Handbook of Guitar Mechanics

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Introduction

This manual has a mix of practical to highly technical information about how your guitar works. Keep it as a reference for when you run into problems or have questions about how your guitar is operating. This information is also valuable if you're considering buying a guitar. It has several diagnostic tests that can uncover "deal breaker" issues that signify instruments you should not buy.

Contents

Part I. What Controls Action and Can I Improve Mine?

All of us are aware that action--the height of string above the frets--plays a large role in how easy or difficult it is for our left hand to fret the notes. There is no "correct" action setting. For each player, there is an optimal setting that depends on right and left hand technique. Here we have a compromise between low enough to be easy on the left hand, but not too low that the strings buzz against the frets. The optimal height not only depends on right hand strength and technique, it also depends on the dynamic range called for by a player's repertoire. For practical purposes, the loudest, most forceful passages determine the upper action height requirement. This gives a safety margin for clean playing.

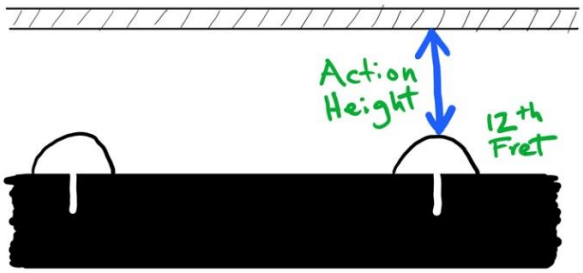
Understanding the basics of what controls action will help you decide if you need some optimization and what adjustments should be done on your instrument. Within each guitar's geometry

(much of which was set at the time of construction), there are practical limits of what can be done to optimize action. If you're considering buying a guitar, there are some signs that could be deal breakers.

You should have your action adjusted in consultation with a local luthier. Playing classical guitar is hard enough, so we need all the help we can get. This is why you should get to know and develop a relationship with a luthier.

Action Height

By definition: "action height" is defined as the distance between the top of the 12th fret and the bottom of a given string. The action of **each string** should be evaluated and adjusted accordingly.



How do I know if my action is too low or too high?

For the dynamics in the repertoire you are playing, ideally the action should be set just above the point of buzzing on the frets. When I work with players, I watch them play different pieces in their repertoire, and together we decide what action will best suit them for each string.

Here is a diagnostic to determine if your action is too high or too low

Step 1: For each string, play the open string and each fretted position ***fortissimo (ff—very loud*)** and then ***triple forte* (*fff—very, very loud*)**. Can you make it buzz?
Step 2: Write which frets produce a buzz. If no buzz, leave the box blank.

String	*ff*	*fff*
6		
5		
4		
3		
2		
1		

Your results

- If a note played at ***ff*** causes a buzz in any open or fretted position, **it shouldn't**. Your action is probably **too low** or the fret next to the fretted position is too high.
- If a note played at ***fff*** causes a buzz, **it should to a small extent**. If it doesn't, your action is probably **too high**.

What action setting for me?

The actual adjustments to achieve higher or lower action are small--on the order of tenths of millimeters of string height at the 12th fret, but our left hands are extremely sensitive and can feel a change of 0.2 mm. A change of 0.5 mm is considered very large. Small distances can have big consequences on our playing.

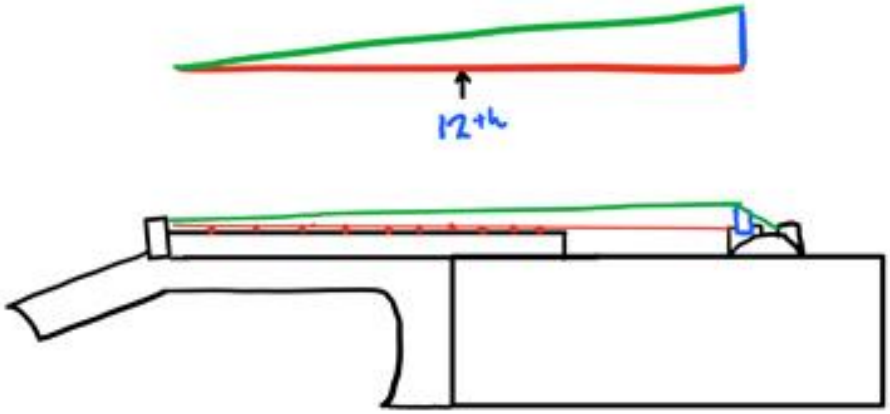
Some typical action settings might look like the following. Special rulers or calipers used by luthiers are needed to measure them, and the numbers are usually more meaningful to your technician because it gives a relative sense of your playing needs and the geometry of your guitar. For each of the three settings below, an important aspect is the heights of the different strings relative to one another.

String	Low	Medium	High
1	2.8 mm	2.9 mm	3.1 mm
2	3.1 mm	3.2 mm	3.3 mm
3	3.2 mm	3.3 mm	3.5 mm
4	3.3 mm	3.5 mm	3.8 mm
5	3.4 mm	3.6 mm	3.9 mm
6	3.4 mm	3.7 mm	4.0 mm

The geometry of action

A guitar's action is determined by the positions of the tops of the frets, the top of the saddle and the string. A builder first designs a guitar according to these positions, and then builds the rest of the guitar around that. In turn, the top of the frets point toward the saddle at an angle that's determined by how the neck is joined to the body. These geometrical relationships are critical to playability. If you don't have the geometry correct, the sound won't matter.

Action height measured at the 12th fret is convenient because it gives an indication of the action up and down the fingerboard. This is because the action at other positions along the string will be in proportion to that at the 12th position. A right triangle defines the geometry of action and gives the conceptual framework for how action can be altered it in a very precise way.

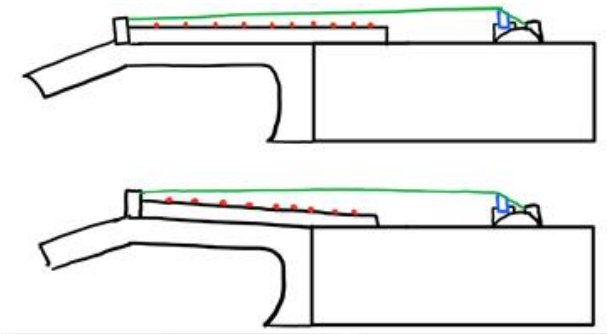


Changing the Action by Altering the Height of the Saddle

The fix for low or high action: Let's say you want to optimize your action by either raising or lowering it. The plane of the frets and the angle it projects back to the bridge is usually set in stone during construction. Thus, changing the saddle height is our only means to adjust the action. It's a perfectly good solution and straightforward for a luthier to do within practical limits. A luthier can make a taller saddle or place a shim under the existing saddle to raise the action. Conversely, the luthier can file off the top of an existing saddle to lower the action. **Considering our right triangle geometry, the 12th fret is a special position because it is the halfway point in the string's length.** (This is why fretting at the 12th fret gives you the octave). From this relationship, you can see that **changing the action height a desired distance at the 12th fret requires the luthier to add or remove twice that distance to the height of the saddle.**

Red flags: faulty neck angles

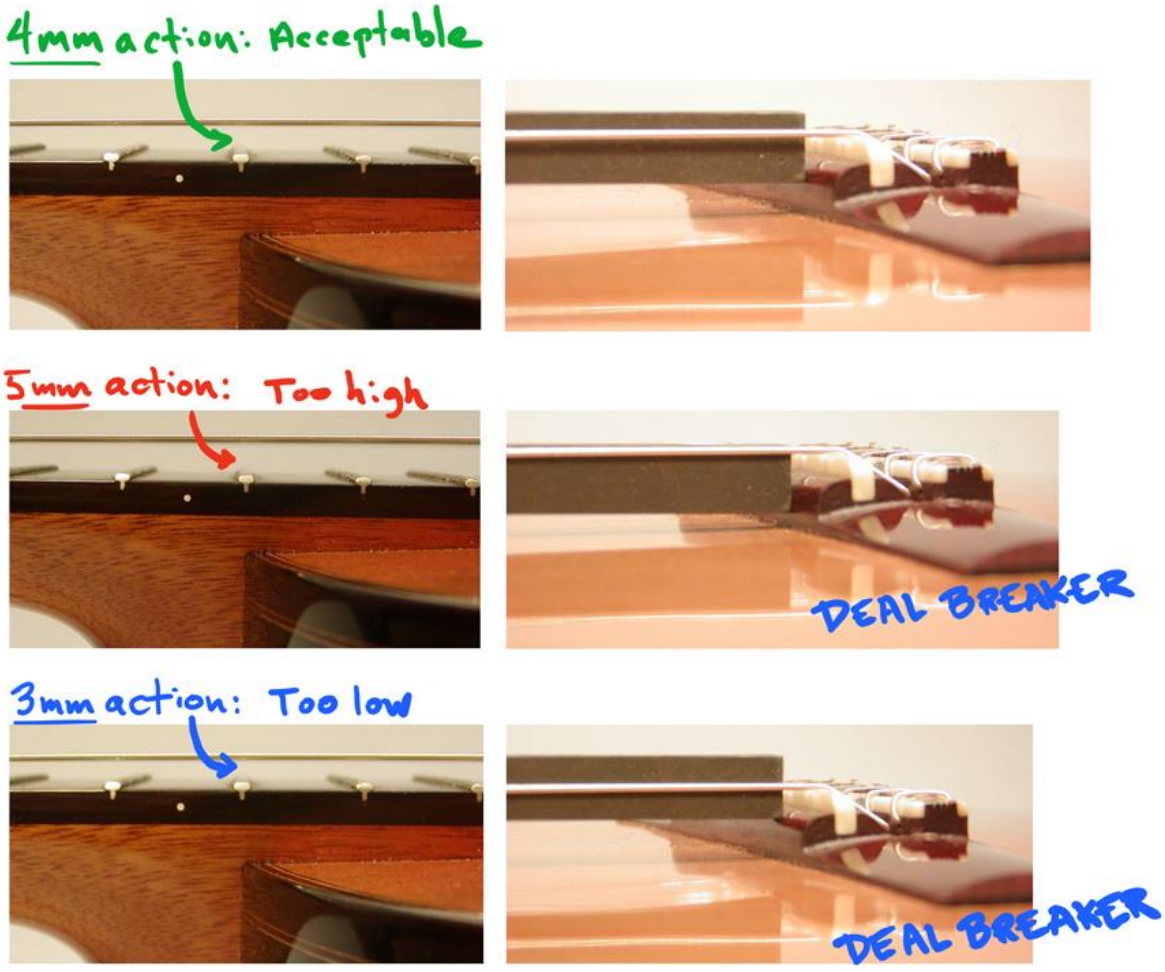
Although it can change with age, neck angle is largely set in stone during construction, and from the diagrams below, you can appreciate how the neck angle can allow (upper diagram), or prevent (lower diagram) optimized action. In the lower diagram, the neck angle is too high and the action could never be made comfortable no matter how much the saddle is lowered because it would need to be below the surface of the bridge.



