PlateTuning.org

http://www.platetuning.org/

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So, what is this site for?

A website for the serious amateur violin maker, restorer and tinkerer. A violin front and back (the plates) can be tuned using tap-tones. Use tap tones to adjust the 2 plates of a violin to get the best sound, the kind of sound you want, or make an instrument that is easy to bow.

This site has something for you if you are either making a violin or you want to improve a low cost violin or viola. By tuning the top & back plates you can get a good instrument that responds well to the bow and that can sound like a £1500 instrument.

This site is for people who are making a violin or viola, and also for those who want to modify a low-cost and poor-sounding instrument to dramatically improve its tone and playability.

I’m not trying to sell you anything here. And there are no ads or malware. Really. I believe strongly in the 'Wiki' idea: I feel a need to communicate what I know, so that’s what I want to do for other amateurs. What I ask in return is to hear your story, so please comment in my blog, or better mail me back to let me know what you’ve learned in fiddle making!

The parts of a violin

First, what are the parts making up a violin? Have a look at Hans Johannsson’s site: there’s good stuff on the construction of a violin. You can see the front and back ‘plates’ in his diagram left - click on it.

Tap Tones for the front and back of violins.

The two pieces of wood that make up he front and back of a violin are called ‘plates’ seen on the left.

If you open up a violin, or you are making one from scratch you can change (which means reduce) the tap-tone frequencies of these plates using a tiny thumb-plane and scraper by removing wood from the inside of them. You can measure these tap tones as you go by using a microphone and your home computer so that the violin (or viola) will sound really good. As well as thumb plane and scraper you'll need some kitchen scales and a thickness gauge. You can then be confident that your first or your next fiddle will sound excellent! Or perhaps you could also improve the tone quality of low-cost, poor sounding violins as I do!

This isn’t my work really. It’s using, summarising and building on the years of work others, the great names have done over the last 60 and more years. I have no problem with standing on the shoulders of others. I’m an experimental researcher by inclination and training: ‘try it!’ I say. And I love reading and learning what others have written and I hope you benefit.

Good tone: the search for the grail.

At the heart of getting good tone from a violin is matching the tap tones of front and back plates. The plates’ tap tones are a measure of the key properties of the plates. What tap tones do is show up the quality of the wood itself, especially the spruce of the front or belly. So don’t just use any old wood. Use good old wood.

By setting these tap tones to chosen frequencies, as well as matching them front and back, almost any factory violin can have its tone dramatically improved, whatever wood it is made from. Have a look at the example violins (and violas) on the Violin viola examples ref. page. For interest I’ve also
included pictures of what the best makers did over 300 years ago with some pictures of the outstanding instruments at the Ashmolean Museum, Oxford, UK. Do see them in person if you can.

The tap-tone method outlined on this website allows you to choose the tone you get too. It could be a ‘student’ tone for easier bowing, or perhaps you want a 'solo' instrument tone with harder bowing, but very powerful, and suited to real solo work.

My personal preference is for ‘chamber’ and ‘orchestral’ tone instruments midway between the two: easy to bow, and flexible in use, suited to an Irish pub session, a quartet or in a symphony orchestra.

The key to this choice of tones lies in the key violin body resonances or modes, and there’s more details on those modes on this page here, but that is definitely running before we can crawl. Get the plate tap tones right and the assembled body resonances, with some skill and craftsmanship, come out right!

Limitations: you need craftsmanship too

This however is not a cure to all human suffering. Much or most of a violin’s quality of sound derives from just ‘good practice’ in its making. There is no substitute for proper, patient, practiced craftsmanship and artistry in the making and modification of an instrument. It should be, it must be a work of art! I cannot begin to teach any of that. I can only help with some of the science and engineering aspects. Go to a craftsman for craftsmanship, and set aside some years to do it.

Tuning the plates

Plate tuning can help make your first or your fiftieth violin a good instrument - a fine reward for 10’s of hours of work. And it is not at all difficult. I personally mostly use this method to improve the tone and playability of factory-made or damaged fiddles, such as ones with bad soundpost cracks.

Significantly, I have found a way of quickly measuring Mode 2 and Mode 5 frequencies of violin backs and the back’s weight, without removing the back from the bouts (sides and blocks). So using a short knife and warm isopropyl alcohol / water I only remove the front and fingerboard to measure and work on the inside of the back to set up the back’s ‘stiffness factor’ and Mode 5 (ring) tone. Then I modify the front to match it.

The Mode 5 of a back plate is reduced by about 15%, as can be seen in John E. McLennan’s paper (UNSW) on page 5 & 6. However, usually Mode 5 divides into 2 frequencies up to 40 Hz apart, one either side of 300Hz.

