The Tiny Book of Violin Technique

A modern approach from the perspective of physics, kinesiology, and experiential learning

Foreword

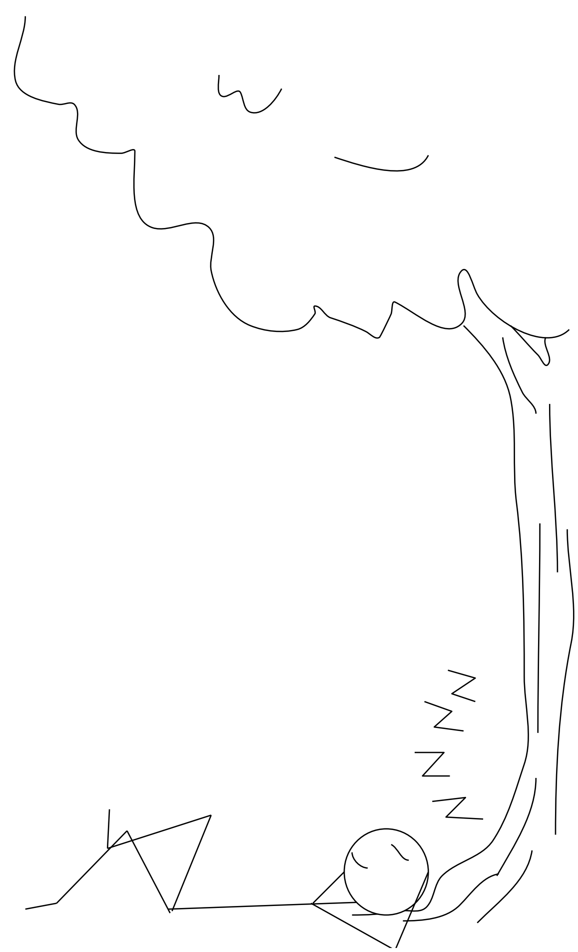
The number of individuals to whom I am indebted for the content of this little book are diverse and scattered throughout the last several centuries of history. They range from pedagogues who devoted their lives to passing ideas to the next generation, to the modern physicists/musicians like Schelleng, Cremer, and Guettler, who studied multiple facets of string instruments scientifically, to the performers who simply by experimentation managed to create technique that no one had ever imagined. To all of these artist-humans, I am deeply grateful.

In the last 80 years, technological and scientific advances have rendered necessary an update to string instrument technique. These advances have been particularly astounding in the field of physics. Fortunately for our purposes, a knowledge of physics, while it takes a bit of effort to acquire, actually simplifies and streamlines technical concepts. This book forms an abbreviated resource of foundational and advanced violin technique, combined with the current discoveries of acoustical physics research and kinesiology (how the human body moves). Since the focus of this small volume is efficiency, a knowledge of some of the older, more basic concepts of acoustical physics will be assumed. (These concepts are familiar to most professional string players). For a deeper discussion of all concepts, techniques, and their applications, please refer to the full-length volume entitled *Theorhym: An Approach to the Development of Violin Technique Based on Acoustical Physics.*

Day Zero

Before you begin,
Close your eyes.
Forget stress,
And rest.

Take a day off.
Or better yet a week off.



While You Rest

First:
Make sure that your violin is adjusted correctly.

A machine is a device that changes one form of energy into another form of energy. The violin is a machine which transforms the kinetic energy of physical motion into sound energy. All machines lose some energy in the process of transformation. In the case of the violin, a large portion of energy stays as kinetic energy and continued oscillation (inertia), while some escapes into the air as sonic energy (sound), and small amounts escape as entropy, (heat). (Entropy causes your violin to get warmer as you play).

The playability of your violin depends on what physicists call Quality factor, or “Q” for short. Basically, if the violin is a poor instrument, or is not set up properly, it will have low Q (low quality/efficiency) and you will have to exert a great deal of energy to play well. Much energy will be lost to competing forces and very little energy will find its way into sound. On the other hand, if your violin is set up well and is a properly made instrument, you will have much better results. You will have a high Q factor, and MUCH more sound with MUCH less effort.

While you rest and prepare to rework what you know:

1. Have a luthier set your violin up.
2. Get your bridge straightened and your sound post moved.
3. Do all repairs necessary, from gluing open seams to re-hairing your bow.

There is no need to own a Stradivarius, only to find an excellent set-up that makes your own playing easier. Now you are ready for experimentation!

Table of Contents

Eighteen Days of Practice

Day One

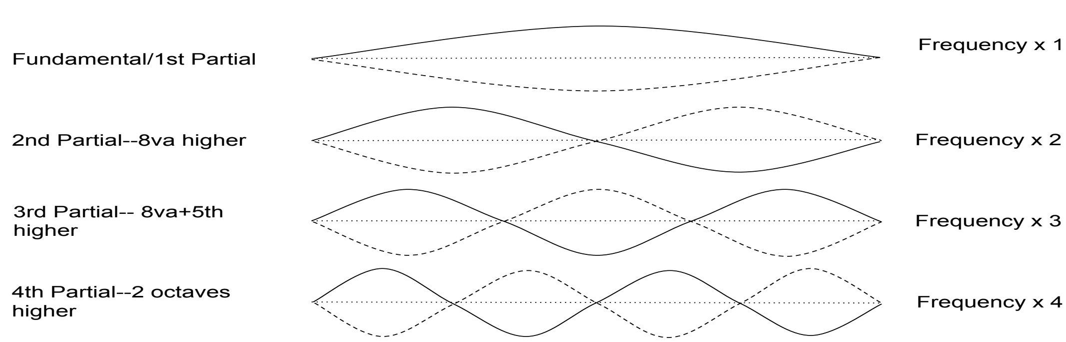
Overtones

Tune your violin. We will begin with the basics of sound waves and overtones, also known as *partials*.

Every note you play contains several pitches audible to the human ear. Pythagoras, in the 6th century BCE, discovered that if string lengths were arranged in simple ratios to each other, they made harmonious, pleasing sounds. For example, one string might be set at half the length of the other, to create an octave, with a vibrations-per-second ratio at 2:1. Or, it might be set at 2/3rds the length of the other, to create a fifth, with a ratio of 3:2. From this experiment, Pythagoras suggested the idea of Pythagorean tuning, the premise of which we still use today. The core idea behind the system is that the simpler the ratio, the more times per second the strings will "sync up" with each other. If the ratio is simple enough, the notes will form a pure consonance. Theoretically, in a 3:2 ratio, the motions of the strings will sync up together many times per second, causing the resonators inside the human ear to also move in collaboration with each other. It is thought that this synchronized motion is perceived as more pleasing to the brain than a less frequently synchronized complex ratio (say 10:9, the Pythagorean version of a whole-step).

Interestingly enough, each individual string also oscillates in multiple ways simultaneously. Like the separate strings in Pythagoras's experiment, the individual strings your violin vibrate in halves, thirds, quarters, etc., to create up to 20 additional notes or partials during the sounding of a single pitch. Each of these partials is represented by a "mode" of vibration. While the first partial (the note that is being played---also called the *fundamental)* has the greatest amplitude and is thus the most audible, most of the sound colors and timbres you perceive are due to the number and amplitude of partials numbered 2-20. Creating these additional partials is part of creating excellent string sound. Let's look at how the string vibrates during the production of various partials:

Vibrations of a Stretched String (Simplified Representation)

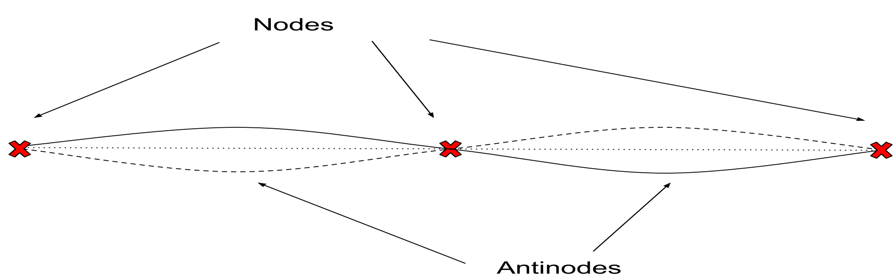


1. First Partial: Ex. Open G string (sounding G3), 196 Hz.*
2. Second Partial: natural harmonic half way up on G, (sounding G4), 392 Hz.
3. Third Partial: natural harmonic on G string at D4 (sounding D5), 588 Hz.
4. Fourth Partial: natural harmonic at C4 AND G5 (sounding G5), 784 Hz.