Here is a diagnostic to determine if the neck angle is within acceptable limits:

Step 1: Take a straight edge (such as a ruler of approximately 18 inches) and rest it on top of the frets like this:

Step 2: Slide the end of the straight edge toward the bridge until it hits the front of the bridge. This allows you to see how the neck and top of the frets project toward the bridge. **The rule of thumb for a good neck angle is that the straight edge intersects the front of the bridge in the middle one-third of its height.** This will allow you to obtain any reasonable action by raising or lowering the height of the saddle as shown in the 1st row of photos below. Here the action is comfortable, and the neck projection and saddle height are perfect.



Deal breakers: In the 2nd row of photos above, the action is uncomfortably high and the straight edge projects below the middle one-third. In this case, it would be impossible to obtain an acceptable action because the saddle would need to be lowered below the surface of the wood on the bridge. Conversely, in the 3rd row of photos, the action is too low and the saddle would need to be raised excessively high (more than say, 12 mm above the soundboard) which will lead to excessive torque and stress on the soundboard. **These are deal breakers if you are considering buying the guitar.**

Changing the Action by Altering the Height of Nut Slots *or* What Causes Open String and Back Buzz?

At the opposite end of the string at the head, the bottom of the nut slots control the heights of the strings above the frets. Here, the slots must bring the strings extremely close to the frets because the left hand cares deeply how close the strings are to frets. The tolerances are extremely small and require optimization. Consider the relationship between the bottom of the nut slot and the clearance of the 6th string above the first fret:

The slot must be cut to a level that is easy for the left hand to fret, yet high enough so that the open string does not hit the top of the first fret and cause buzzing. It's a trade-off that depends on your right and left hand technique and how hard you want to attack the open string. Among all the strings, the open 6th string oscillates the greatest distance and the 1st string the least, so the string clearance from the 1st fret should be set progressively smaller as you go from the 6th to 1st string. Consult your local luthier to get your slots optimized.

Here is a diagnostic to determine if the nut slot is acceptable:

Step 1: Play the open strings at least *fortissimo* with your normal right hand technique and listen for unacceptable levels of fret buzz. If so, the bottom of the slots are too low.

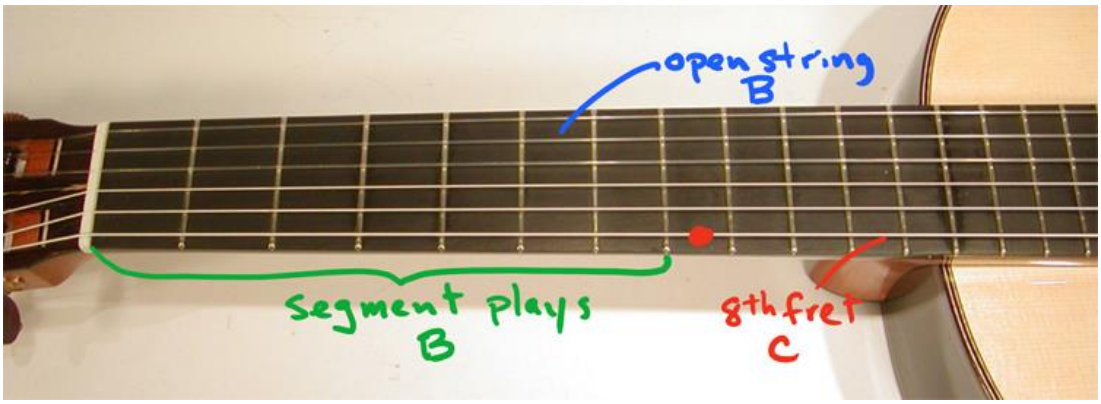
Step 2: Play the notes in the first and second position. If the action is taxing your left hand and there is no buzzing of the corresponding open string, the slot may be too high. Consider having your luthier lower the slot. Remember that you are trying to find the perfect balance between left hand ease and buzz-free playing of the open string.

Further examination allows you to get a more refined estimation of the string clearance:
Step 3: With the head facing to your left, use your right hand to fret the string next to the 2nd fret as shown below:

A proper slot should create a small gap between the bottom of the string and the top of the 1st fret. The gap for the 6th string is approximately 0.2 mm for most players. That's small and difficult to see, but if you take a left hand finger and hit the string above the 1st fret while still holding the right hand finger at the 2nd, you'll hear a distinct "plink" that signifies the presence of a gap. If the "plink" is absent or barely audible, the string sits too low in the slot and is either touching the 1st fret or too close to it as shown in the photo below:

Back buzz: another symptom of a low nut slot:

A classic symptom of an excessively low nut slot, particularly on the 5th or 6th strings, is back buzz—a phantom-like buzz that can arise when another note is played on different string. Consider for example a chord involving B on the open second string and C played on the 6th string at position VIII. If you hold the C and pluck with your other hand the segment of 6th string between the nut and position VIII (technically the 7th fret), you will find that the note is also a B.



The sound of the open second string is enough to put the 6th string segment into motion through sympathetic resonance. If the 6th string's nut slot is too low and places the string segment too close to the top of the 1st fret, it will hit the fret as it vibrates, creating the buzz. If you try **step 3** of the diagnostic test, you will probably find a situation that looks similar to that shown two photos above.

The fix for faulty nut slots: If you need to raise the bottom of your slots, a quick do-it-yourself fix is to loosen the strings and slide out the nut. Cut a piece of heavy paper or index card the same size as the nut's footprint, replace the nut with the paper beneath it, and bring the strings back to tension. Since the height needed to raise the slot is typically very small, you will probably immediately notice a decrease in open string buzzing or the disappearance of back buzz. This fix will raise all the slots equally and most likely will make your left hand work unnecessarily harder on the other strings. As soon as possible, you should work with your local luthier to optimize the height of each string by lowering the other slots using a nut file or making an entirely new nut. Some players use the trick of placing a small piece of paper between the troubled string and the nut slot to raise the slot. This works, but the open string can sound muffled since paper is soft compared to bone.

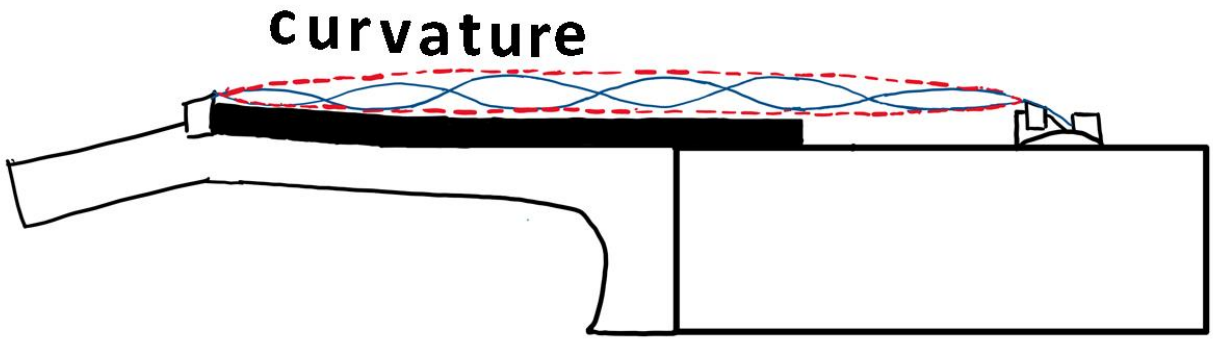
Fingerboard Relief: Help vs. Hindrance

The Remaining Piece in the Playability Puzzle

Fingerboard relief is one of the least understood and the most obscure variables in a guitar, yet it has a profound influence on playability. In the previous two blog posts, we discussed how action and neck shape and size contribute to left hand playability. Now let's examine fingerboard relief—the last piece of the puzzle that can make a guitar play like a dream or a nightmare. Let's begin with the take home message and end with the details.

What is fingerboard relief and why is a tiny amount a good thing?