Mode 2 of a back plate when in the bouts is only slightly increased, but the neck with no fingerboard unfortunately has a resonant frequency at almost exactly the same frequency, so we have to move the neck’s resonance out of the way to measure it!

Get in touch with me if you want to know more.

If a back is good and with specially resonant tap tones, carving a brand new spruce front can also give you remarkable results: but you have to start with good seasoned spruce for the belly though!

Arching and thicknesses

If you want to know what arching and thicknesses to use for the plates, have a look at this page.

I have now included 2 figures that show how to thin plates to get Modes 2 and 5 just where you want them. This data is from Acoustics for Violin Makers by Erik Jansson in “Chapter V: Vibration Properties of the Wood and Tuning of Violin Plates”, and here is just page 25 extracted from it, with a scheme to gradually reduce thicknesses of plates in an appropriate way while keeping Modes 2 and 5 under control.
This series of papers by Erik Jansson is a key reference work on acoustics and the violin: and it's free! He used to work with Carleen M Hutchins (CAS) and really knows his stuff. Have a look on the links page too.

History: let’s start at the beginning

Every journey begins with but a single step, and every organisation begins with a single member. That’s me. My committee meetings always run without a hitch.

I’ve always wanted a Stradivarius or Guarnerius violin, but somehow I can’t seem to muster that first £ million. I played a Guarnerius violin once, and it spoiled me: how could I, that bowing arm be making that fabulous sound? That sound, that’s a bit like a professional soloist on a CD? Well, with all the arrogance I could muster as a qualified engineer, I decided if I couldn’t buy one, I’d have to make one. And of course, I know that as soon as I get a Strad then my amateur scratchings will be instantly transformed into something truly wonderful ......

I am now retired, with violin repair and violin making as a (fanatical) hobby. I can spend time building and rebuilding violins and violas as experiments to test out ‘plate tuning theories’ as the fancy takes me. I have no commercial interests, and that gives me a big advantage: a fiddle shop just cannot afford to do that!

A rationale, and Carleen M Hutchins.

Over the years, while trying to make some awful violins sound better, I needed a rationale to this mending and tinkering. My long-suffering wife bought me the collected works of the CAS (Catgut Acoustical Society) for Christmas 6 years ago. A remarkably lady, Carleen Maley Hutchins (photo right) co-founded this Catgut Acoustical Society (CAS) nearly 50 years ago, and I remember her first article well: my mum showed it to me in the early 60’s when it was printed in Scientific American, Nov 1962. You may be able to get back-copies if you do a web search. A later article by her I think in 1982 can be found here on a Russian website, which I’ve put into a .pdf file here. The excitement of that approach stayed with me. Carleen died in Aug ’09 at the grand age of 98, and her obituary was published in the LA Times. What a lady!

Traditionally, violin makers ‘tune’ the front and back plates around an ‘F’ to ‘F sharp’ tap tone*. Tap-tone methods has been around for well over a hundred years (see footnote) and probably very much longer. Unfortunately factory-made fiddles, all that many of us can afford, have never even heard of ‘tap tones’ or even suffered much care in manufacture. Indeed many of these fiddles have so much wood in the back that if burned they could heat a small home for an evening.

Quick and free measurement with the home computer

What has changed over the last 10 to 20 years is that the ubiquitous home computer (right), used with a cheap microphone, has made available to us methods for measuring tap tone and violin body resonance frequencies very, very quickly. It takes me a minute or so to measure the tap tones of a violin plate. Carleen would need perhaps an hour, and Signor Antonio Stradivari? Well, he needed a very well trained ear and maybe a a ‘standard’ wooden rod or monocoord to tap for comparison. A good ear helps these days, but is not essential.

At first I found that Carleen’s methods of adjusting the tap tones of front and back to an octave (1:2 ratio of Modes 2 and 5 frequencies in both) just did not seem to produce really good fiddles: but they were better. I think it’s because the wood for factory fiddles, especially the fronts, is not good, low density, prime-choice wood and you have to strip the violin right down to its parts!
Makers can pay as much for the wood as some might pay for a violin outfit. Try Luscombe Violins in the USA, or Touchstone Tonewoods in the UK. Simeon Chambers (in Colorado) has a good range of wood at reasonable prices and plate thickness maps for sale too. He suggests the light Englemann spruce for bellies, with a density (specific gravity) of 0.34 to 0.38, which is much less than than normal European spruce at 0.45, but European makers seem to prefer Bosnian Spruce.

Theory: Dr. Nigel Harris and Patrick Kreit

About five years ago I came across an article by Dr. Nigel Harris that seemed to be the next step in the elusive connection between the tap tones of a violin’s plates, its playability (the violin’s is ease of bowing), and a real quality and depth of tone. In addition, as Dr. Harris puts it, it can make a given tone reproducible, violin to violin.