(*Vibrations per second (Hz) here are based on Pythagorean tuning, not equal temperament, and are intended as an example to explain partial (overtone) content within a single note.)

Things to Notice:

1. Notice first of all, that the graph is taken from a vantage point above the fingerboard. The strings move *horizontally,* in a plane. This will become important so that we can maximize our efficiency, matching the directional motion of the string with the directional motion of the bow arm.
2. Each "mode of vibration" contains places on the string that don't move. These anchor points are called "*nodes.*" The places on the string which move most violently are called "*antinodes.*"



Experiment: Place fingers on nodes to create natural harmonics on the A string

1st partial: Sounding Open A (2 nodes at bridge and nut)
2nd partial: Sounding A5 (node at ½ of way up string)
3rd partial: Sounding E6 (node at 1/3 of way up string: E in third pos)
4th partial: Sounding A6 (node ¼ of way up string: D in first pos)
5th partial: Sounding C#7 (node 1/5 way up string: C# in first pos)
6th partial: Sounding E7 (node 1/6 way up string: approximate C in first pos)

These simple experiments help us understand how partials work in harmonics:

Causing the amplitude of a particular partial to increase:

a. Place a finger lightly on the harmonic half-way up the A string (A5). The finger is resting on the node of the second partial. As you play the harmonic, the fundamental will become nearly inaudible, and the mode of vibration for the second partial (the harmonic) will take over. The fundamental disappears because its antinode is located at the center of the string, and your finger has placed a node at precisely the same location. The third, fifth, and seventh partials, partials that have antinodes in this location, will be weaker as well.

b. *Causing the amplitude of a particular partial to decrease:*
   Stop the string from vibrating at the *antinode* of the partial you wish to hide. [One example: Place a finger lightly a third of the way up the string, a location near the antinode of the fourth partial. The fourth partial and its multiples will weaken due to lack of vibration amplitude.]
c. **Changing the amplitude of a partial and its multiples during a regular note:*
   Disappearing partial: Bow at the node of any partial. The increase of amplitude at the node will cause it to all but disappear. Try this in *flautando.*
   Appearing partial: Bow with great amplitude at the antinode of a partial you wish to be present in the sound.

Day Two

Pizzicato

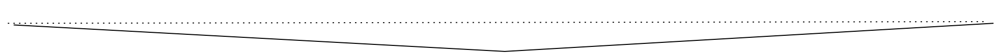
Now that we have discussed the basic diagrams surrounding partials, here is a video link to demonstrate the motion of the string during pizzicato.

https://www.youtube.com/watch?v=Qr_rxqwc1jE

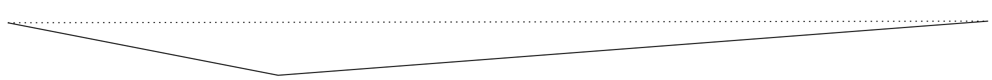
It is important to note that the motions of the string are complex. It has only been in the computer age that we have been able to form equations that accurately reflect the complete complexity of the motions of a stretched string.

Notice these phenomena as you watch the link:

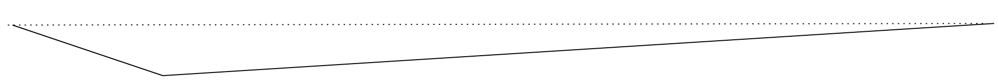
1. A corner (more or less rounded) is created by the finger.
2. The corner splits in two.
3. Both corners reflect from the ends of the string.
4. The corners pass each other without apparent interruption and continue on their way around the string.
5. As the corners continue to move around the string, the elasticity, tension, and mass of the string gradually cause the motion and sound to die away. As this happens, the corner rounds out and the highest overtones disappear.
6. If the video were not slow-motion, you would "see" an envelope of motion that looks like a jump rope, similar to the first partial (fundamental) in the graph from yesterday's lesson. This is what the naked eye sees on the violin. Let's look at what is really happening. Notice the correlation between corner angles and overtone content:



1. Slight angle on corner: low partial/overtone content, fundamental shows greatest amplitude



2. Moderate angle on corner: midrange partial/overtone content, with strong fundamental and lower partials.



3. Extreme angle on corner: large partial/overtone content, with less percentage of the energy concentrated towards the fundamental and more energy concentrated toward the upper partials.

The sharper the angle of the initial corner, the greater the number of the partials produced by the string. Due to the bending stiffness of the string, the corner is always at least slightly rounded, but may have a more obtuse or less obtuse angle. [(You also may want to notice that after the initial pluck, the string pursues its own perfectly "free" oscillation. Thus, pizzicato (free oscillation) motions differ from bowed string motions ("forced" oscillation)]. Partial content within pizzicato is entirely due to the angle and roundness of the corner initiated by the finger. You can create different corners/angles by:

1. Pulling the string farther to the side
2. Pulling the string from different points along its length
3. Pulling the string with different fingers or different parts of the finger. This creates a more rounded (lower partials) or less rounded corner shape (higher partials) since some fingers are wider than others.
4. Any combination of the above.

Also observe the decay of the sound during the pizzicato. Let's look at how partials affect this decay.

Let's look at two examples: one with a sharp corner (large percentage of sound focused on high overtones), and one with a less extreme corner (larger percentage of fundamental pitch). If the greatest percentage of the string energy is concentrated into the production of overtones, the sound will die quickly, because the shorter wavelengths (higher notes) have the lowest Q factor. These high frequencies have the greatest resistance to maintaining oscillation and are absorbed most quickly by the room boundaries (walls), internal damping, and surrounding objects. In contrast, if the greatest amount of energy in the pizzicato is concentrated towards the fundamental, the entire sound will continue for a longer length of time, because the fundamental has the greatest mass and thus the most inertia, the widest amplitude, and the highest Q factor.

The strings vibrate mostly in a horizontal plane, so for your own motion to be effective, you must focus it along the horizontal plane of each string. The plane of the G string is different from the plane of the E string. If you pull the string far to the side, the amplitude (sideways motion and volume) will be greater than if you pull only slightly to the side.

Experiment: Understanding how amplitude and partials affect continuing resonance in pizzicato

a. Pluck at the center of any string. This focuses energy towards the antinode of the fundamental, allowing a good Q factor and resonance.
b. Pluck about a third or a fourth of the way up the string. This focuses energy towards the lower partials and the fundamental, allowing a slightly wider amplitude and more projection due to the sharper corner.
c. Pluck very close to the bridge. Although the overtone content is high, the sound is strident and often dies quickly due to the concentration of the energy towards the higher frequencies (lower Q), and less amplitude of the fundamental.

Day Three

Bowed String Motion

Bowed string motion is quite different from pizzicato, but it does bear a few significant similarities. The first is that once again, there is a corner as the bow pulls the string to the side. The second similarity comes from the fact that the sharpness of the angle of the corner directly corresponds to the overtone content of the sound. Beyond this, the similarities fall away.

During bowing, oscillation is not free, but "forced." (Although not aesthetically desirable, we will use the physics term here.) The corner is constantly replenished, leaving open the possibility of sustaining motion, and thus enabling a wider array of continuing colors than pizzicato. Since the motion of the string away from the bow is extremely complex, we will focus first on the motion of the string *at the point of bowing*. This motion is defined in physics as "slip-stick friction". At the bow, there are two phases of motion. The first is when the bow pulls the string to the side (sticking friction), and the second is when the friction of the bow can no longer hold the string in its sideways position, and the bow releases the string, which "snaps" back to the other side (slipping or sliding friction). Sticking friction and slipping friction both occur in phase with the circular path of the corner. In other words, the Helmholtz corner and slip-stick friction happen simultaneously and influence each other directly. The sticking friction phase is always the longest and the slipping friction phase (the "snap" back") is always the shortest.