Relief refers to the upward curvature of the fingerboard (and therefore plane of the frets). In the exaggerated diagram below, consider the vibration of a string which sweeps across the guitar in an area shaped like a square parabola:



Luthiers introduce small amounts of upward curvature into the fingerboard to resemble the shape of the strings' paths. In doing so, string action heights can be lowered, which will make your left hand very happy. Relief is usually most pronounced beneath the 6th string, which oscillates considerably more than all the others, and least (or non-existent) beneath the 1st.

The correct action height of the strings (as adjusted by the height of the saddle) and an appropriate amount of upward fingerboard curvature work together like complementary puzzle pieces, providing buzz-free notes with minimal left hand effort. The optimal amount of curvature is surprisingly small—between 0.2-0.5 mm deviation from a dead-straight fingerboard. To give you an idea of scale, a credit card is about 0.7 mm thick. **Read the "The Details" in the latter if you want to better understand how relief is introduced and assessed.**

Why is too much relief a bad thing and what causes it?

Beyond a small amount of upward curvature, excess concavity in the fingerboard means that fretting requires pushing the string an extra distance before it contacts the fret. More than approximately 0.5 mm of relief under the bass strings and anything more than 0.3 mm under the trebles can make your left hand work too hard. The cause of excessive fingerboard relief is often insufficient neck strength to counteract the tension of the strings.

If you are considering buying a guitar…

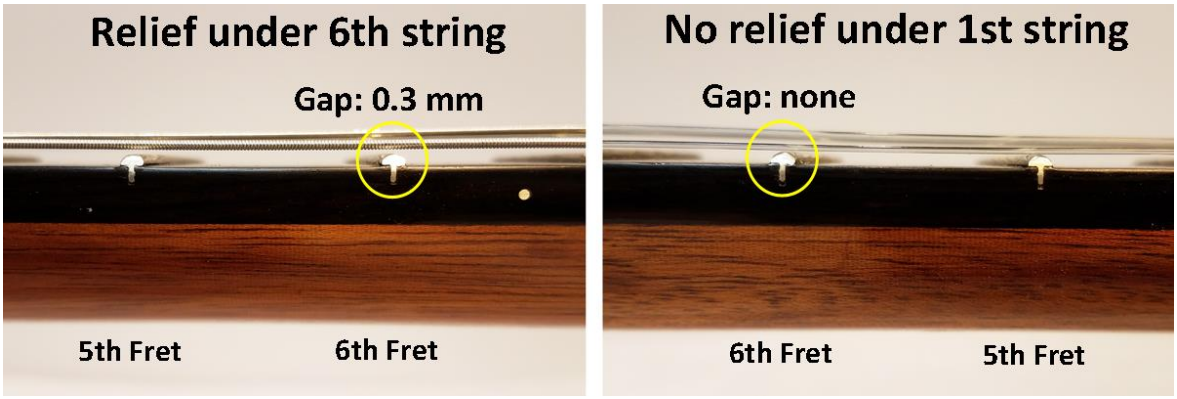
…and the string action heights at the 12th fret seem reasonable, but the left hand still feels taxed, the guitar may have excessive relief. If the relief is astronomically high, simply sighting down the edge of the fingerboard along the length of the 6th string will reveal an arc. To assess the actual amount of relief, use the diagnostic test below. The relief should ideally be close to zero beneath the 1st string and no greater than 0.5 mm beneath the 6th. It's generally wise to walk away from a guitar with excessive relief. On the other hand, the absence of relief may not be a deal breaker for some players so long as the left hand is comfortable. It really depends the nature of their right hand attack and whether it is prone to making the strings buzz. Like many things in guitar, it comes down to player preference.

If your current guitar has excessive relief…
…consult your local luthier. There are remedies that could improve your left hand playability, but they require significant work costing in the neighborhood of at least $500, but probably more.

The Details

Check your relief with this diagnostic test

Step 1: Place the guitar on a table with the 6th string facing you. Place a capo on the 1st fret and then fret the 6th string at the 19th fret with your right hand. Using the fretted string segment as a straight edge, look for the gap between the top of the frets and the bottom of the 6th string as shown in the left panel of the diagram below.

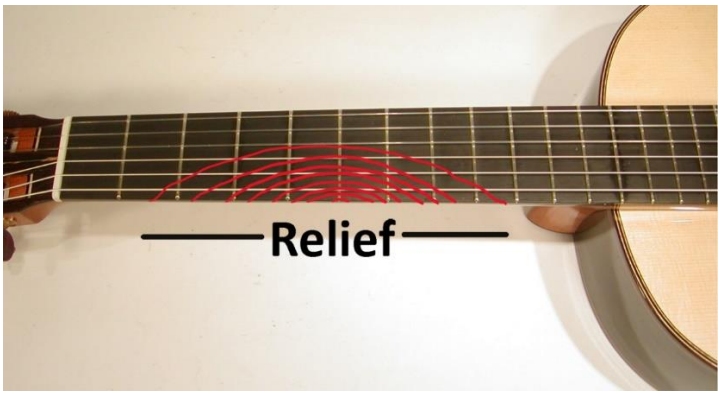


The gap, *which is the relief*, should be largest near frets 4-6. As a rule, the largest gap you can spot should be between 0.2-0.5 mm for string 6, and progressively less for the others. You can estimate the size of the gap by sliding the edge of a credit card next to the gap. The card is approximately 0.7 mm thick, so if you can slide the card into the gap without moving the string, you definitely know you have excessive relief. On the other hand, if the gap is small, it can be difficult to see. Try hitting the string above one of the frets with a left hand finger while still fretting with the right hand finger at the 19th. You will hear a distinct "plink" that signifies the presence of a gap.

Step 2: Turn the guitar around so that you can get a good look at the 1st string while you repeat the procedure for the 1st string. **There should be no or extremely little relief under the 1st string, as shown in the right panel of the diagram above.** If the relief on the 1st string is more than approximately 0.2 mm, you have excessive relief.

How do luthiers create relief?

Luthiers typically create relief by combining 1) the natural bending of the neck caused by string tension and 2) the planing and sanding of the fingerboard in a strategic location. The result is a distribution of relief depicted in red in the photo below.



This spatial distribution adjusts for the larger movements of the bass strings compared to that of the trebles. It's unnecessary and uncomfortable for the left hand to have relief under the 1st and 2nd strings. Beyond approximately the 9th fret, the action heights are higher so the distance of the strings above the frets is already sufficient to prevent buzzing so no relief is required in this region.
Relief is set by the maker during construction and is typically not adjustable unless the neck has a truss rod. Weak necks can continue to bend over time and explains why vintage guitars often develop excessive relief.

What does a truss rod do?

The reason why steel string guitars have truss rods is to counter the string tension that is roughly twice that of a classical. The truss rod is tightened to straighten the inevitable curvature of a steel string neck. Since the string tension on classicals is relatively low, truss rods are generally unnecessary if the neck is properly built with quality materials and possibly the insertion of carbon fiber rods. Occasionally, contemporary classical guitars are equipped with truss rods which provide the opportunity to fine tune the relief.

What Neck Features Determine Left Hand Comfort?

Next to your guitar's sound, the way it feels in your left hand will determine if you are going to have a happy relationship together. What is it about some guitars that makes them feel so comfortable? Second to action, which we addressed in Blog 4 [link]**, the key to left hand comfort is the correct neck shape followed by width and thickness.** These variables are set during construction, so if a guitar purchase is in your future, it's helpful to know what factors to pay attention to.

Let's start with the take home message, then get to the details later

If you are considering buying a guitar that's already built…
…pay particular attention to how the shape and size of the neck influences the comfort of your left hand. **Apply the same level of scrutiny to the feel as to the sound.** Both the feel of the neck and the sound are generally locked in at the time of construction and cannot be undone. Are you equally happy with both? If not, it may not be the guitar for you.

If you are having a luthier build you a guitar…
…have an in-depth discussion with your luthier about the types of neck and fingerboard shapes/sizes that you have liked and disliked in the past, and how those compare to what the builder proposes to build for you. Before I build a client's new guitar, if I cannot work with the player in person, I will sometimes ask him or her to send tracings of the cross-sectional shape of their favorite neck. As shown in the photo below, a contour guide purchased at a hardware store can be used to get an imprint of the back of the neck.

Even if a new guitar is not in your immediate future…
…keep mental notes of the necks you've liked or disliked (and why) when you try your friends' guitars or those at stores and festivals. What is it about the shape and size of their necks that made them a joy or a pain? This awareness will be valuable to you when the time comes for your next instrument.

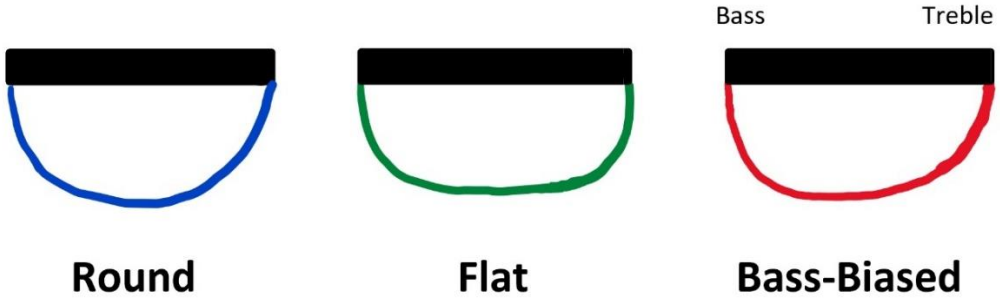
Now for the details

Small Differences Are Meaningful

Your hands are incredible. They are so sensitive that they can feel differences in shape and size that you'll never see. It's not surprising that your hands can have a preference for differences as small as 0.4 mm. It's not necessary that you *see* what is or is not comfortable to you. Trust your extraordinary sense of *feel* to decide what's too much, too little or just right. Unless the fit is close to perfect, it could feel like you are fighting a piece of raw lumber.