Dr. Harris (right) who sells some seriously good, pricey violins at Harris & Sheldon (violin.co.uk) links the plates’ Mode 5 (called the ring tone), Mode 2 (the ‘X’ Mode), and the weight of the plates into what he calls each plate’s ‘Stiffness Figure’. His work on 1000 + violins shows that if the front and backs have a similar ‘stiffness’ then a good fiddle will result.

I did develop an elaborate theory over the last few years based on combining Dr. Harris’ and Carleen Hutchins work, but it dawned on me a few months ago that the significance of plate weight at the heart of Dr. Harris’ idea of plate stiffness figure mentioned above is easily tested. I just needed to make 4 similar (ideally identical) violins:-

1) with a heavy front and heavy back plate,
2) with a heavy front and light back,
3) with a light front and heavy back, and finally
4) with a light front and light back plates,

and then see what the differences are.

The criteria for the quality of the resulting violins would be based on
a) where the key 6 resonances below 600 Hz fall, and
b) what the 2 violins are like to play: their tone and response under the bow.

Fortunately, with practice, the key body resonances are quick and easy to measure, and if the weight of each plate really is a significant factor then the violin with heavy plates would probably turn out to have low key body resonances, in particular B1- and B1+.

Results

For 1), with heavy back and heavy front (belly) I found that taking an old Maidstone Strad-model violin to pieces and reassembling it (in fact with a new maple back I made) showed that the weight of the belly and back plates has almost no measurable effect on any of the key body resonances.

Most importantly, B1- and B1+ resonances. The belly is 17 to 20 grams too heavy (at 82 grams), and the back 25 to 30 grams too heavy (at 127 grams) and when belly and back are heavy only the Mode 5 and Mode 2 plate frequencies mattered. The Maidstone, originally a very cheap violin for beginner students dating from about the year 1900, now plays very well and easily and with good tone, especially on the A and G strings. Details of all the parts and final body resonances can be found here as a .pdf page using the format laid out below.

2) For a violin with a heavy front and light back I had mended and tuned the plates on an old Hopf copy from about 1810/1820, which gave very good results - but it isn’t Strad. model of course!

3) I have yet to find a violin with a light front and heavy back to work on, so there is still plenty of work to do.
And for 4), a good quality violin with light plates? Well fortunately, Patrick Kreit (below left) has published a book called “The Sound of Stradivari”. I came across this rather costly book (€ 285) last year. Mr. Kreit links the Mode 5 frequencies of the violin’s plates to the resonant modes of the final violin body, step by step. He has done 10 to 20 years work in exploring the relationships between violin plate’s resonances (with Mode 2 set to half Mode 5) and the 6 key body resonances: see the ‘Resonances of the Violin body’ page. He has found a method for consistently getting the lightest possible plates .... so I did not need to make a Strad-model violin with very low plate weights to compare it with: all the data is in his book.

Limitations to Dr. Harris’ work have shown up too in Jo Curtin’s work, published in The Strad Journal: vide this page revealed by his his article on Strads. The effects of gluing each plate to the stiff bouts seems to dominate!

Simple theory

My findings so far are that Carleen Hutchins got it right: if you set the Mode 5 tap tone of front and back with the belly just a few Hz below the back, at 340 to 350 Hz (measured with low moisture content in the wood), your fiddle will turn out sounding good!

To get more consistent results, especially helpful for beginners, the other change to traditional practice the Mr. Kreit introduces is measuring and setting what he calls the Coupling Frequencies.

There are two Coupling Frequencies are the tap tones or resonant frequencies measured when

1) just the back plate is glued onto the bouts (or garland), and then
2) just the belly is glued onto the bouts (or garland).

These are easily and quickly measured, but do require that one of the plates is first temporarily glued (using weak glue and cigarette papers!) to the bouts or garland, and then removed before the other plate is glued to the garland.

This puts an important intermediate step between setting the tap tones of the pates and then setting the difference between the coupling frequencies of back and belly to about 25 Hz, as shown in the figure right (click on it).

This makes very important violin body resonant mode frequencies much more predictable².

Plate weight

So does it matter if violin plates are heavy even though they are tuned to the right Mode 2 and 5 resonant (tap tone) frequencies? Well, yes, a lot. The weight, or rather the lack of weight in each plate is a measure of its quality, providing it has low losses when it vibrates. A light plate has the right arching and thicknessing on good wood, and there is less wood for the bow and strings to move: it will respond more quickly and give out more sound energy.

So, if you are making a violin you will to need to buy the best wood you can afford. However, ordinary wood will make a good violin (as the Chinese student violins now show!) provided you get the plate tap tones right!