For the previous video and the graphs on the following page, follow these steps:

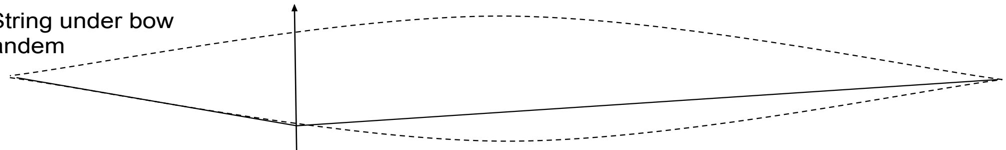
1. Graph 2: Follow the progression of the point of the string under the bow (shown by the colored splotches).
2. Graph 1 and 2: Then, follow the progression of the corner around the string and compare the timing of the two motions (the corner and the frictional motion)
3. Finally, watch the GIF again to see an animated version of the same motion. Notice the shorter phase of slipping friction.

The corner leaves the bow and zooms in one direction around the string, reflecting from the ends of the string. These ends are defined as the bridge and the nut (in the case of an open string), or the bridge and the finger (in the case of a stopped string). How efficiently the corner reflects depends on the softness of the reflecting surface (aka ebony (hard), or finger (varying degrees of softness depending on placement). The corner made by the bow and the corner reflected by the finger/nut each continuously influence the development of the other.

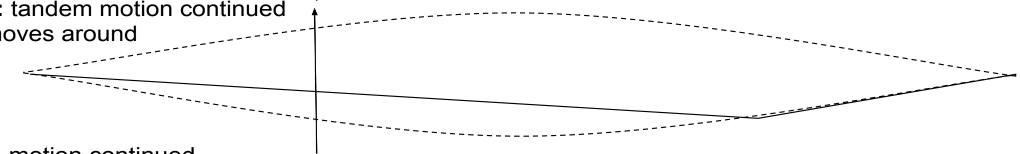
Experiment: Visualizing a single stick-slip cycle: Single and multiple string stops.

a. Place the bow on the G string. Allow the arm weight to sink into the string in such a manner that the friction of the bow hair silently pulls the string far to the side. Continue pulling silently until the string completes a single "snap" or "ping" sound. I find this works best when holding the violin upright in your lap in a "cello" position.
b. Hold the violin in the normal position. Allow the arm weight to sink into the bottom three strings, feel the bow pull the strings to the side, then allow a quick motion of the fingers, *colle',* to bring about the simultaneous "snap back" and continuing free oscillation of all three strings.

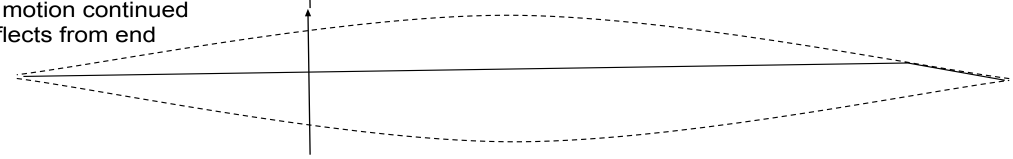
Sticking: String under bow
Moves in tandem
With bow



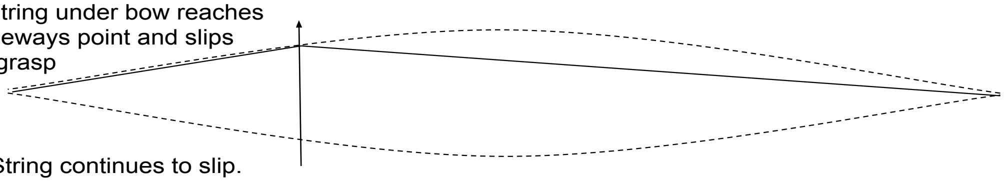
Sticking: tandem motion continued
Corner moves around
string



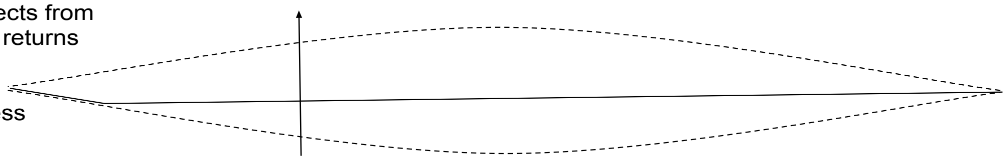
Sticking: motion continued
Corner reflects from end
Of string



Slipping: String under bow reaches
Farthest sideways point and slips
Away from grasp
Of bow



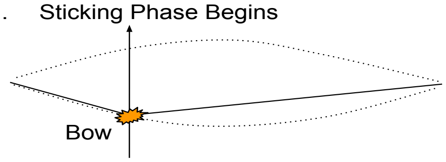
Slipping: String continues to slip.
Corner reflects from
Bridge and returns
back
To bow,
Then process
repeats.



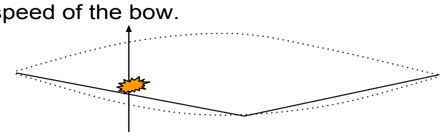
Motion of String after Periodic Sound is Achieved

Sticking Phase (longest phase)

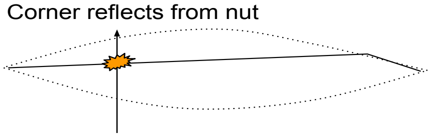
1. Sticking Phase Begins



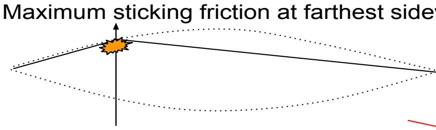
2. Corner continues past the bow, as the bow pulls the string back to the other side at the speed of the bow.



3. Corner reflects from nut

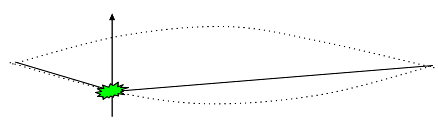


4. Maximum sticking friction at farthest sideways point

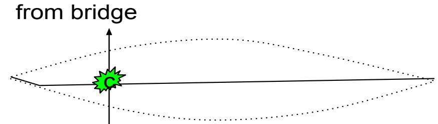


Slipping Phase (shortest phase)

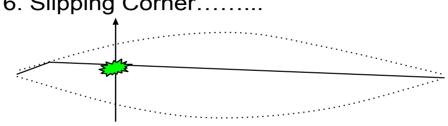
8. Maximum slipping friction reached and bow grabs string again



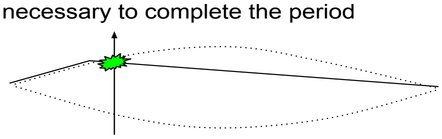
7.Corner continues to slip and reflects from bridge