The Top 5 Factors for Left Hand Comfort
In decreasing order of importance

1. **Neck Shape.** By neck shape, we are more specifically referring to *cross-sectional shape.* The diagrams below show three basic shapes.

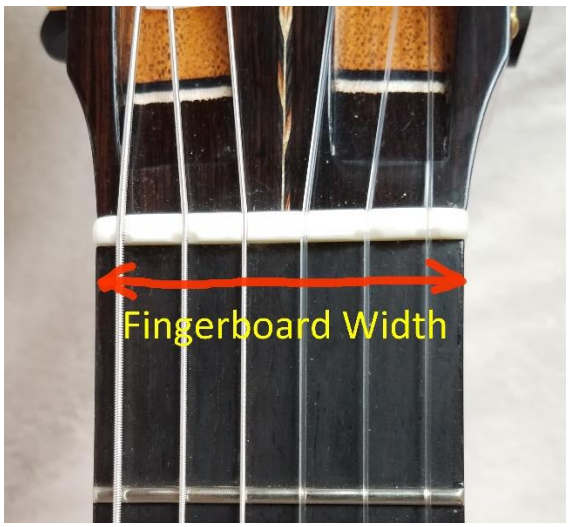


Like everything else in guitars, personal preference guides what is best for each player. Having watched hundreds of guitarists' left hands while listening to their comments about comfort, the back of the neck that lies behind the 4th and 5th strings is one of the most influential regions for left hand comfort. As shown in the photo below, the reasons are two-fold: 1) in this location, the thumb and fingers have the least amount of gripping strength, and 2) it's where the back of the neck starts to rapidly curve toward the fingerboard.

To some players, a small hump in this region can feel like an abrupt cliff. As a consequence, many players prefer it flat or rounded here, while others prefer it to be the thickest spot on the neck's cross section instead of directly in the middle. The bottom line is if the thumb doesn't sit comfortably in this crucial region, the player will suffer from a lack of efficiency.

2. **Fingerboard Width.** A fingerboard's width, in conjunction with the string spacing, sets the difficulty of vertical stretches. While decreased width makes vertical stretches easier, the decreased string spacing makes finger placement more cramped, requiring greater accuracy. Fingerboard width on

most contemporary guitars ranges from 52-53 mm at the nut and widening to 62-63 mm at the 12th fret.



3. **Neck Thickness.** Similar to cross-sectional shape, the thickness of a neck strongly influences left hand ergonomics. While intuitively it may seem that thinner is better, for the technique and anatomy of each player, there is an optimal thickness that maximizes left hand efficiency. Thicknesses typically range from 21.5-23 mm at the 1st fret to 22.5-24 mm at the 8th fret.

4. **Fingerboard Relief.** Relief refers to the slight, upward curvature of the fingerboard. As we will discuss in the next blog installment, a little is helpful, while too much can make your left hand feel as if it is drowning in quick sand.

5. **Scale Length.** Many players assume that scale length is at the top of the list for determining left hand comfort. For most experienced players playing contemporary guitars, however, that's usually not the case. Look at positions of the fret slots on a 650 mm scale fingerboard compared to those on a 640 mm scale fingerboard. Since half of the 10 mm difference falls between the 12th fret and

nut, the reality is that only 5 mm of the difference is spread among the first 12 frets. Unless you are playing a 660 mm or larger guitar, scale length is a relatively minor factor.

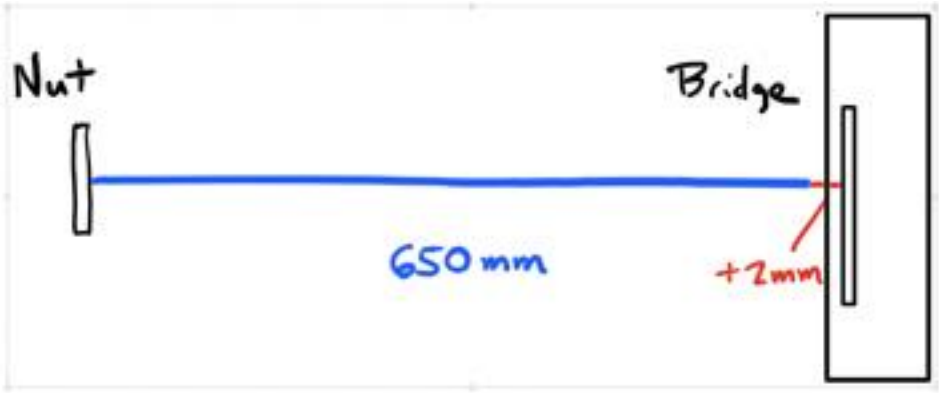
Part II. What Controls Intonation and Can I improve Mine?

Often even the nicest guitars have less than perfect intonation. We shouldn't accept this because an instrument that has good intonation sounds more in focus and more musical. While the movement of vibrating strings can be described precisely by mathematical equations, guitar strings in the real world behave less than ideal due to their material properties and stretching during fretting, which requires luthiers to build in corrections in their lengths called "compensation". In today's precise world of lutherie, errors in intonation almost never arise due to improperly placed frets, but rather, from errors in positioning the string ends at the saddle and the nut.

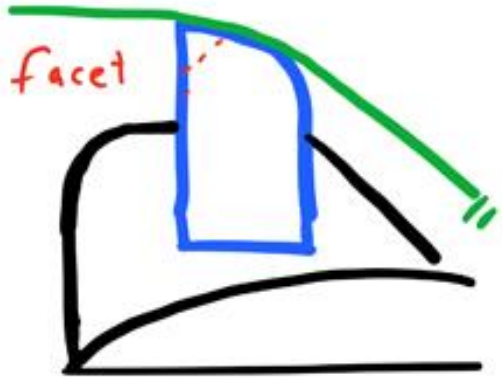
Let's look at two reasons for why we need compensation. The first is the most intuitive. The act of pushing down a string to a fret stretches the string increases its tension which raises the pitch. This makes fretted notes sound increasingly too sharp as you progress up the neck. The second is that strings have thickness and stiffness, which makes them behave as if they are shorter than they really are. Again, the effect is that strings play sharper than what the idealized math says they should.

In order to correct the sharpness, luthiers add extra distance (compensation) to the vibrating string length—on the order of 1 to 2 mm depending on the string. This is achieved by gluing the bridge (and thus the position of the saddle) 1 to 2 mm farther from the frets. The thickest, stiffest strings—strings 6 and 3 need the most compensation, whereas the 1st string, which is the thinnest and most flexible—needs the least. Further refinements can be achieved by faceting the front edge of the bone saddle by filing to further flatten the pitch, if necessary.

A typical layout would look like this:



And faceting of the saddle by filing looks like this:



With distance added at the bridge-end to correct the pitch of fretted notes, consider what happens to the pitch of the open strings which are not fretted and stretched. Uncorrected, they sound flat relative to the fretted notes. In many modern guitars, the open strings are corrected by moving the position of the nut (the strings' other end-point) closer to the frets by approximately 0.8 mm. This works because the nut position for the most part only affects the open string.

There are many old-school and even contemporary guitars that do not employ nut compensation, and when played, the player may be driven bonkers trying to get fretted and open notes

to play in tune relative to one another. **Unless you know that your guitar's intonation is very good, you can see why tuning to open strings only can be a disaster.**

Intonation Diagnostic

You can try the following diagnostic to determine how good your guitar's intonation is and differentiate the errors arising from fretted vs. open notes. Be aware that intonation is highly dependent on string type (especially nylon vs. carbon) condition and tension, and action height. Before evaluating a guitar's intonation, make sure that your guitar has a relatively new set of your preferred strings and that they have settled for at least a day. Each string has a different material property so the diagnostic must be done for each string, as is compensation.

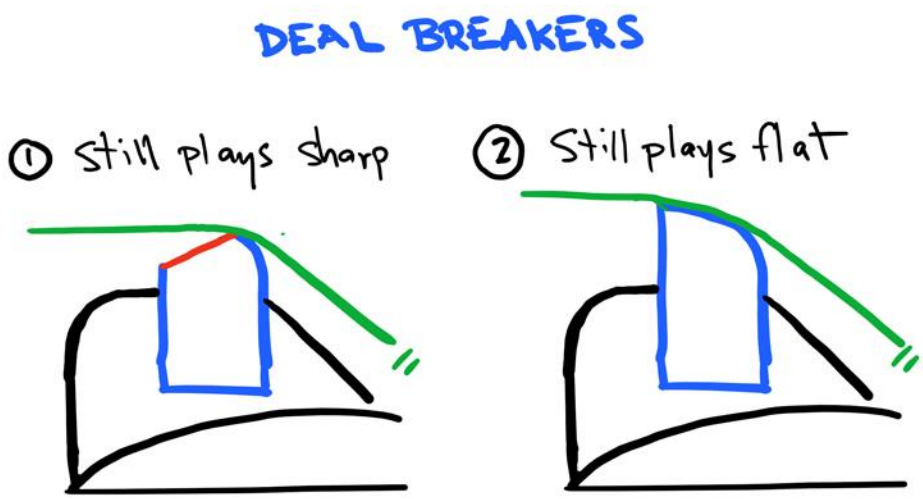
First, let's check the intonation of fretted notes up the neck. Use the Intonation Score Sheet below to record your findings.

