if you keep adding a small amount of energy to a

system — but at just the right time — it will add up and amplify tremendously fast — the proverbial snowball

effect. Every physical object has one or more resonant frequencies. This is usually a good thing but there are some examples of where it is not. For instance, some violins have a problem called a wolf-note. When a particular note is played, it matches a resonant frequency in that particular instrument and comes out way too loud or “wolfs.” The most extreme example of accidental resonance has to be the Tacoma Narrows Bridge in the state of Washington. On November 7, 1940, this newly built bridge began to resonate in response to a forty-two mile-per-hour wind and destroyed itself.

You can read about it and see the amazing video clip at www.eng.uab.edu/cee/reu_nsf99/tacoma.htm.

One final observation: Many years ago, there was a guest on Johnny Carson's Tonight Show. He had made a device that snapped onto the mouth of a beer bottle and it created the perfect

aperture to make a note when you blew into its short tube. He then attached a small rubber hose to his device so that he could set the bottle down and still make a note. He then set up several bottles and ran all of the hoses to a holder so that he could play tunes like you would play a harmonica or the panpipes. Then he had Johnny walk with him to the stage where he had mounted bottles on several plywood

walls. These bottles ranged in size from a small medicine bottle up to a large Sparkletts bottle. He then sat down at a keyboard and played real music on this collection of bottles. I searched the web for this person and his bottle organ but could not find any information. There is, however, a modern incarnation of this concept in the Peterson Beer Bottle Organ. You can see it and hear it at www.petersontuners.com/news/bbo/index.cfm.

So save your beer bottles, keep making music and, as always, stay tuned.

Roger Goodman is a musician, mathematician, punster, reader of esoteric books and sometime writer; none of

which pays the mortgage. For that, he is a computer network guy for a law firm. He has been part of the Los Angeles old-time & contra-dance music community for over thirty years. While not a dancer, he does play fiddle, guitar, harmonica, mandolin, banjo & spoons. Roger has a penchant for trivia and obscure and sometimes tries to explain how the clock works when asked only for the time. He lives with his wife, Monika White, in Santa Monica, CA.



BY
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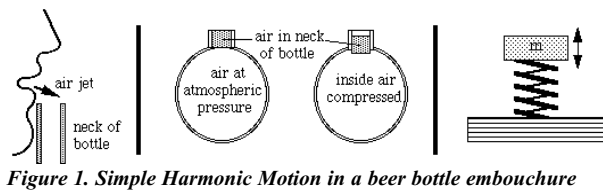


Figure 1. Simple Harmonic Motion in a beer bottle embouchure



Figure 3. Tacoma Narrows Bridge



Figure 4. Peterson Beer Bottle Organ



Vietnamese Banjo

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