6. Slipping Corner………



5. Bow releases string, and the corner zooms around the string at whatever speed is necessary to complete the period

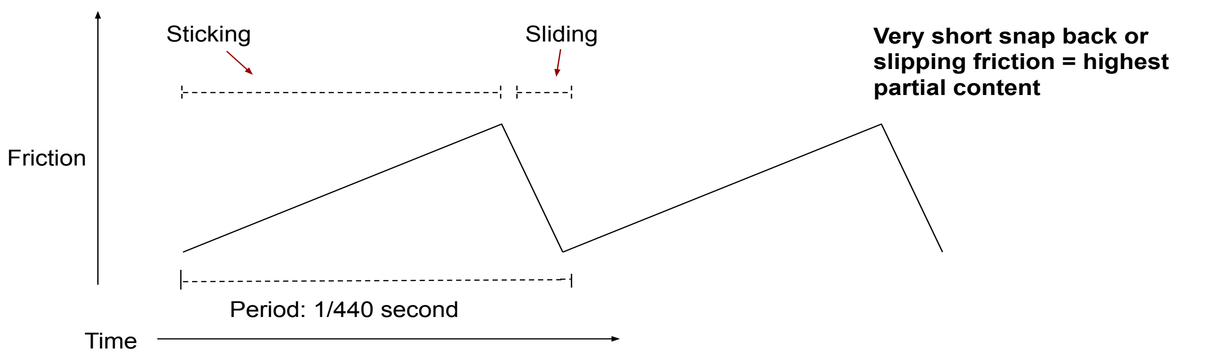


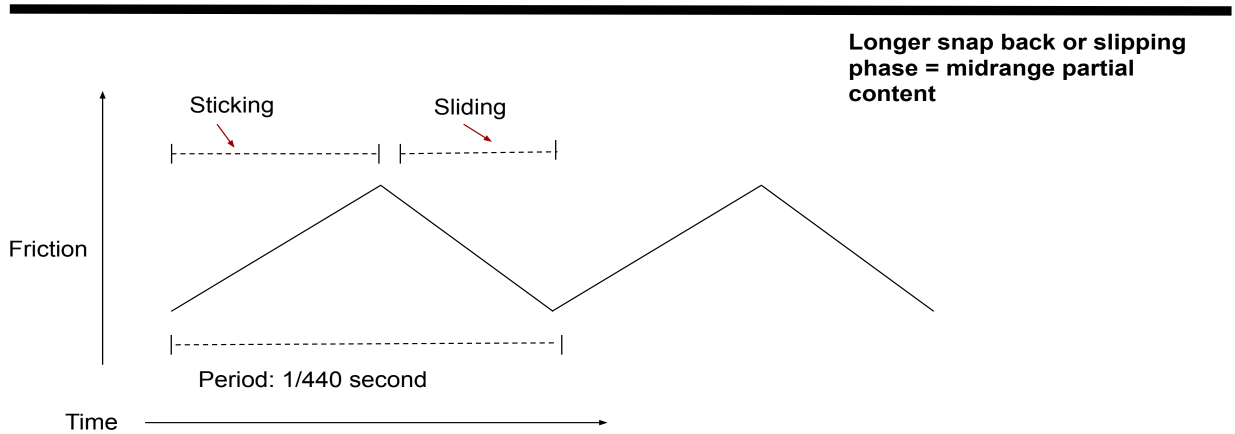
Day Four

Dynamics and Tone Color

The complete period of a string during any given note is always related to the number of vibrations per second, also known as Hz. “Period” is a term that represents the time it takes for one complete cycle of stick and slip friction. For example, there are 440 complete periods per second during the sounding of the open A string. Each single period takes only $1/440^{th}$ of a second. If due to too much pressure, the sticking friction is too great for the string to move freely, the two phases of friction simply do not fit into the time frame allowed for them. The period lengthens. When both phases do not “fit” in to the $1/440^{th}$ of a second, the pitch is lowered (Ex. Period might equal $1/438^{th}$ of a second; The note is flattened=438 Hz).

Where do the possibilities of tone color occur in such a time-sensitive system? They occur INSIDE that $1/440^{th}$ of a second, within the comparative time of sticking friction and sliding friction. For example, sticking friction might take most of the time during the period, with a lightning-fast snap back, (soloist sound, high weight, sharp corner) or, sticking friction could take just a little over half the time, leaving more time for sliding friction (orchestral pianos, blending chamber music sound, low weight, more rounded corner). Infinite variations occur between, though sticking friction is always the longer of the two phases.





There are many different schools of thought on sound, and in my opinion, all of them should be used to achieve the widest array of tone colors. One other important note is that in real string playing, the phases of sticking and slipping are ever constantly changing from period to period because of multiple counterbalancing influences of the bow, the corner, the reflections, the friction, and the various mechanical impedances within the instrument. Playing well requires great sensitivity.

Experiment: Degrees of player input and sensitivity with regard to consistent sound production.

1. At a high weight, the sharper corner causes small interruptions in the regularity of Helmholtz motion as it passes the bow. A portion of the difficulty in playing at this high weight is due to the interruptions, and another portion is the amount of mechanical energy that escapes as sound energy. When bowing weight is high, the player must constantly replenish 4/10ths of the energy to maintain the sound. The player must learn to not only put energy into the string, but physically feel the string, allowing the right hand to "listen" to its constantly changing response.
2. When bowing weight is low, the player only has to replenish $1/10^{th}$ of the energy for sound to be constantly maintained, even at high bow speeds. There is much less interruption in the Helmholtz motion with the more rounded corner, and thus greater ease. If you have a good instrument, there is not necessarily much less projection.
    a. Practice replenishing energy continuously and consistently. Try as many differing weights and speeds and locations as possible, from the *son file* to the fastest manageable whole-bow-per-note speed during a three-octave scale.
    b. Practice replenishing ever slightly more energy than is necessary for sound maintenance to gradually to create a crescendo. Pay attention to string compliance (what the string WANTS to do and how it WANTS to be treated). Pay attention to the relaxation and constant motion of your arm.
    c. Practice replenishing less energy than is needed (relaxing gradually) to create a diminuendo). Pay attention to string compliance (what the string WANTS to do and how it WANTS to be treated). Pay attention to the relaxation of your arm.
    d. Notice that different bow speeds are required for different pitches due to the faster or slower motion of the string. Notice how different the bow speeds on the G string and E string can be in optimal circumstances, and try to narrow the gap for fun, especially by traveling with a faster bow speed on the G string. The sound you achieve in this fashion on the lower string will have great amplitude and may pleasantly surprise you.
    e. Begin to imagine that the bow and the string are building your sound for you. Now we are ready for our next concept: nearly free oscillation (resonance).

Day Five

Beyond Resonance: Nearly-free oscillation

Search videos of the "Tacoma Narrows Bridge collapse" on YouTube before you begin your practice today. These videos will give you an excellent visual for imagining resonance, even though the phenomenon portrayed in the video has a slightly different term in physics (called aerostatic flutter)(Knill).

The bridge is oscillating in one of its natural frequencies, where the mass of the bridge and the inertia created by its movement keep the losses in the system very small. This means only a little energy is needed and added to keep the vibration going. Our goal is for the violin string to build up a similar amount of inertia so that the energy of the string will result in continuing motion with minimum assistance from the player, even in forte. In the case of the Tacoma Narrows Bridge, the wind replenishes the very small amount of energy that is continuously lost from the system. A similar phenomenon should be true in expert string playing. The bow should effortlessly replenish the very small amount of energy needed to keep the string vibrating. For string instruments, in mechanical terms, the amount of energy lost into the air through sound production is quite small when compared with the oscillating energy of the string. In other words, the inertia of the string is high, and the mechanical Q factor is high. (Cremer, The players work level is low. The violin is very efficient and WANTS to work with you.

Exercise: Understanding how resonance builds up beneath the bow and continues after its release.

a. Open strings only. Practice using a fast, sideways motion to create resonance in the string. First, place the bow on the open D string and use a fast bow-speed to traverse the length of the entire bow, taking off from the string like an airplane, and letting the string ring for entire SECONDS after you leave it. Try this a few times. You will know you have achieved resonance when the sound continues for a long time after the bow leaves the string. Make sure each bow stroke feels like one motion, a single event.
b. Now we will try the same exercise with the bow staying on the string. Use pull and push motion (up and down bows, respectively). Each bow feels like a single fluid motion or event, and the string should resonate over the bow change. Start over the fingerboard for ease, with the bow moving as quickly back and forth as possible. (You will quickly discover any habitual ineffective motions in your bow arm at this fast pace.) Slowly move closer to the bridge without decreasing speed. Feel the sound begin to maintain *itself.* If the kind of resonance achieved *while the bow is on string* is similar to the resonance from the previous exercise, the bow changes will be smooth to nearly invisible. Cremer refers to this as "nearly free oscillation." It is the favorite of west European-school chamber and orchestral players.

What is actually happening in nearly free oscillation? How can the bow changes be so smooth? No experiments exist to date, but I would hypothesize that as long as the bowing weight is not extremely "sticky", a nearly magical moment takes place. The string escapes the bow to pursue its own free oscillation for a few periods (representing a tiny portion of a second). Sliding friction occurs in both directions on the string until the bow changes direction once again catches the string, and the sticking phase of the string re-approximates the motion of the bow in the other direction. A nearly seamless bow change results, especially in higher positions, where the back and forth motions of the string are faster. This is the solution for the nearly invisible bow changes in the slow movement of the Beethoven Concerto or the Mendelssohn Concerto. It is called nearly-free oscillation and it can happen with predictability only when the bowing pressure is at a *minimum* for the chosen weight and speed. (Cremer, 56, 60).