Quick results: Plate Tuning for Dummies!
Violin Plate Tuning

There is a page called “Plate Tuning 4 Dummies” for those who want quick results and simple rules of thumb to make a good fiddle first time round.

I have 8 or 10 beautiful and well-made violins by amateurs that look wonderful on the outside, but play like the old cheap school fiddles - simply because they did not have their plates tuned at all!

So have a a glance here for the basics: but you'll still need to know how to hear and or record a tap tone on the “How to Tune Plates” page of course!

What this is all about? Make a $150 violin sound like a $3000 violin

So this web site is all about just how to measure tap tones to help you make a new violin, or to modify an existing and poor-sounding $100 factory fiddle to get it to play and sound like a $2000 violin.

So have a look at the various pages here. In particular, have a look at how to easily measure tap tones, and how to use them to get matching front and plates even when using less than the best spruce and maple. I'll show too the various stages of how I modified some constructionally challenged instruments.

You can't do much damage to a £40 ($60) violin: at worst it's £40 of experience. But Warning: but do not do this on your Concert Strad.

Feedback: tell me what you think, and tell me about your experiences.

Let me know what you think of this site and its contents: violin plate tuning seems to evoke strong emotions in luthiers ...... so email me now ! It's all work in progress, so I'll include your comments, but no promises though.

So please Email me, or comment here in my blog ......

PS: Amusingly, this website is also available in the Russian language. It is also available in all the major world languages here at Google translation in French, Spanish, German or Greek ....

Footnote **:  F# is 370 Hz, F (natural) is 349.2 Hz, and E is 329.6 Hz. The reference here is to Ed. Heron-Allen’s book on violin making of 1885-6. Believe it or not he refers to Modes 2 and 5 and ‘nodal lines’ on p.133, and tells the reader how to make them visible using sand and a bow! Yes, that's from 125 years ago.

Footnote 2): In particular the B1-, B1+ and CBR body resonances. Since the two coupling frequencies are present on the finished violin, they are in fact “eigenmodes” or “eigenfrequencies” of the whole, finished violin. So they can be adjusted or set at the intermediate stage during the building of a violin, i.e. with just one plate at a time glued to the bouts or garland. The two Coupling frequencies then control and set the B1-, B1+ and the CBR (C2) body resonances.

1) Many authors (Hutchins, Molin, Moral, Schleske) use the terms “eigenmodes” or eigenfrequencies”: they are just body resonances of the violin corpus, in part or finished state.
Violin Plate Tuning

What are the Modes?

Modes: other sites give lots of information on how to see the patterns that arise when a plate of any shape is vibrated at one frequency. Have a look at the [Really Useful Links](#) page. These were originally discovered by a Mr. Chladni. His patterns of vibrating plates are well documented: have a look for instance at the UNSW site, and look at [Chladni patterns for Violin plates](#) or look on [YouTube](#). This [Ernst Chladni](https://en.wikipedia.org/wiki/Ernst_Chladni) (1756-1827) was a German physicist, and is known as the 'father of acoustics'.

What they tell us

The Modes, particularly Modes 1, 2 and 5, tell us about important characteristics of the wood:

- its bendability (speed of sound) **across** the grain is 'measured' by **Mode 2**, and
- the speed of sound or 'bendability' **along** the grain is 'measured' by **Mode 5**.

If we get these under control (i.e. known), then we are 'copying' what Sr. Stradivari did hundreds of years ago, and he knew that if he made a plate a particular way then an excellent violin would result. By setting the Modes 2 and 5 to 'standard' frequencies, just as we make all the other dimensions of a violin completely standard with a Strad or Amati model, we control at least 2 of the **4 key body resonances of a violin**. These 4 key resonances have a profound effect on the tone of a violin and are as follows:

- The **B1**- and **B1+ body modes** are directly affected by setting the tap tones to 'standard' values.
- The **A1 mode** is determined by the internal length of the violin, which is partly why violin length is standard to within 5 mm. **A1** is unaffected by tap tones.
- The **A0 mode** is the Helmholtz or cavity mode, and is affected by the internal air volume, the size of the f holes and the stiffness (and mass) of the plates and bouts.

So the tap tones put the **B1- and B1+ body resonances** in the right places, and by using standard dimensions for the body we get the other 2 in the right place. And what about all the many higher body resonance modes? We rely on good craftsmanship, choosing good wood, and a dollop of good luck.

We may find that a tap tone of say 350 Hz on the free plate produces a resonance of say 440 Hz in the final violin and not 430 or 450 Hz. It reminds me of aiming an arrow when shooting a bow. We calibrate the sights on the bow because gravity, the arrow and how it flies are almost the same every time. We set the tap tones as suggested because a violin is, as far as we can make it, a standard shape, and the ~1.5 times increase (a fifth) in the tap tone to become the main body resonance is what it does when we glue the body together. [Patrick Kreit's book The Secrets of Stradivari](#) takes this a whole lot further.