Step 1: With an electronic tuner, tune the first position note to the correct pitch: in the case of the first string, play F and tune it perfectly according to the tuner. Then play up the neck and record the deviation from in tune (sharp, flat or in tune). Frets 5 and 12 are convenient positions to try. Beyond 3 cents sharp or flat is worth having corrected by your local luthier.

Intonation Score Sheet

String	1st Fret	5th Fret	12th Fret	Open String
1	In tune	#,b, in tune?		
2	In tune			
3	In tune			
4	In tune			
5	In tune			
6	In tune			

The fix for faulty fretted notes: (1) If the notes are progressively out of tune on the sharp side, then more compensation at the nut is needed, which requires filling away the front edge of the saddle to increase string length. For example, your luthier may need to move the string exit point on your saddle back ~1.5 mm for every 5 cents of sharpness. (2) If the notes become flatter up the neck, then less distance is needed and the luthier might have to remove existing facets by making a new saddle. **Two red flag situations may arise as shown below:** If in (1) the notes play sharp, but the saddle is too thin and additional faceting is not possible or in (2) the notes play flat, and there is no faceting present, in which case the bridge would have to have its slot widened toward the frets (to add more saddle) or the bridge removed and re-glued to change the saddle position. **Either is a deal breaker if you are considering buying the guitar.**



Next, let's check the intonation of the open strings.

Step 2: Next, check the open string vs. the perfectly tuned first position note (e.g. E vs. F on the first string). Errors in the open string are almost always due to flatness, particularly on the 3rd string. This means that the nut should have been moved toward the frets during construction. In many modern guitars, about 0.8 mm is chopped off the nut-end of the fingerboard.

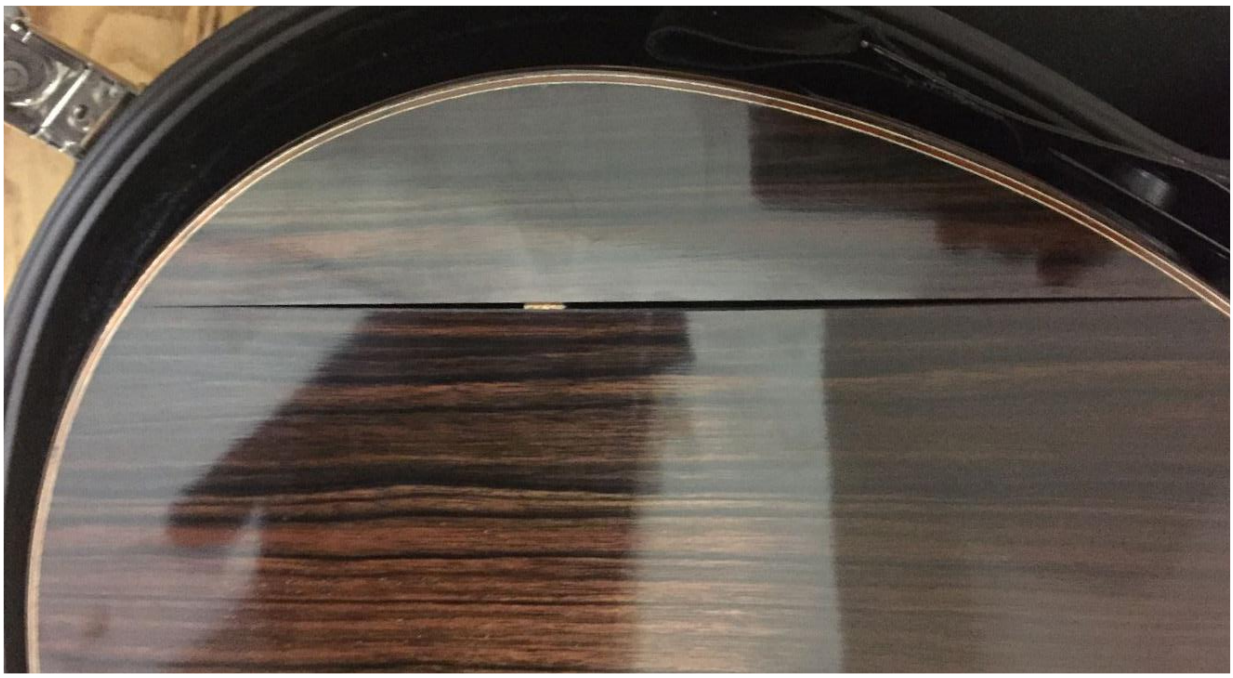
The fix for faulty open strings: If the fretted notes play in tune relative to one another, but the open string plays flat, it's possible to correct the flat open string by gluing a piece of bone or wood extension to the fret-side of the nut to shorten the string's length. That will sharpen the open note predominantly over the fretted. It's a Band-Aid approach that can work. Alternatively, in a more heroic procedure, about 0.8 mm of the fingerboard can be removed next to the nut slot and a wider nut installed to shorten the string's length. **In any case, if you are considering buying the guitar, this is a deal-breaker.**

Part III: Guitar Maintenance

1. The Real Reasons Why You Should Humidify Your Guitar

Let's get to the point
I'll defer the typical technical explanations about humidity until the end. Let's get to the point: the real reason why you should care about humidifying is that failure to do so **can cost you practice time, money, psychological torture, and possibly a successful performance.** Why? Because your guitar may end up cracked and sitting in a workshop like mine, undergoing repair. If you want to learn the technical details, read the last two paragraphs.

Every winter when the air is especially dry, I receive a barrage of phone calls and emails. Panic-stricken players who failed to humidify contact me to fix their cracked soundboards or backs. The good news is that once repaired, the cracks will likely not change the sound of their guitars. What will change are the players' bank accounts, time spent with their guitars while they're being repaired, and the instruments' value. It's a stressful experience.



Adopt a practical approach
As a devoted guitarist, it's a given that you need to have your guitar out of its case for often hours at a time. But when you're done with your practice session or ready for a break of 30 minutes or more, put your guitar closed in its case with a **humidifier that is working**. No cheating here. Your job is to ensure that the humidifier is always filled with fluid and your case's seal is adequate (we'll talk more about cases in the next blog installment). The inside of a case also absorbs moisture from the humidifier and acts as a large moisture reservoir for your guitar when it's inside. When your guitar is out of the case, close the lid with the humidifier inside to preserve this buffer.

Which humidification device to use?

There are several good commercial humidifiers with different designs available from online string dealers. I favor those with sealed, large-capacity reservoirs over those having low capacity (such as sponges) because they circumvent our laziness toward constantly having to add water when they run dry. Two that I like are the Oasis OH-1 and the D'Addario Two-Way Humidification System. The D'Addario has two advantages: 1) you never have to add water because you simply replace the fluid packs when they get dry, and 2) the fluid packs not only release moisture when the air is too dry, but also remove moisture when it's too wet. If you live in a very dry climate and you must practice for many hours at a time, consider buying a room humidifier.

Lastly, the technical details

What's too dry or too wet? **From your guitar's perspective, any change in humidity compared to what it was when your guitar was glued together will make the parts move to some extent.** The reason is that wood behaves like a sponge—it loses water and shrinks when the air is relatively dry, and absorbs water and expands when the air is relatively wet. Once the wooden parts are glued together, their movements—shrinkage or expansion in different directions—can cause trouble, such as a change in your guitar's action. A hallmark of dryness is the protrusion of fret ends as the fingerboard shrinks (no, your frets are not growing!). In the extreme case, dry conditions can lead to severe wood shrinkage, as shown in the photo above. Here, a split formed along a grain line because something had to give.

Buy an in-case digital hygrometer to tell you the actual humidity level. The same string dealers sell them. The scale will read in percent relative humidity (RH)—that is, relative to full saturation of water vapor in the air (100% RH means it's raining). Luthiers typically control the RH in their workshops between 40-50% in order to match the average conditions their instruments will experience in the real world. If the RH in your case reads higher than 50%, you can safely remove the humidifier until drier weather arrives.

In general, small humidity *decreases* away from 40-50% are far more dangerous than even large *increases* because of the high cracking potential under dry conditions. At high humidity such as beyond 75% RH, wood expansion tends to break glue joints, rather than the wood itself. One sign that the humidity might be getting too high is the appearance of rust on your frets.

2. How to Clean and Oil Your Fingerboard

Is this your fingerboard?

Gunk. Grime. Gook. There's no official name for it, but you've probably had it on your fingerboard. It's not necessarily a bad thing. The waxy amalgamation of sweat, skin and dirt is a badge of honor signifying that you've put in serious practice time. While the build-up is not directly harmful to your guitar, here are a few reasons why you might want to invest 15 minutes once or twice a year to clean and oil your fingerboard:

- A clean guitar gives you a better outlook on your instrument and playing. You might practice more.

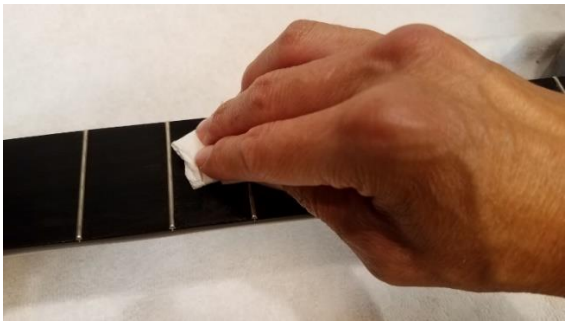
- Cleanliness might increase the longevity of your bass strings. Sweat and dirt are bass killers as they corrode the metal windings and dull the sound. A clean fingerboard keeps the perpetrators out of range. For complete preventative medicine, consider washing your hands before playing.

