PERCUSSION TECHNIQUE AND THERMODYNAMICS

Jeffrey Ryan

Introduction

When principal percussionist of the New York Philharmonic Chris Lamb teaches, you'll hear him say the words "continuous motion" dozens of times. The foundation of his pedagogy is relaxed continuous movement. When I studied with Professor Lamb, I had trouble connecting with this idea. I trusted him, and saw great improvements when I implemented his techniques in my playing. However I struggled to fully commit to the continuous motion bit. Two years after I first heard the suite of Lamb-isms, that changed. When I read H. C. Van Ness' *Understanding Thermodynamics* suddenly everything made sense. Since reading that book, my technique and ease of playing have improved rapidly.

This paper isn't about claiming a mathematically correct way to play percussion, nor will it make any claims about how to convert movements into appealing sounds and visuals. What it will do is explore the connection between the thermodynamic model of energy and the mechanics of playing percussion. Before we can discuss how Lamb's "continuous motion" is an implementation of a reversible process, let's first understand the general framework of thermodynamics.

Thermodynamic Systems

How can we start thinking about playing percussion in terms of a thermodynamic system? In thermodynamics, every problem is started by defining a boundary. If we tried to consider all the things whirling around in the universe at the same time, we'd never get anything done! Instead, we pick some small cluster of stuff and make reasonable assumptions about how that stuff behaves. Anything inside this imaginary boundary is called a system. Let's choose our system to be the player and their instrument. Once we pick our system, we decide which details are and aren't important. Let's set our player-instrument with the following rules:

- Energy is only initiated by the player
- Energy change is only caused by the player or an instrument reacting to the player
- Other forces–air resistance, temperature differences, etc.–are negligible

What is meant by energy changing? By the first law of thermodynamics, energy cannot be created or destroyed–but it can change form. When the player strikes an instrument, the physical energy of their movement is sent into the playing surface. When that surface vibrates, the energy converts into sound. Voila, music! The same process can happen in reverse, like the iconic opera singer shattering a wine glass.

Making this model may have felt pedantic, but its specificity is what makes it so powerful. We can now generate several useful insights about the mechanics of playing. If we invented a perfect sound generating device, this equation would describe its behavior: $S = E$. Here "E" is the total amount of energy our invention can generate and "S" is the total amount of sound created. In this equation, 100% of the energy is perfectly transformed into musical sound.

But if we're not careful, things can get in the way. If our inventions had parts that slid around, but we didn't use oil–for example–friction would steal some energy that could have been turned into sound. We'll call this wasted energy W and update our formula: $S = E - W$. Sadly, some proportion of energy–W/E–never gets to become sound.

How does this apply to human performers, instead of our hypothetical invention? Answering this question gives us the first thermodynamic insight into continuous motion. The two culprits that tend to prevent continuous motion in performers are hitches in movement and tension. Unfortunately, these losses of energy do even more damage than friction in our imagined machine. When we play, it requires our own energy to stop a motion with a hitch or create tension. Then, we spend even more energy to reverse the hiccup we caused and push forward. If W is the energy wasted in a machine, which doesn't exert energy to create wasted energy, the energy waste in a human system is around 2W. Which is to say:

$$S = E - 2W = E - (W_{creating\ hiccup} + W_{pushing\ past\ hiccup})$$

If the player wants to achieve the same sound as a system without tension, they will have to exert significantly more energy. Specifically:

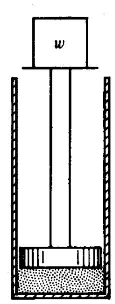
$$E = S + 2W$$

This explains why playing with tension is often difficult and limiting. If tension is used when the player needs more energy, they create a loop of diminishing returns. If instead, we relieve tension so it approaches 0, the system approaches it's ideal state $S = E$.

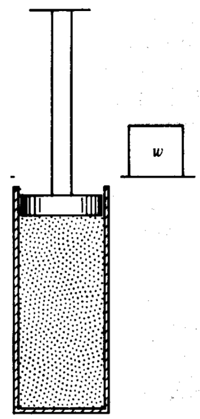
Demonstrating a reversible process

Now that we understand how to define and model basic systems, we can discuss reversible processes. Reversible processes are key to using a system's energy most efficiently, but how do we know if a process is reversible? Let's start with an example that *isn't* reversible, which we'll see gradually morph into a reversible system. (The illustrations and explanation are summaries of H. C. Van Ness' section on this topic from *Understanding Thermodynamics.*)

Imagine we have this system, a piston with a weight of mass *w* compressing a pocket of air. For simplicity, we'll assume the piston itself is too light enough to compress the gas without the weight on top. We'll also assume the piston is well lubricated, and does not have friction with the walls of the cylinder.