Have a look at [Carleen's paper](#) for more on these key body resonances, and there’s much more on my 'Resonances of violin body' page too. What we are missing however is the Italian Special Magic of scraping here, scraping there that allowed Sr. Stradivari to tune the plates after the violin was assembled ('in the white') to turn a good instrument into
one of the best violins ever made. I do think Herr Schleske has come closer to reproducing this magic consistently without having to resort to sacrificing frogs legs and/or nubile virgins.

Again, good violinmaking practice is the foundation. I have found that I need to convert the violin I’m working on to be as near a ‘standard’ good-practice violin as possible. It needs good blocks: you may need to add corner blocks if they are missing, as so often the case with old, cheap factory fiddles, and you may need to reduce the bouts (sides) to 1.0 to 1.4 mm thick by carefully grinding then down with a Dremel hand-router fitted with a sanding cylinder. Some fiddles have bouts over 2 mm thick. By adding good, standard blocks and thinning the bouts I remove most of the variations in sides (bouts) and the structure so that a tap tone of say 350 Hz on top or back plate really does become 440 Hz in the complete violin.

Historically speaking

The first reference I can find to these ‘Modes’ and ‘nodal lines’ on violin fronts and backs is in a Victorian book on violin making of 123 years ago! “Violin - Making: as it was and is” by Ed. Heron-Allen, published 1885-6. The author studied under (one of the) Georges Chanots, probably in London or Manchester.

There are some contradictions and “mistakes” especially on belly tap tone frequencies, but amazingly, re-reading it the other day, I found a reference to Modes 2 and 5 tap tones visualised using sand, using a rosined bow drawn across the edge of the plate to excite the modes. Chladni’s book on plate acoustics was in circulation a full 70 years (1787) before Mr. Heron-Allen was writing.

It’s fascinating to think that he may himself have seen patterns in sand, as shown right, as he drew a bow across the edge of a plate he was holding. This is on pages 132-133 of his book. He refers to Mode 2 as the “normal tone”, and believe it or not, refers to “nodal lines” in the tech. footnote on page 133. As a reality check, this is from 125 years ago. What’s new under the sun?

Here is a webpage at UNSW that shows these modes of vibration.

What are the Modes?

What is Mode 2 or the X-Mode? and what is Mode 5 or the Ring-Mode? Here are the ‘tea leaf’ patterns that show up when the plates are vibrated using a loudspeaker underneath at a particular frequency - the ‘tap tone’. It is a resonant frequency of the plate as a whole.

On the left here is one of the excellent photos on Joseph Curtin’s website and shows the most important Mode in a belly plate, Mode 5, the ring tone. The black lines are the nodal lines on a violin belly vibrating in Mode 5 at about 350 Hz. The pictures below show Mode 2 in a front plate at about 170 Hz. Have a look too at a BBC web page
Violin Plate Tuning

Here that uses “holographic interferometry” (!) to do the same thing - only even better!

These pictures show that when a plate, either the front or back of an instrument is vibrated at one constant frequency then fine sand, tea leaves, sawdust or glitter placed on it will move to areas of the plate that are not moving i.e. not vibrating. This only happens at particular resonant frequencies, and finding those resonant frequencies is what this is all about. These lines of no motion are called the ‘nodes’, or in this case the ‘nodal lines’. Anti-nodes are where the motion is at a maximum.

In summary: The “nodal lines” are the black lines in the photos and videos where the plate does not vibrate at that particular frequency. So the plate can and must be held somewhere on a nodal line without affecting the vibrating pattern of that Mode.

There is a good YouTube video by Jonathan McKinley (click on the picture left) that clearly shows plate modes 1, 2 and 5 vibrating as the tea leaves migrate to the lines of zero-vibration - the nodal lines of the violin plate as the vibrating frequency is gradually increased. Jonathan McKinley has photographed his violin parts here too: but his belly: Mode 2 is high, and Mode 5 low!

Understanding these Modes and their shapes is fundamental to understanding tap tones. You will need to know how to get these Modes vibrating. It was Carleen who first used a speaker placed under a plate at an anti-node, and fed the ‘speaker at various frequencies until a glitter pattern showed up.

These patterns are well illustrated by other website pages to be found in the “Really Useful Links” page. If you click
on either these two glitter patterns you can see the nodal lines on a back plate that Alan Jhones from Brazil sent me (thanks!). Mode 5 is the one above, and Mode 2 is on the right.