- If you're in the market to sell your instrument, a better look will earn you more money.

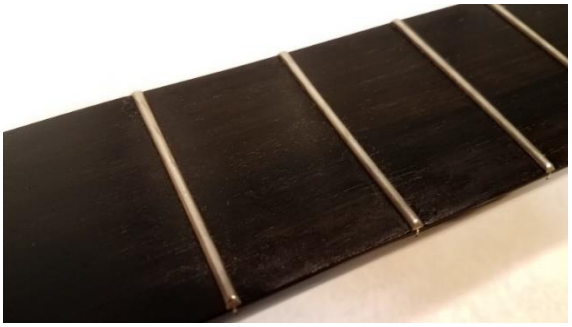
How to clean and oil

If your fingerboard is free of gunk, all you need to do is oil it. Buy a bottle of mineral oil at the grocery store. With all the strings off the tuners and stuffed into the sound hole, apply some oil on a folded paper towel and wipe it on the face of the fingerboard. It's fine to wipe it on the frets. Avoid adding so much oil that it runs over the edge of the fingerboard and down the neck. If it does, simply wipe away the drips with a new towel.

Let the oil sit for about 5 minutes. Using new towels and a buffing action with pressure, wipe away as much oil as you can from the fingerboard and frets. Make sure to reach the corners where the fingerboard meets the edges of the frets.

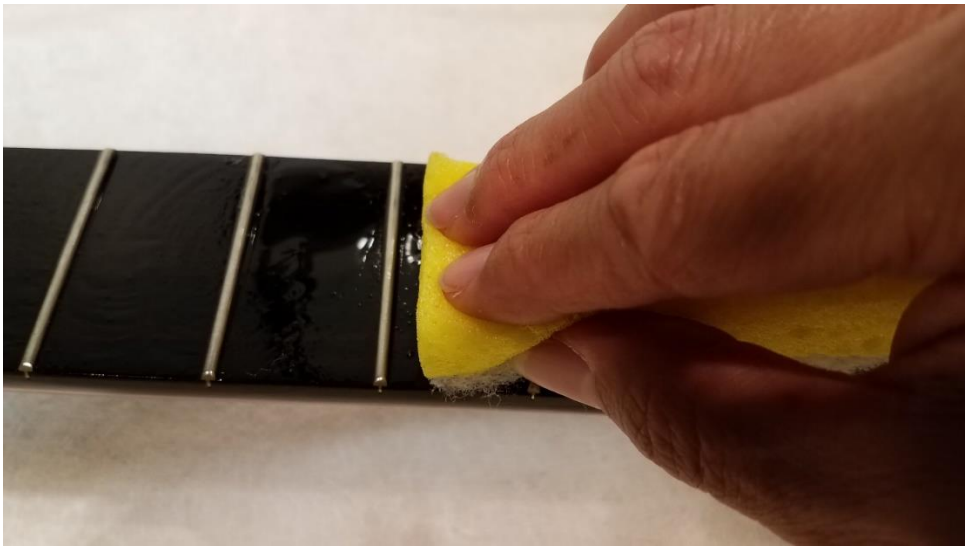


The results are rewarding:



If your fingerboard has gunk, apply some mineral oil to the corner of the abrasive side of a dish sponge.

Lightly scrub away any build-up, using the oil as a lubricant and solvent. Scrub right up to the edge of the frets.



Wipe away the excess oil and loosened grime with new paper towels, as described above. If the build-up is severe, you may have to repeat the process.

Take a moment to inspect your guitar

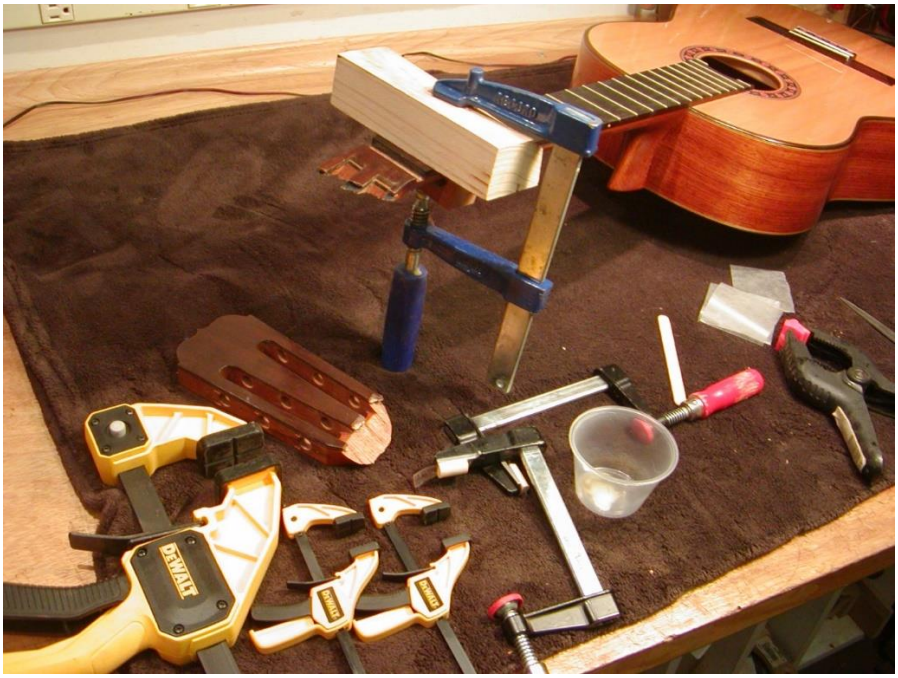
Now is the perfect time to do a global inspection of your guitar. Look carefully for things like cracks, separating joints, and protruding fret ends. In the next installment, we'll talk about how you can work with your local luthier to remedy these problems.

3. What to Look for in a Case

Cases have changed considerably in the last 10 years. The use of lighter, stronger materials, in addition to more user-friendly features means that the era of the heavy wooden case is coming to an end. Our instruments are safer and easier to carry than ever before. I'll discuss the most important factors to look for in a case and suggest a few brands that fulfill the criteria. The last four factors are the most obvious, so let me start with three that I feel are crucial, but often over-looked.

1. **Vapor-resistant seal.** In my last blog entry on humidification, I mentioned that a good seal on the case is crucial for storing your guitar at the proper humidity. Without a seal, an in-case humidifier will never do its job because the infinite volume of air outside the case will suck any moisture out. Therefore, a plastic or rubber gasket on both edges of the shell will ensure a vapor-resistant seal. The most economical case with a seal is the Crossrock CRF1000CBK.

2. **Head support.** Many players store strings and other paraphernalia in the open space below the head. While convenient, the empty space is a deadly accident waiting to happen. Even a slight drop of the case can snap the guitar's head off in a whip-lashing motion. The photo below shows one unfortunate guitar being repaired. Believe me, this happens a lot. Bam cases have a support.



Easily make your own head support now! Prevent your guitar's decapitation by cutting a piece of rigid foam with a serrated knife, making sure the bottom of your tuners slightly contact it when the guitar is in the case. For the foam insert shown in the photo, I cut a slot in the side to hold a D'Addario humidifier pack. Alternatively, you can fold a cloth and use it like packing.

3. **Configured for backpack straps.** Once you have backpack straps and two free hands, there's no going back. Travel becomes a breeze. Bam, Crossrock, Hoffee and Visesnut cases all have this feature.

4. **Impact-resistant shell.** Hardness of the shell is very important, but it's not the only factor. Diffusing the energy of impact counts for a lot, even if the shell gets a little deformed in the process. Your needs will vary depending on whether you're traveling around town or around the world on airplanes. Two cases considered flight-worthy are by Hoffee and Visesnut.

5. **Interior padding that floats the guitar off the shell**. Hoffee and Visesnut cases are particularly good at this.

6. **Weight of 9 pounds (4 kg) or less**. There is a break-off point at about 9 pounds, above which a case feels too heavy to carry comfortably. All of the cases mentioned fall in this range, but Bam cases are especially light, weighing about 6 pounds (although less secure).

7. **Price.** You will ultimately choose a case based on price versus quality of the above features. Here are the approximate prices in USD: Crossrock fiberglass ($400), Visesnut Active ($700), Bam Hightech ($1,000), Visesnut Premier ($1,000).

4. What's New and Old in Tuning Machines

Why Tuning Machines Matter

We've all met guitars whose tuning was handicapped by low quality or poorly installed tuners. When tuning becomes a guessing game, tuning can become a distracting sideshow. You have enough to worry about on stage, and a properly functioning set of tuners lets you get to what's important.

Some Things Never Change

Before describing the latest features in modern tuners, let's talk about three important factors that ensure great performance in **any** set of tuners.

1. **Correct placement of the roller holes**
   Unless the builder drills the roller holes exactly perpendicular to the plates and with precise spacing, the rollers will bind against the wood as they turn and the gears and worm shafts will fight against each other. Even if you can't see it, symptoms of poorly drilled holes include 1) the feel of high resistance and jerkiness when turning the knobs, 2) squeaking of the rollers, and 3) the appearance of metal shavings near the gears due to parts wearing against each other. Inaccuracies in roller hole placement are troublesome, but possible, for repair persons to remediate. On the other hand, if drilled correctly from the beginning using jigs such as the one pictured below, tuning can be exceptionally smooth and consistent given a quality set of tuners.