The other lovely aspect of this type of bow change is that a portion of the energy is continues during the bow change. One experiment showed that, in expert cello playing, the bow speed increased a split-second (approximate 4/10ths of a second) before the bow change. I would suggest that this increase is mostly inaudible for the audience and subconscious for the player, but allows for the bow to change motion while the string continues to move. It is also possible that the increase of sound simply drowns out the sound of the bow change. Either way, this is probably what Cremer meant by "nearly free oscillation." It is a wonderful trick, although it requires a great level of sensitivity from the player. Even in forte, this wonderful, resonant sound can be maintained, lending ease to concerto and solo playing.

Experiment: Examining your own school of thought

Few teachers explain the nearly free oscillation model, supposing that it will develop eventually. In reality, it develops only rarely. The most efficient way of achieving resonance and nearly free oscillation is to simply start a note and allow the string's inertia to continue periodic motion with constant, slight replenishing of the corner by the bow arm.

1. Relaxed arm weight must be trained and takes time to build as a habit. Weight is probably the most important aspect in creating the corner in terms of physics, but it is not perhaps, the most effective focus for the player's mind.
2. Once weight is trained (readily available to most professionals), and relaxation is present (not as readily available), the most important focus for the mind is undoubtedly bow *speed.* Here's why:
   a. Habits of faster bow speed create the highest rate of success in performance due to the immediate release of fluid motion. (Muscles tend to contract under pressure, and constant motion negates physical tension).
   b. Since the string moves within the horizontal plane, fast bow speed creates a simple plane for the arm with little room for ineffective habits.
   c. Most professional players increase weight naturally when told increase bow speed, leading to a nicely sharpened Helmholtz corner with lots of overtones and great amplitude. Interestingly, if you ask the same professional players to increase weight, they are not as likely to increase speed. The sound becomes "crushed."

Thus, after weight has become a trained habit for a student, as a teacher, I more often verbally emphasize bow speed. Watch the Berlin Philharmonic for examples, or Anne Sophie Mutter, or the online videos attached to this section (www.wendycase.com).

Day Six

Transients and the Four Bowing Parameters

There are many different schools of thought on tone, with the largest differences coming from those that suggest weight as a means for projection, and the schools of thought that suggest speed for projection. We need all the styles and everything in between if we are to create the widest tonal palette. The Galamian method mentions three factors in bowing: weight, speed, and location. Scientific measurements in the last 20 years have created a fourth: during the very beginning of each stroke, regardless of style, it has been shown that the bow accelerates rapidly. Musicians usually call this acceleration "articulation" and it has a great deal to do with achieving periodic motion and continued resonance. If the articulation is ineffective for any reason, periodic sound is quite difficult to achieve after the start of the note. If periodic sound is not achieved, resonance is impossible. Fortunately, there are over 100,000 useful transients in the finest instruments, from nearly invisible to quite abrasive. It can be safely assumed that perfecting the ability to execute the initial acceleration or transient is the largest cause of the difficulty in training young string players. Unfortunately, most transients happen in under 5/10ths of a second, and thus comprise for the most part a subconscious activity. The young player must learn to hear and feel all the moments surrounding the transient for the event to become "conscious."

What is a transient in physics terms? Just as the Tacoma narrows bridge took a while to begin periodic motion, periodic motion on the violin takes several split-second-periods to achieve. During these chaotic motions, we hear the "transient." On the journey to achieving periodic oscillation, the chaotic motions creating the transient are actually the sounds we know as high frequency overtones. The transient is made up mostly of these overtones, with a nearly invisible fundamental pitch. As the chaotic motions become the periodic motion of the string, all of the overtones heard in the transient continue into the following sound, although the proportion of their amplitude drops in relation to the greater amplitude of the fundamental. Since all partials present in the transient continue into the following sound, articulation has an extraordinary amount of influence over the color and character of the continuing sound. (Cremer, 184.)

Experiment: Consonants and continuing sound

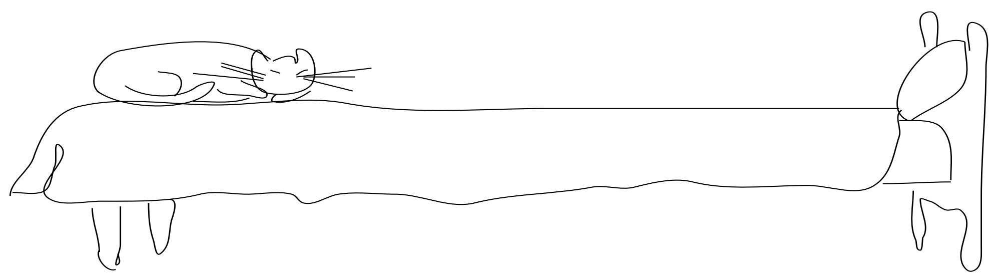
Play with different consonants on open strings as articulations and notice the time it takes to achieve resonance after each one. Notice the different colors that result from different articulations. Notice that even an "invisible" orchestral piano articulation is still a type of consonant and that periodic oscillation still takes time to achieve. Remember to stay relaxed and see how many types of consonants you can achieve. Next, try various sections from pieces of contrasting composers. Notice that a hard consonant such as "K" or "T" will achieve periodic oscillation more quickly than a soft, orchestral consonant such as "B" or "P". The overtones of the former are extremely high in range. The overtones of the B or P are lower in frequency or pitch. The overtones of the consonant dictate the color of the following note and thus, comprise 90% of character.

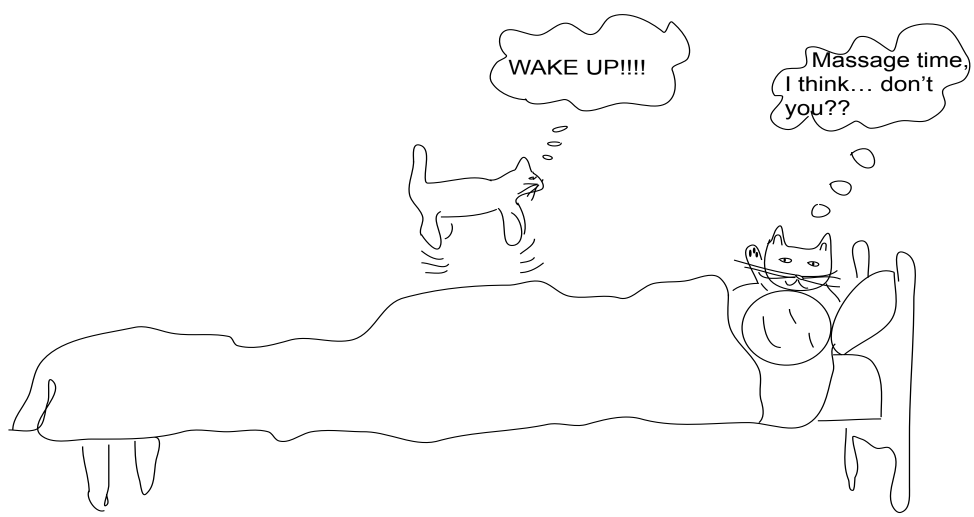
Day Seven

Rest

Good work. Take the day off. Your brain actually learns during this day off. It solidifies and processes all your new knowledge.

Look who is waiting for you….





Day Eight

Seven types of Transients

There are only seven types of articulation. Two are self-explanatory: the pizzicato (left and right hand), and the bouncing bow stroke, where the slight circular motion of the string creates an extra moment of not-quite-periodic motion before the beginning of the sideways oscillation. In fast bouncing strokes, a strange microscopic phenomenon occurs, but I will leave that to the longer book on technique since it occurs subconsciously for the player.
There are five other types on which we need to concentrate.

Articulations with the Bow

1. Back and forth bow: The corner on the string reverses direction, and it takes a few periods to achieve periodic motion in the new direction. If you want a smoother change, you must insure that you have achieved "nearly free oscillation" or resonance so that the sound of the continuing oscillation covers the change in the bow. If you wish for a clearer articulation, it will happen naturally as a result of switching bow directions.