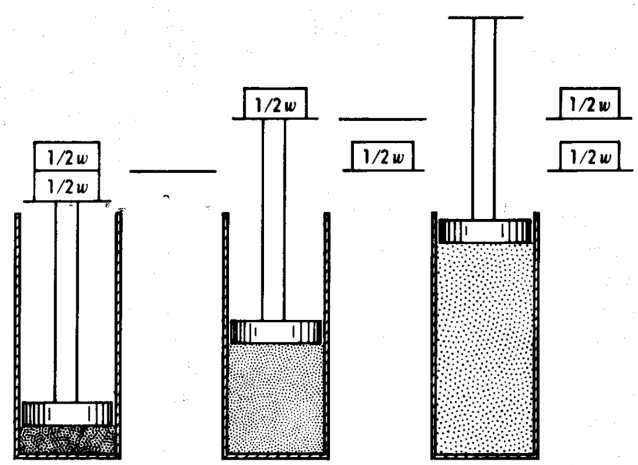


What happens if you slide the weight off?



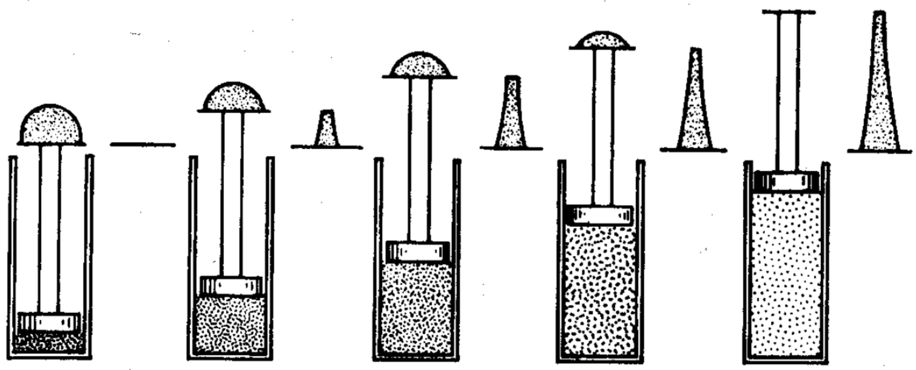
The piston is now fully uncompressed. However, we didn't get much utility because there was no weight left to be moved up. Also, you can't return the system to its initial state without adding energy to lift the weight.

Can we use the same system in a more clever way to create a small elevator? What if we cut the block in half and set each chunk aside one at a time?



This works better. The first half of the block didn't gain any height, but the second half of the block did. Not coincidentally, half the piston's max height. And what if we took this to the extreme?

Let's take the block and smash it into microscopic little specks. Now it looks less like a block and more like a pile of sand. What happens if we remove these specks one at a time?



That’s quite an improvement! Such an improvement that this is the physical maximum for how much this system can lift. Most of the specks get lifted a moderate amount, and some almost the height of the entire piston.

This third scheme has a special property, the reversibility we mentioned earlier. If we made the specks smaller and smaller, the weight of each speck would approach 0. Once their weight is indistinguishable from 0, the piston rises a height of 0 per speck removed. In this state, we could slide that speck right back on the piston without lifting it. After sliding off all the specks into a pile, we could slide them back onto the piston until it reaches the initial state, for 0 energy cost. More generally, we can move the position around as much as our heart desires in either direction as long as we only slide one speck at a time and don’t run out of specks. This is a reversible process.

The first two uses of this system get stuck once you run the process. Since you can’t run the process in reverse for 0 energy, they are non-reversible processes. This property is not unique to this particular system. All thermodynamic systems will operate most efficiently when using a reversible process.

Reversible systems in percussion playing

The concept of reversibility is not just an analogy to continuous motion in percussion playing, it is the physical proof of why the concept works. Since our bodies, implements, and instruments are physical objects, continuous motions are the most efficient way to turn a performer’s energy into sound. Whenever a performer moves in a way that has hiccups or stops, it necessarily takes away energy that could be sent into their instrument.

There are two things that limit the application of reversible processes in an artistic context, and should be considered when practicing or teaching these concepts. First, it is physically impossible to achieve a perfectly reversible process. Take the piston example from earlier, atoms cause a lower limit on how small our specks can be. Even if we could comfortably split atoms, it’s impossible to create a shaft with no friction. Even the tiniest amount of friction would cause the process of reversibility to break down, because each speck alone would be unable to break past the initial friction.

In our bodies, tiny amounts of tension and biological limitations will prevent our motions from being truly continuous. However, this does not mean thinking about reversible processes is not useful. Since the reversible form of whatever process we execute is the best possible energy use, doing things that move s system towards being reversible will make it use its energy better, even if that goal is never 100% achieved.

Second, this physical examination of playing does not make any artistic value judgments. It is a tool to help us explore how we play and a potential path to improve execution and reduce strain. Always exercise your musical judgment and implement changes which open your artistic expression.