We can also get the plates vibrating by holding at a point on a nodal line, and tapping at an ‘anti-node’, or a point where the vibration is or will be a maximum: it works well, but there is information lost about the detailed shape of the nodal lines: Carleeen thought that is important.

Animations of plates vibrating
Borman Violins also shows some excellent and fascinating animations of violin and other plates here vibrating in situ on a violin and viola, made possible by the work of instrument maker George Stoppani.

This helps us understand how the vibration of the belly and back plates vibration modes while free (as we measure them) are linked to how they behave actually in a completed instrument.

Vibration modes of the completed violin
Getting the tap tones right for the plates will give you a good chance that the resonance modes of the completed violin body will be right - or at least similar to the world's greatest violins! Have a look here for the resonances of the completed violin body ......

...but what tap tones don't tell us
Well you won't make a violin that sounds like a £15,000 violin using tap tones like this unless you are very, very, very lucky and at least prepared to let an expert choose the (costly) wood to start with.

There is another and much higher level of the art, experience (and science) that the master craftsman has that us mere mortals can only dream of.

You can glimpse some of it in the work some are doing to actually listen openly to what violins sound like: there's a discussion here on maestronet for instance, which I've edited to a .pdf document here to make more of a narrative (and remove the occasional name calling these forums suffer from).

Others for instance have tried area tuning (see this fascinating site of Keith Hill's) and 'Vigdorchik strip' tap tuning (see David Langsather's example here) which I think has great possibilities, but you will need a lot of faith, patience, and a very, very good ear to do it. And much of a lifetime.
How to Tune Plates

Where to hold a plate to hear the tap-tones

Measuring the tap tone frequencies of interest (Modes 2 and 5, and possibly also Mode 1) takes only a couple of minutes, and involves no tuning forks or loudspeakers. The pictures below will show where to hold the plate: the belly or the back.

A plate needs to be held at any point on a nodal line, where the vibration amplitude at that selected resonant frequency is zero. This picture shows where to hold a plate (belly) to get Modes 2 and 5. Click on it or the one below for a better view.

Have a look on this page for the nodal lines. The ‘black lines’ seen there are these nodal lines on the back & front plates, for Modes 2 and 5.

Mode 2 is called the ‘X’ mode as the nodal lines are shaped surprisingly like an ‘X’ - useful to help remember, but the ‘X’ is two back-to-back C’s on a belly!

Mode 5 is called the ring tone, as the black nodal lines (or the lines where tea leaves/sawdust migrates to when the plate are resonating above a ‘speaker) are ring or ‘O’ shaped, particularly on the back plate. The front’s or belly’s (black) nodal lines are more like a pair of wavy brackets, one above the other, that extend right to the edges.

The point to hold a plate is in the middle of the upper bout, as if the plate had an ‘eye’ there as is the picture above. Importantly, holding here allows both Modes 2 and 5 to resonate when the plate is tapped, and suppress all the other Modes (and there are lot!). Their nodal lines do not pass through that point. I also use other points right on the plate edge that allow only one tap tone to resonate like the upper corner for Mode 5, and choosing that holding point damps all other modes. Experiment, play around! You will soon find where the best holding point is if you hold the plate up to your ear, and listen where the mic should be. I warn you: you will look ridiculous.

Flatter plates (with lower arching), and bellies without bassbars need to be held lower down the plate.
Where to tap a plate, and what with

I usually tap the plate right in the middle (the bridge position) for Mode 5, and at an edge (C-bout) for Mode 2.

The tip or pad of the first or second finger works well for Mode 2, and the knuckle for Mode 5. I’m using the knuckle here. You can use the eraser on the end of a pencil: it gives a higher Mode 5 and also many higher Modes too.

Where to locate the microphone.

The mic, preferably one on a ‘stick’, must be placed close to 1 - 2 inches away from an anti-node. The anti-node is in the middle of the plate for Mode 5, and at one edge (C-bout) and at the bottom block position for Mode 2: have a look at the pictures. With the mic at the centre of the plate, Mode 5 will be strong (as there’s an anti-node there), and Mode 2 weaker. Actually a Mode 2 broad nodal line is there, but it is still picked up a bit. You can see this from the FFT pictures below. In one case I measured, there was no Mode 2 picked up by the mic at all - because of this nodal line (no vibration) down the centre line of the plate. I usually move the plate up during the tapping so the mic’s opposite the bottom block position to make sure Mode 2 is picked up.

Screen capture and dB’s

In the screen dump of the FFT (see later), Mode 5 is 15 dB above that of Mode 2 when the mic stays at the centre of the plate and it it tapped with a ‘harder’ object: a pencil eraser (on the pencil!) or the knuckle. I use the free Ashampoo ‘Magical Snap’ for screen capture, turning what’s on screen to a .jpeg picture file. Or use Photoscape (also free). I then paste the picture directly into Serif PhotoPlus (the ‘SE’ version is free) or into Photoscape!