2. String Crossing: This articulation is usually introduced late in training. If you cross the string by allowing the bow to move quickly through a sharp angle, the new string will need additional starting momentum for producing an acceptable transient since the bow is already moving at a high speed. Usually this additional starting momentum comes from a sharp angle change from the bow, producing extra weight. (see starting the fourth bowing parameter on day 6). Note that conscious acceleration during a high-speed run may prove difficult, so we are adding a tiny bit of extra weight to start the new string. A sharply crossed string creates a slightly higher weight, allowing a smaller needed parameter for speed. This is technique is especially important in fast, slurred runs. On the contrary, a smoother string crossing in a legato passage can be created by a less extreme angle change between strings. (For example, when crossing from the G to the D string, one must simply allow the bow to lean towards the D string at the end of the G string note so that the transition is more gradual.

Articulations with the L.H.

1. Fingers dropped: Dropping the fingers with speed (force = mass x acceleration due to gravity), creates a click. The string is vibrating vertically for a brief moment, but this energy transfers quickly into sideways motion because of the shape of the bridge. (I'll leave the reasons for that to the larger book). However, in the meantime, the L.H. has given a "jump start" to the note. Force= mass x acceleration due to gravity. ***After the drop, instant release of pressure, almost a bounce in the finger, is essential to prevent injury.***
2. Fingers lifted (oblique angle): The fingers move at this oblique angle naturally since the hand is already at an oblique angle to the neck of the violin. All that is needed is to drag the fingers swiftly across the string, back towards the hand, for the quick plucking motion that articulates a downward scale. Placement of the fingers to the left side of

the string on the pads is desirable in readying the hand for this articulation (and also for the vibrato, which is usually most effective on the pad of the finger). This placement of fingers runs contrary to most prevailing opinions on student-level technique.

3. The Shift: As the shifting section suggests, the slight lift of the finger as it slides creates space (see day 12), and the drop of the finger into the new place creates a small click that begins the next note. I prefer to introduce this technique by shifting between 1^{st} position and 2^{nd} position on the D string. (1^{st} finger E, to F#, and back again).

These are all the types of articulation you will ever need. While multiple factors happen on a subconscious level in the science for the thousands of different articulations, these are the only necessary conscious methods of articulation. Once you have them, you need only use one type per note, except in very rare cases.

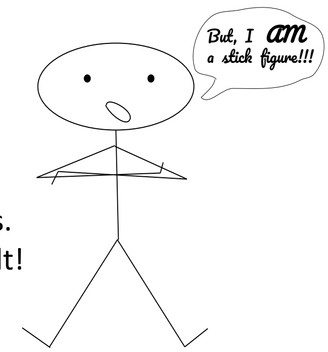
Experiment: Consciously checking transients in technique

a. Step 1. Practice saying type of articulation out loud while playing slowly the runs in the Bruch or Sibelius Concerto. Ex. "start, drop, drop, drop, cross, drop, drop, off, drop, shift… etc."
b. Step 2. Feeling the articulation, using the artistic parts of the brain, rather than giving each articulation language.

Day Nine

Relaxed Motion: Kinesiology

Muscles can only contract. They cannot expand. This means that every motion you make with your arm consists of a set of muscles which first contract, and then relax, while a different group contracts to move your arm in the opposite direction. Use mental energy to focus on the alternating groups of muscles that *relax* during bowing.



Contracting two opposing groups of muscles at the same time causes tension. Tension makes motion more difficult. Constant physical motion, conversely, makes tension less likely. Try a thought experiment: One's fastest speed of sprinting requires constant contracting and releasing of alternate muscle groups. Imagine attempting to run with legs that acted like sticks……it may prove difficult!

Desired articulation and resonance must be achieved without tension in the body. The violin is very sensitive. Even the slightest tension in the body will make itself apparent in the sound. Here are some concepts to apply:

1. The follow through: like a tennis swing, follow through is important and is useful in producing nearly free oscillation.
2. Constant motion: Allow constant motion in the hands to negate tension. Even when practicing slowly, do not allow any stops in the movement of either hand.
3. Starting a note: start with fluid motion, even if that motion is placing the bow on the string immediately before beginning the note. Again, remove pauses in motion from your playing except for rare dramatic effect. Most of us are not aware of how many "stops" in motion are built into our technique by the slow practice induced by our teachers. Of course we should practice slowly, but our brain should think quickly and our muscles move constantly, maximizing directional efficiency of motion. Even heavy articulation can be achieved without tension.

Experiment: Practice both resonance and follow through or constant motion
Find the Bach g minor fugue in your music file. Play at about half tempo, with all of the same motions you might do in a fast tempo (probably a bit larger, of course).

1. Create constant motion between notes, even if that motion in spiccato passages requires "air time," Use follow throughs.
2. Notice how efficient string crossings can be if every moment is imbued with purposeful and directional movement towards the new string.
3. Vibrate every note in the left hand gently at a moderate speed for constant release.
4. Notice where you have habits of tiny "stops" built into your technique, and cause them to vanish into fluid, efficient motion.
5. Practice all transients from the previous day, and releasing between notes in BOTH hands, even if that means lifting a L.H. finger between repetitions of the same note. This will get you ready for tomorrow's experiment.

Day Ten

Cleanliness and Release

Cleanliness is simplicity. Most players think of articulation as the beginning of a note, but what if articulation is also made clear by the ceasing of the vibrations of the previous note? In other words, cleanliness can also be the space between notes, and then the re-articulation. This may sound like a lot of steps, but if you apply the ideas of constant motion, it results in less work.

Today's topic applies to both slow and fast passages. In a slow passage, the ratio of release time to playing time is smaller than the ratio of release time to playing time in a fast passage. In a fast passage, we may even have nearly half playing and half release time, as in spiccato. In a slow passage, we will "sing" with the bow and put more effort into the middles and ends of notes, with less space between. We may even choose to seamlessly combine the notes of a phrase together without much articulation. In this all cases, whether constant sound or space creates cleanliness, constant motion in both hands must form the basis of relaxation.

In a fast passage, the story is different. Clarity FIX only requires two conscious steps: articulate, then release. If the articulation is truly excellent, resonance results between the articulation and release. *Release is essential and frequently forgotten, even by professionals*. The release must be practiced even in a slow tempo, with smooth, constant, relaxed motions. Why is the space important? Imagine two very fast notes. Without space, the consonant of the second note will blend somewhat into the vowel of the first note, especially if nearly-free-oscillation is taking place. In certain cases, this is acceptable (detache), but it does not allow for the highest clarity (bouncing strokes and martele). With space, the second note can have its own consonant of choice, and the fingers get a break from working *between* notes.

As you practice these concepts, keep in mind the law of inertia, which says that objects in motion stay in motion unless acted upon by a given force. The string continues motion. Your body is in motion. Even your arm has momentum during the bowstroke. You may change direction or intention, or even its intensity, but one can nearly always remain in motion. In terms of the concepts of articulative space, this means that the string itself may continue to resonate while the follow through of the arm continues the slight motion of changing the direction of the bow.

Let's look at an example of articulation and release:
When an object falls, it picks up speed. The further the drop, the greater the increase of speed. In playing, the finger is dropped to the fingerboard with considerable speed. If you have dropped your finger quickly enough, the string contacts the fingerboard with directness. At that moment, your work is nearly done. The string is placed, the finger has landed. At this moment, many teachers insist on continuing to press the finger into the fingerboard. This is incorrect, since the greatest amount of energy needed to bring the string to the fingerboard has already occurred. Even keeping the string on the fingerboard requires next to no effort, and can provide a conscious release if your hands are properly strengthened. Simply allow the relaxed

weight of the finger itself, transferring into the constant motion of vibrato, to keep the string down.