2. **Precise gearing**
   You get what you pay for, and what you primarily pay for in high-quality tuners are better materials and precisely-machined gears and worm shafts. The result is a mechanism that directly drives the roller with even the slightest turn of the knob. Two symptoms of poorly-made (or worn) gears include 1) delayed movement of the rollers, and 2) the ability to slightly shake the shafts from side to side when the strings are removed.

3. **Clean and oiled**

   Finally, tuners will function their best if the gears are clean of debris and lightly lubricated. Players often make the mistake of over-lubricating with low-viscosity oil, which wicks behind the plates and damages the wood and finish.
   To clean and lubricate your tuners, buy some high-viscosity bicycle chain oil at your local bicycle shop. As shown below, apply a small amount to an old toothbrush and use it to lightly brush dirt away from the mechanisms. Wipe the used oil off the brush often with a paper towel and repeat the process until you've covered all the surfaces of the gears and worms. The small amount of oil that is left on the parts is all you need to keep them happy.

Friction-Resistant Rollers—the New Standard in Tuning Machines

Over the last 15 years, the development of “friction-resistant rollers” has greatly improved the performance of tuning machines. As shown in the photos above and below, the design employs bearings at the ends of the rollers which sit motionless in the inner holes of the headstock. When the knobs are turned, the rollers spin independently of the bearings, eliminating any friction caused by movement against wood. Tuning becomes noticeably smoother and predictable. As they say in the U.S., “it’s like butter!”

In some designs, friction is further reduced by placing steel balls in the bearings and adding bushings which sit stationary in the outer holes. **Friction-resistant rollers have become the new standard in virtually every brand of quality tuner.** While not a substitute for perfectly drilled roller holes, the design can improve performance with less-than-perfect holes.


An Investment You Can Keep

The purchase of a good set of tuners represents an investment that you can keep, even if you change guitars. It's easy to move tuners from one guitar to another, so it's a good idea to keep your old set in case you decide to re-install them later. As mentioned in the last blog post, a luthier or repair person can install your tuners, but if you're handy, chances are good that you can install them yourself. **In either case, consult these installation instructions before purchasing your next set.**
https://www.garrettleeguitars.com/teaching

Pricing

Don't expect that twice the cost will get you twice the function. In truth, it's far from that. Even the lowest priced tuners mentioned below will provide excellent performance. While it is true that higher-priced tuners will have more precisely machined gears, other factors such as engravings and plate and knob materials contribute to their cost. Here are the approximate starting prices of some selected tuners that feature friction-resistant rollers (prices in USD):

Sloane $250
https://www.stewmac.com/Hardware_and_Parts/Tuning_Machines/Classical_Guitar_Tuning_Machines/Sloane_Classical_Guitar_Machines_with_Stippled_Bronze_Baseplates.html

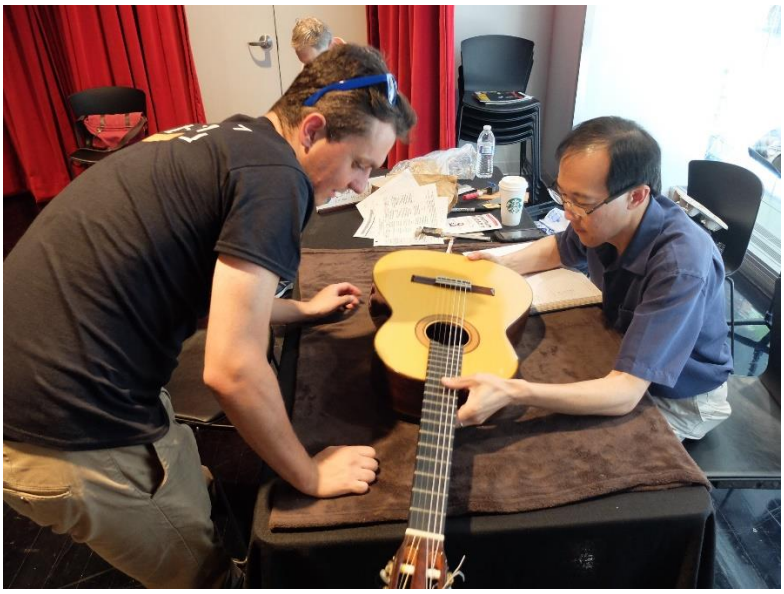
Kris Barnett $550
https://barnett-tuners.com/collections/gallery

Scheller $800 (Not to be confused with Schaller brand)
https://www.gitarrenmechaniken.com/en/

Rodgers $900
https://www.rodgers-tuning-machines.com/

5. Why You Should Add a Luthier to Your Team

Every year, I do free diagnosis, adjustments and minor repairs at a local guitar festival. When I go to the guitarists, they gladly have me adjust their guitars. However, I've noticed that players rarely seek a luthier or repair person until a major problem like a crack forces them to do so. **The lesson is that many guitarists are playing guitars that have not been optimized to their own playing.**



Since your guitar is your expressive tool and perhaps your means of making a living, there are many advantages to getting acquainted with a local luthier who can keep your guitar running in tip-top shape. I've used the term luthier broadly, which includes repair persons. Here are some useful things a luthier can do for you:

Optimize Your Action and Intonation

These are the two most compelling reasons to visit a luthier at least once in your relationship with any guitar. Surprisingly, many players I meet never considered they could make their guitars easier to play or sound better.

The action heights of your strings should be set according what best suits *your* playing. Since it's highly individual, the optimal action height of *each string* is best set with you in the presence of the luthier. In a typical session, I'll ask the player to play a variety of pieces with different dynamic ranges as we discuss the cleanliness of sound (or presence of fret buzz) vs. left hand ease (or difficulty). We decide together whether to adjust each string up or down. **Through the arc of a player's career or choice of repertoire, the optimal setting may change several times.**

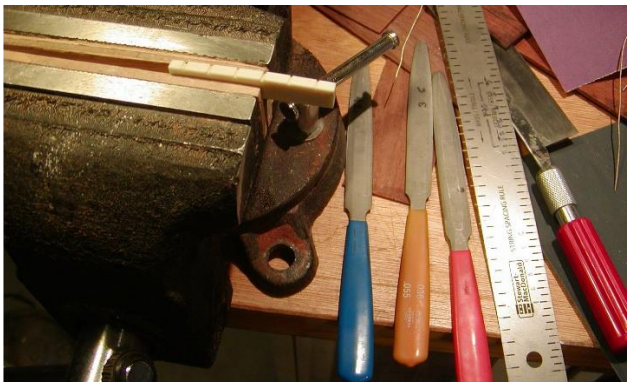
If you wince even slightly over your guitar's poor intonation, it's worth your time to work with a luthier who can usually improve it. I say "usually" because there can occasionally be structural constraints in some guitars that prevent improvement. ("Usually" also holds for optimizing action). Several factors can contribute to inaccurate intonation, but in this age of laser-cut templates, it's usually

not due to incorrectly positioned frets. The most critical factor is the correct placement of where the ends of the strings leave the saddle and nut. This is fortunate because saddles and nuts can be easily adjusted whereas frets cannot. Finally, **because treble string material properties affect intonation, it's common that players who change brands and/or models of strings experience changes in intonation.** This is especially true of nylon versus carbon trebles. If you've noticed this phenomenon, consider working with a luthier.

Modify Your Guitar

Beyond optimizing your guitar's action and intonation, there are several modifications that a luthier can assist you with that will increase the performance of your guitar. **The most common modification I'm asked to do is change the tuning machines.** In the next blog installment, I'll discuss why you might want to upgrade yours.

The second most common modification is to alter the string spacing, which requires making a new nut. In addition to altering the distance between strings, a player can benefit by adjusting the spacing between the 1st string and the edge of the fingerboard. Most players prefer—to varying degrees—a larger distance between the 1st string and the fingerboard edge compared to that on the 6th string side. On descending slurs, this extra distance provides insurance against the dreaded slipping of the string over the edge.



Repair Your Guitar

It's obvious that one would seek a luthier to repair cracks and lifting bridges, replace or level worn or protruding frets, and touch up worn finish. **What's not so obvious is the benefit of establishing the relationship before something major happens.** In the emotional roller coaster that accompanies a severe accident or injury, you will save time and uncertainty knowing a qualified person whom you can call.

How to Find a Luthier

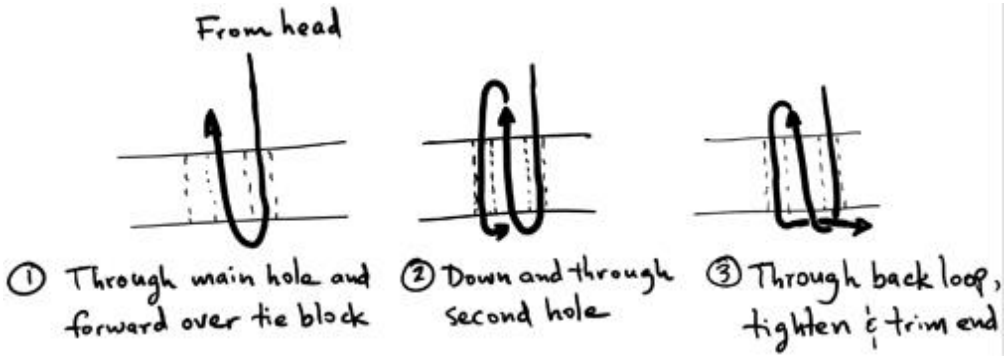
While developing the relationship with a luthier is easy, finding the right one in your area can be challenging. **Like finding a good auto mechanic, word of mouth is the best route.** Start by asking the professionals in your area, such as instructors, professors and performers. Other sources worth contacting for referrals are guitar societies and guitar departments within conservatories and universities. Keep in mind that classical guitars are specialized in the guitar family, so you'll want to informally interview a luthier to make sure he or she is experienced in performing the type of work you're interested in. Finally, some luthiers only build guitars and don't do repair work. However, any luthier should be able to recommend a skilled colleague who does.