“15 dB” here means about 8 times bigger in amplitude as dB’s are a logarithmic scale. Usually the Modes 2 and 5 are about the same strength on the FFT screen when you move the plate during tapping so the mic picks up Mode 5 at the centre, and Mode 2 around the bottom block position.

How to get and interpret the results: the tap tones of Modes 2 & 5

First you will need to download and install the Audacity software from the ‘Sourceforge’ download page. This is a superb,
free PC program to record and analyze sound picked up by your PC microphone. I always use mono recording as there’s only one mic! There’s also a version for the Apple Mac.

Now record the plate tap tones using this Audacity software by pressing the red button with the mouse pointer. This button is top left in the picture on the right - click on the picture to see it. I usually tap the plate in the right place about 10 times in 5 seconds.

Select the 2 silences at the either end of the waveform with the mouse left hand button pressed and delete them using the delete key. This leaves a good waveform to work with: you may need to adjust the mic sensitivity down so the mic is not overloaded.

Select all the recorded waveform left in the window using “Control + A” keys pressed simultaneously and go to the ‘Analyze’ option on the top line of the window and select the ‘Plot Spectrum’ menu item that drops down. This calculates the Fast Fourier Transform (the FFT) of the selected waveform: that is it shows all of the resonant frequencies or tap tones present in the sounds picked up by the microphone.

You will need to enlarge the ‘Frequency Analysis’ window, and at the bottom left of the screen select ‘Spectrum’, 16,384 (the sample window size), Hanning window, and finally ‘log’ (or logarithmic) display.

I’ve included 2 pictures (screen dumps) of typical Audacity windows, one above showing the waveform, and one right showing the FFT screen. Click on them for the full size pictures.

In this example of a front (belly) with a good bassbar fitted, Mode 2 peak is at 167 Hz, and, also shown selected with the cursor is the 333 Hz of Mode 5*. What’s so good about Audacity here is that the cursor pops automatically to the nearest peak and shows its frequency under the display, under the purple area bottom left. Be careful to read the ‘peak’ frequency on the right and not the ‘cursor’ frequency on the left! Now write it down - I keep a small transparent folder for each violin to record all progress, results and calculations.

You can find instructions for using Audacity software here, or use a 10-part tutorial on YouTube here.

Audacity also allows the export of data to MS Excel (or an OpenOffice spreadsheet) to calculate the energy at various frequencies. It’s shown as an ‘Export’ button, bottom right of the Freq. Analysis window, and allows a
graph of amplitude v. frequency to be drawn in the spreadsheet using the ‘X-Y plot’ option.

Other Software options

There is some very old software called ‘CoolEdit 2000’ (windows XP only), and I’ve included here a screen-dump showing the tap tones for a belly. It can be found on the web as a trial but I’ve used it for years, as the FFT still works long after the 30 days! It is my favourite waveform capture, with a very good FFT function. You can see here mains hum at 50 Hz (!), and then the Mode 2 peak, and the Mode 5 peak clearly. There are other small peaks too, and these are the other Mode resonance’s of the plate, which apart perhaps from Mode 1, are of little interest. Note how broad each peak is: a good plate will have a very high, sharp i.e. narrow Mode 5 peak. The higher and stronger the better.

Another possible waveform/FFT software program is “Visual Analyser 2011” by Alfredo Accattatis. It is free to use, and has a pretty good real-time spectrum analyser as well as a standard FFT function you apply to a captured waveform. Note that the X-axis for the FFT does not plot to a log scale. The controls are a little quirky. You will need to use the ‘hold’ function to record a spectrum in real time - it works quite well, and is quick. Erase the spectrum by deselecting (un-ticking) ‘hold!’

There is also a free version of Overtone Analyser from Sygyt software which can be downloaded from here. An example of a screen dump from Overtone Analyser (Free Edition) is here leftt: click on it. This is the spectrum for a belly with no bassbar where Mode 5 is at 301.5 Hz Pieter Swanepoel wrote in to say he uses it, but I find it a little confusing as the plate is tapped and the tones are not continuous: but each to his own. The paid-for versions are much more versatile. The ‘Live’ version is 99 Euros.

Strobe Tuners

A company called Peterson make a range of strobe tuners, best described on this YouTube video. The latest is the ‘StroboSoft’ PC software for about $50. Strobe tuning techniques have been in use since Lloyd A. Loar’s outstanding work in the 1920’s on the Gibson F4 (and F5) mandolin plate tuning. They have a flat or rather carved front and back plate. His work has encouraged plate tuning on all kinds of instruments in the USA ever since, as the F4 and F5’s from that era are truly the ‘strads’ of mandolins! Roger Siminoff is the
current US guru on plate tuning, and has published several books.