Now we must consider the law of the conservation of energy, which says that energy is neither created nor destroyed. *Therefore, the energy created by the finger must go somewhere.* Where it usually travels (in even professional players) is into a subtle type of tension, a “hold” or “pressure” in the finger. This is also is incorrect although many references are made to “holding the string down” in very fine technique books. If we are to be nearly tension free, the energy of the drop must travel elsewhere. Here is where it should go:

1. Sound waves (the initial sound of the string contacting the fingerboard). This effectively “starts” the note. (L.H. articulation)
2. Some energy is absorbed and thrown back into the finger by the elasticity of the string, like a trampoline. (the finger “bounce”)
3. This thrown back energy is the impulse for the vibrato, allowing the finger to absorb the impact.
    a. to demonstrate this, drop a pencil, eraser end down, onto the floor. Notice how its angle of impact is likely to cause a bounce sideways when absorbing the impact. Also imagine how an athlete may roll to absorb impact during a tumble.
    b. The vibrato is purely the “roll” of the finger to absorb impact. Eventually, like the instincts of athletes, it becomes nearly automatic.
4. Note that heavier fingers will require less speed of dropping since they have more mass. Force = mass x distance x acceleration due to gravity

Experiment: creating ease through drops in the fingers and bow

1. Scale without bow, L.H. only. dropping fingers. Treat the string like a trampoline since it is elastic. Notice how the drop both assists the articulation of the note and rebounds into vibrato. Bow releases and finger drop releases.
2. Slow spiccato drops from the air with the bow, allowing a natural high rebound from the string, and a return to the string caused by gravity.

Day Eleven

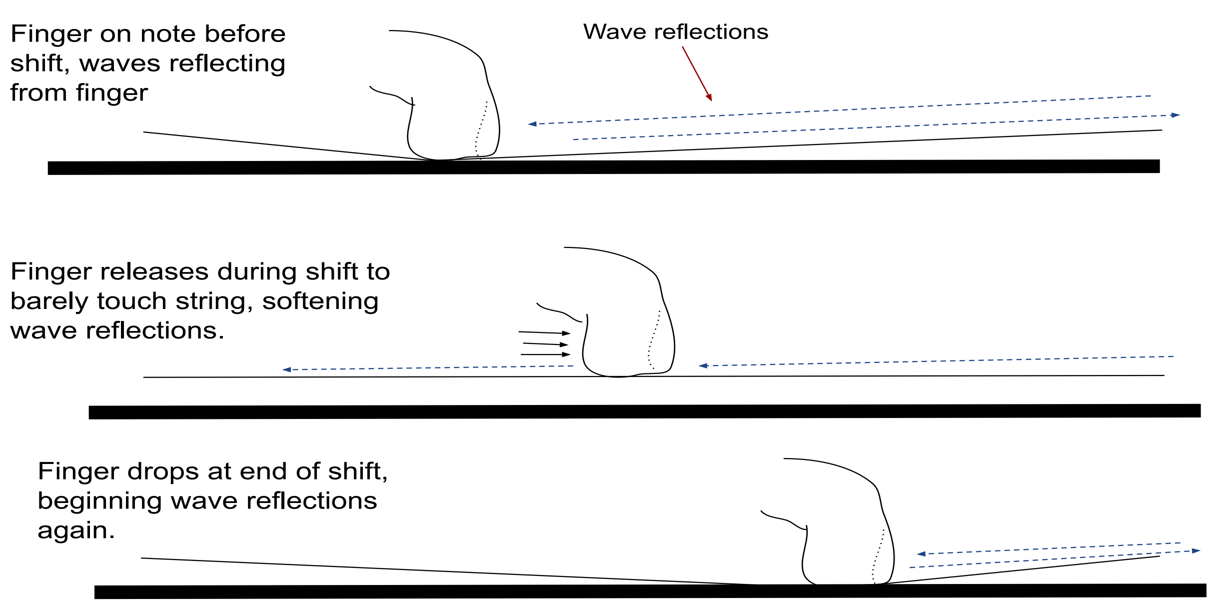
The Vibrato
Much effort has been spent on developing vibrato in other texts, so allow me to say something that has been said very little. The human ear detects pitch based on overtones. The greater the number of overtones, the better the pitch detection. Therefore, if you want an audible vibrato, you have to start with audible overtones and the bow, not the left hand. Let's perform an experiment. Play a first-position G on the D string. Put the bow over the fingerboard and bow as fast as you can with little weight, and without a squeal, back and forth. Keep going. While continuing the same fast speed and nearly the same weight, move the bow gradually towards the bridge until you are at the maximum proximity to the bridge before achieving ponticello. (This should remind of you of the exercise in day 5, letter B). Keep going with as fast a bow speed as possible. (Fast bow speed allows ease of resonance while activating the high overtones). Gradually add the tiniest vibrato wiggle and notice how wide it sounds since you are producing many high frequency overtones.
Beyond this exercise, I must say that although I routinely work to develop my student's vibrato, their vibrato usually becomes fully mature at a strange moment at which their hearts begin to love playing. For this reason, I believe that, although vibrato can be trained, far beyond physics, it comes from the "soul."
One should also make a note that vibrato usually causes varying wave reflections on the string and thus in the bow. Responding to these reflections requires a bow hand sensitivity that can takes years to develop. One of the largest obstacles to developing this sensitivity is that the highest weight of playing contains several irregularities within each period, leading to great difficulty of sound maintenance. Therefore, in the development process, since high-speed bowing with minimum weight contains more regular Helmholtz motion, I recommend speed as a focus until nearly free oscillation has developed. Once the nearly free oscillation bowing style is present, one can attempt to produce it while training differing bow weights, gradually increasing the "stakes."

Experiment:
1. A three-octave scale: with fast, fluid bow speed and whole bows, finger drops, and vibrato rebounds. The vibrato is a part of the release into constant motion.

Day Twelve

The Shift
What happens at the level of the string itself during the shift? Most of the time, we focus on hiding shifts, or even on shifting smoothly, but neglect fundamental physics.

Wave reflections are happening constantly at the nut and the bridge, (or in the case of a fingered note, at the bridge and the finger). These reflections are essential to continuing periodic sound. These waves behave in similar ways to the waves in a bathtub. Once you start, they traverse around the string, back and forth, continuously. In a bathtub, the surface is hard, so the waves reflect with near perfection. On the violin, the finger is soft, and the pad of the finger reflects only some of the energy, while the harder ebony fingerboard reflects more of the energy, and a little of the energy passes the finger, un-reflected. For an experiment, do not press the string all the way to the fingerboard, and you will see how few of the waves reflect and how quickly the sound dies. (In high positions, this technique can be used to prevent the highest overtones from making the sound too shrill.) Similarly, if we want to hide a shift, all we have to do is stop the wave reflections by lifting the finger so that it barely touches the string and slide. We do not need to shift quickly, or wait until the last moment, or find the pitch by leaning into the fingerboard on the slide. Instead, the finger moves from its place and makes a timely arc in gentle contact with the top of the string, once again dropping into place on the new note. The true brilliance of this concept is seen in released tension, but also in very slightly audible (only to the player) slide. If practiced slowly and enough, it becomes a near fool-proof way of perfecting shifts even in atonal music.



Day Thirteen

Intonation

What is frequency?

Frequency is a number of oscillations per second. In general, if two notes are being played simultaneously and we hear them as consonant, the number of periods approximating a simple ratio. For example, the pitches A440 and the octave above it, A880, line up every two periods, creating two separate coordinating sensations within the ear, which we perceive as consonance. Fifths are the 2:3 ratio, fourths 3:4, and pure sixths 4:5, and pure thirds 5:6. Needless to say, seconds, sevenths, and tritones do not have simple ratios.

The basics of developing a good sense of pitch revolve around the ability to train one's fingers into finding, and ears into hearing the ratios.

Due to the presence of overtones, consonant intervals must line up with the matching overtone. In a perfect world, this would be a simple ratio. We will discuss advanced intonation choices in detail in the larger book. For now, suffice it to say that in actuality, every violin contains something known as inharmonicity. Styles and degrees of inharmonicity are different for different instruments, and we must learn both the style of our own instrument, and the style of the instruments and players with whom we collaborate. Each violin, each piano, each orchestra, and each concert hall is different. In order not to repeat many of the wise things that have already been said, you can learn more about tuning systems and their variants in a fantastic book called *"How Equal Temperament Ruined Harmony and Why You Should Care,"* by Ross Duffin. In summary, great intonation requires instantaneous flexibility.