Part IV: More Guitar Maintenance: Q &A

1. How do you tie the strings at the tie block?

For a 2-hole (12-hole) system:

Bass String:



Treble String:

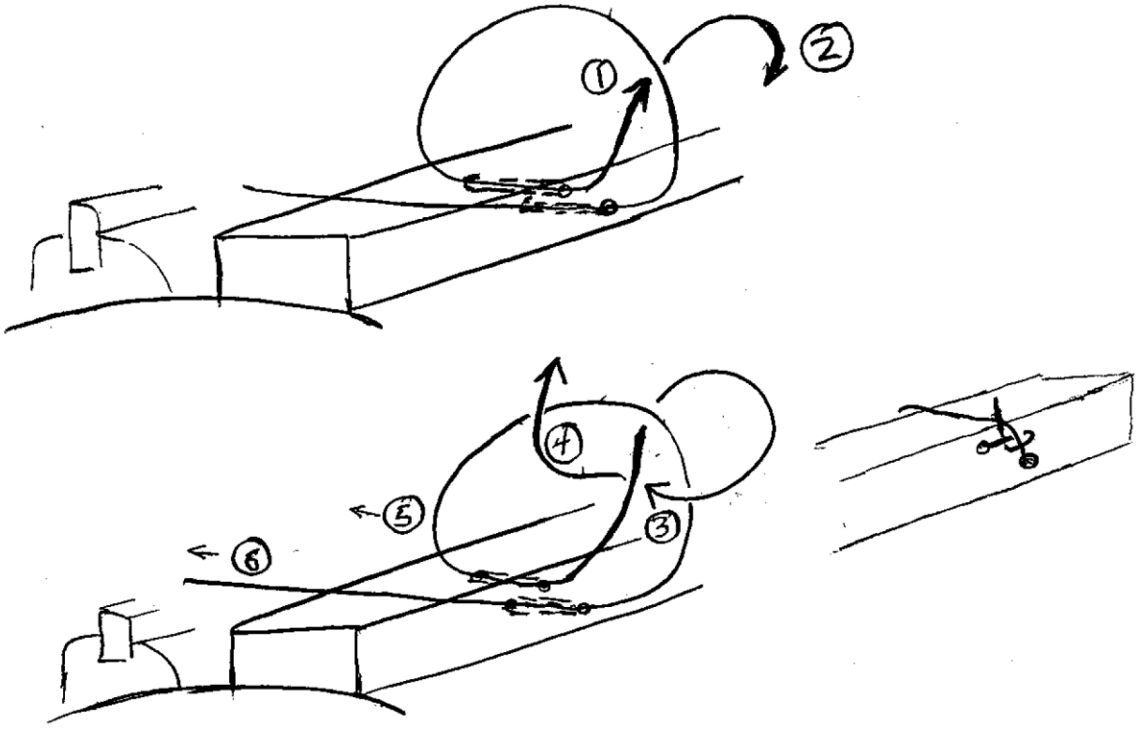
Improved Treble String Knot

From the sound board side of the tie block, thread the string through the lower (main) hole, bring it over the tie block and thread it through the upper hole to the back. Leave approximately 4 inches of tag end past the tie block.

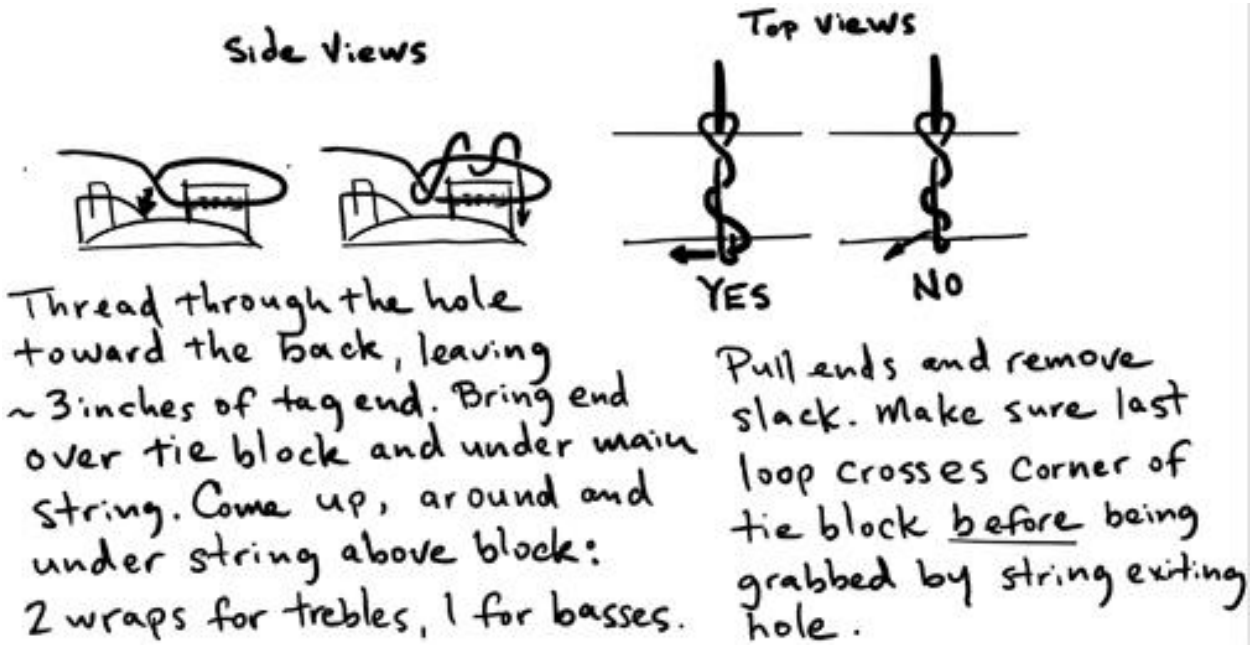
Thread the tag end under and through the loop you created (1) and bring it around toward you (2).

"Snake" the tag end through the two halves of the original loop (3 and 4).

Hold the tag end vertically with your right hand, remove the slack in the knot by pulling from the upper hole (5) and then the lower hole (6). Cut the tag close to the tie block.



For a traditional 1-hole system:



2. How do you tie the strings at the head?

Players often use too many knots and wraps onto the tuner rollers. This makes taking strings off difficult and time-consuming, but a more important consideration is that fewer wraps allow the new string to settle faster because there is less slack to work out. About 2 wraps is all you need around the roller.

Method: 1) Thread the string through the roller hole and remove any slack. 2) With your right hand, grab the string at the nut and pull it half-way between the nut and the 1st fret. That's the length of extra string you will need to put on the roller. 3) Bring the tag end of the string up and over the roller and tuck it under the string right where it enters the roller hole. For all strings except 3 and 4, when you tuck it under, the end of the string should exit facing the center of the headstock (away from the gear). Pull out the slack, make one more wrap and tighten the wraps well against the roller. 4) With your right hand, pinch and hold that bundle of wraps, then guide them to the roller as you turn the knob with the left hand. Guide the wraps *toward* the gears so that the gears can efficiently take the force of the pulling string. 5) The only exception is strings 3 and 4: do the tuck with the tag end exiting *toward* the gears and roll the wraps *away* from gears. This makes for a less severe angle of string entering the nut slots. 6) Cut off the tag ends of string so they don't rattle.

3. Is it bad to take off all the strings at once?

Q: How long can the guitar exist without the tension of the strings without doing damage to the neck?

A: For changing strings, it's okay and more time-efficient to remove all the strings at once. The short time changing strings won't change the sound. [The only exception is Ben's guitar where the neck is

attached only by the tension of the strings. In that case, he needs to have at least one string on so the neck doesn't fall off]. Having loose or no strings won't structurally hurt the guitar, but since guitars are designed to be under tension, longer than an hour or so may require time for the guitar to equilibrate before it gets its sound back. The exact amount of time depends on how long the strings were loose.

4. How do you clean your guitar?

Q: Is there really any need to clean your guitar besides the obvious of, who wants a grubby looking guitar!? Does it in some way help the wood to have the occasional rub down?

A: Cleanliness is a matter of personal taste, but it can help preserve your finish and value of your guitar. On high-end instruments, the finish is often natural shellac, which can be degraded by some players' skin secretions. Whether the guitar is finished in shellac or a synthetic finish, wiping with a clean, water-dampened cloth is usually all you need. Use something like a soft bath towel or a D'Addario wiping cloth and inspect it to make sure there are no particles that can scratch. Very lightly dampen one end of the cloth with water and rub firmly on the areas of the guitar that need it. Immediately dry any moisture with the other end of the cloth. Strings can benefit from wiping too. Avoid cleaning and polishing products which can do more harm than good.

Every 6 months to a year when you are changing strings, clean and moisturize your fingerboard. Generously apply boiled linseed oil (get at Home Depot or a hardware store) to your fingerboard using a rag or paper towel. Let the oil sit a few minutes and wipe away the excess. If you have built-up grime, you can use the oil as a solvent as you scrub away the goobers with the rag.