Experiment: Building flexibility into pitch and the Sevcik paradox

a. Pick any major scale and play it with separate bows, vibrato, and a drone on the tonic note. Pay special attention to the perfect intervals in the scale and the notes of the tonic chord. (3^{rd}, 4^{th}, 5^{th}, octave). (Vibrato is important in this exercise, since it fundamentally changes the finger placement and what tuning is heard. Although most of us were taught to vibrate below the note, psychoacoustical experiments show that the human ear hears the pitch in the *middle* of the vibrato, not the top. Probably this trend to vibrate at and below the pitch began as a teaching tool to counteract the overall tendency of violinists to play sharp).
b. Pick the same major scale and play it with a drone on the supertonic note. Adjust all notes that form the minor ii triad and perfect intervals with the supertonic as you play at normal speed. (4^{th}, 5^{th}, 6^{th}, 2^{nd})
c. Pick the same major scale and switch to a drone on the median note. Adjust in the same manner (5^{th}, 6^{th}, 7^{th}, 3^{rd}). Now you have practiced flexibility on every note of a scale.

Day Fourteen

Rest

Good work. Take the day off. Do something fun! Take your cat on a walk…..

Day Fifteen

Concepts of Ease and Inertia in differing resistances

Take a large washer, place it on a spring, and let it find a resting place. We will call the resting place **equilibrium**. Equilibrium implies that all competing forces on the spring are temporarily equal.

Now, create **friction** by placing your thumb and index finger on the mass. Create enough friction that the mass is pulled down by your fingers. Pull it and let it go. Watch it bounce. Notice the two forces at play: **gravity (**downward) and the **elasticity** of the spring (upward). The alternation of the pull of the forces upon the washer (the mass) create something called a frequency of oscillation, or a number of times per second. If the spring did not have a restoring force (elasticity), and the mass did not have weight, there would be no oscillation.

However, once there is oscillation, another principle called **inertia** comes into play. The law of inertia states that objects in motion stay in motion unless acted upon by a given force. The heavier the object (greater mass), the longer it will stay in motion. Imagine a semi-truck going down a hill and a car going down the same hill. The semi-truck will take more energy start motion, but also will continue motion longer because of its greater mass. You can try this with differing weights on the spring. If the mass is heavier, (but not too heavy for the elasticity of the spring) motion will be slower, but will continue longer. If the mass is lighter, faster speed and less inertia will result. Now let's transfer all of that information to the violin. The strings on your violin are in equilibrium when they are silent, stretched between two points.

Once the string is oscillating, certain forces influence inertia, or continuing momentum:

-Mass: length and density of the portion of the string that is moving

-Elasticity: spring-like restoring force, which varies drastically depending on pitch and individual strings. G# in 3rd position on the A string will have less elasticity than g# in 1st position on the E string.

-Mechanical Impedance: although influenced by mass and elasticity, mechanical impedance is also influenced by torc, tension, and the shear modulus and a host of other factors. For simplicity in this book, we will call it "resistance," from musician vernacular.

-Every note is different. For that matter, every note on a different string is different. And one can take this discussion in direction of color, style, response, phrase, etc. Use your critical thinking skills to apply it!

-YOU: Your amount of energy input, your own responsiveness to the violin's feedback to your bow hand, and the continuing influence you exert on the string with the bow.

Experiment:

a. Apply this lesson to varying single pitches, noting differing responses, inputs, inertia, and partial (overtone) content.
b. Experiment with simple open string double stops, putting a slightly greater energy into the thicker string by leaning the bow slightly toward that string. In most of the common situations on the violin, the thicker string has greater mass, elasticity, and mechanical impedance.

Day Sixteen

Double Stops and Physics
Double stops are rarely understood well, even by professionals. If you review both day 13 (intonation) and 15 (concepts of inertia), you will have a good start on today's lesson. Pay more attention to detail than you think is a good idea. Here are some concepts to remember:

1. Sympathetic Vibration: If there is a simple interval ratio, there will be a partial ringing in consonance with the higher pitch. The partial will reinforce the upper pitch's vibrations ***if you play in tune.*** Open strings fulfill the same purpose. *Tuning is essential for resonance.*

2. Mass and Energy: The lowest notes of a chord require the most energy, especially if they are fingered notes and some of the wave reflections are absorbed by the finger (as opposed to open strings, where waves reflect quite freely from the nut). The upper notes usually require *less* energy to maintain oscillation. However, notes played simultaneously must, of necessity, use the same bow speed. *Focus on starting the sound and adjusting angles of the bow rather than pressing. (*Guettler, *Double Stops.)*

3. In sustained double stops, the lower string must receive the most weight, or in practical terms, the bow angle must lean slightly toward this string. This is because it has greater mass, elasticity, and oscillation envelope, AND because the frequency is lower, leading to less perceived sound from the lower pitch. More will be said on differing string envelopes in the larger book. We will cover two additional concepts tomorrow. *Lean the bow very slightly toward the lowest string being played to increase the energy needed for the greater mass.*

4. Resonance and Inertia: If you can create full resonance at the beginning of a chord, this continuing energy or inertia will improve the likelihood of full resonant motion to be achieved on consecutive chords in the same passage. (This is because you are not only moving the strings of the violin when starting motion, but the wood of the entire instrument). In a four-note chord, if the bottom notes are resonant, the top notes will respond much more quickly. Most players simply press too hard to achieve resonance. *Focus on starting on the string with an initial speed in the perfect plane for the double stop you are playing.*

   Experiment: Notice the envelopes/responses for simple double stops. Learn how to lean the bow to one string or the other. Exceptions can be fingered strings with open ones.

Day Seventeen

Double Stops and Left-Hand Kinesiology

5. In order to relax the hand, the upper finger of the double stop must always be placed first. This runs contrary of the vast majority of string technique teaching, which insists on an anchor finger. Here is why the method suggested here is more efficient:
    a. Fingers 3 and 4 are the weakest, so centering the hand from them assists firmness of placement and lack of stretching
    b. Fingers 1 and 2 are more easily able to stretch backwards than 3 and 4 are able to stretch upwards. (you can experiment with this by placing tenths: first start with the 1st finger and reach as high as possible with 4th. Then start higher with 4th and reach backward with 1st. Nearly every violinist achieves a wider interval with the second option.)
6. There are two exceptions to the rule of the upper finger being placed first. They are tritones, which must be placed lower finger first, and octaves made by the first and the third finger. (the third finger is usually a slightly floppy/unstable finger for most violinists. It seems to need the first finger to stabilize it during a high reach.)

Day Eighteen

*Summary and Review: The fundamental challenge of the violin is how to first achieve periodic oscillation, and then change that oscillation accurately at a speed which defies imagination.**

Concept 1. Your violin is very efficient. It wants to work with you!!!!!!
Concept 2. Producing a resonant sound will increase sympathetic vibration and inertia, thus ease of playing. This requires your input and your sensitivity to the feedback of the string and bow.
Concept 3. Since periodic motion is fairly easy to maintain, we must pay attention to its beginning. We must begin the periodic motion of each pitch as efficiently as possible, with a type of transient appropriate to our interpretation of the character of the note or phrase.
Concept 4: Constant motion negates tension. Working on sound using a constant, relaxed motion is an excellent and productive use of practice time.
Concept 5: Release and the transitions between notes are just as important as the notes themselves. Releases of differing types (in combination with constant motion) should be used to relax between fast notes and create cleanliness.

Experiment: Mix and Match
Now that we have reached the end of our whirlwind journey through violin technique, I recommend combining separate days together and seeing how the concepts apply in tandem with each other.
Ex. 1: Resonance and double stops on a scale of thirds.

Ex. 2: Ease in human body motion in detache coupled with transients and release.

Ex. 3-1,000,000: Your imagination……☺

Works Cited

Cremer, Lothar. *The Physics of the Violin.* Trans. John S. Allen. Cambridge: The MIT Press, 1984.

Duffin, Ross W. *How Equal Temperament Ruined Harmony (and Why You Should Care).* New York: W.W. Norton & Company, 2007.

Knill, Oliver. *Linear Algebra and Differential Equations.* Harvard, Fall 2003. Web. 20 January 2014.

Guettler, Knut. *Double Stops.* Web. 13 July, 2019.