The advantage of ‘strobe tuners’ is they allow rapid visualisation of the tap tone’s pitch, and also its harmonics: i.e. a frequency and all of its octaves. This may require a compressor (as used with guitars) to stretch the tap tone out.

* Yes! An octave front plate, where Mode 5 is 2 x Mode 2’s frequency! Octave means twice the frequency, and it is what Carleen recommends.
Plate Tuning for Dummies

I hope this page will help those making their first couple of violins: to you everything is new and so who can tell good from bad?

There are those people, perhaps even many people who regard tap tones as astrology for violin makers, just so much mumbo-jumbo. Once you have enough experience, and I mean many years handling the best violins along with training by professionals, you probably won't need tap tuning: flexing a plate and feeling the thickness profiles will do on its own. But, and it is a big but, those of us who don't have this experience and can't hope to get it either need all the help we can get. Tap tones keep us on the right tracks.

Unfortunately plate tap tones are hardly affected at all by the thicknesses of the plate edges, and yet these very edges are important because the plate is held very firmly by the bouts and linings in the assembled violin. So take care with your choice of edge thicknesses, especially between the C-bouts on the back plate.

The basics of good violin plate tuning comes down to this.

The violin plates measured here have low moisture content at about 6%, which is normal for wood in a heated workshop in winter. All Mode 5 frequencies should be set 15 Hz lower with 12% moisture content (MC) when plates are tuned in summer:

1. The Mode 5 ring tones of both front and back plates are the most important characteristics of the violin plates as far as defining what the violin will sound like and how playable it is.

   The dynamics of the violin are from the belly of the violin, and power comes from the back, in each case how much the plate 'rings' and what frequency it is at.

2. The Mode 5 ring tones of back and front then both need to be between 300 and 370 Hz. If they are not in this range then start again. The back should have a ring tone equal to or just a bit higher than the front.

   This is just what Carleen M. Hutchins recommended 30 years ago, and more modern measurements and work have shown her conclusions were sound.

3. To get a violin that will sound and play superbly then the picture or figure right will help: click on it. [this was updated 2May'12].

   This is not law brought down by Moses from the mountain, but it is a good starting point for your early violins: you won't go far wrong if you follow this!

   What this shows is that if you want to make a 'Solo' toned violin you will need to make plates with ring tones matched in the range 350 to 370 Hz. This figure is for unvarnished plates: varnish adds about 6 Hz to the belly's Mode 5, but hardly anything to the backs Mode 5.

   For an 'Orchestral' tone you need to match them between 330 Hz and 350 Hz.
Violin Plate Tuning

For a violin that is easier to bow and sounds ‘warm’, and well suited to smaller rooms and chamber music you will need to have a back at about 340 Hz, and and a belly plate at about 320 Hz - it will be easy to bow and a delight for chamber and pub music. Violins with the belly’s Mode 5 a whole tone below the back are common and can give very good results.

On the figure/picture given above the Mode 5 ring tones of back (frequency read off along the bottom ‘X’ scale) and the Mode 5 ring tone of the front or belly (read off on the vertical scale) need to fall within the green / brown / purple ‘box’.

The 3 diagonal lines from top right to bottom left are the points where back and belly plates have an exactly equal Mode 5, or differ by a semitone.

Outstanding ‘Solo’ instruments’ have plates with Mode 5’s falling in the upper purple area.

The figure/picture applies to finished, but unvarnished plates with ff-holes and bassbar in place.

I have assumed a typical A1 violin body resonance of 467 Hz \(^1\). If the violin volume (cm\(^3\)), and the f-hole size produce a different A1 body mode get in touch with me!

Making the plates from scratch

Cutting the f-holes on a belly reduces the Mode 5 by about 2 semitones (2 x 6%, about 38 Hz), but the original Mode 5 frequency is then restored to the same (or to a slightly higher frequency) by installing the bassbar.

The belly plate Mode 5 frequency then increases when it is varnished, but note the back increases hardly at all. For a belly, both Modes 2 and 5 go up by about 5 to 8 Hz as the varnish hardens, so follow the figures in the ‘Matching the Plates’ figure above.

(4) The final Mode 2 frequency of each violin plate should also be at or just below half the Mode 5 or ‘Ring tone’ frequency. Having Mode 2 any higher than this serves no purpose and increases its weight.

Mode 2 is less important to a violin’s tone than Mode 5, so just set it at half of Mode 5 using the techniques I show on the arching and thicknesses page, but do not thin the wood between the C-bouts of the back plate too much! In this area generosity is good.

(5) A low plate weight is a VERY VERY GOOD THING. There is less material to soak up the sound energy.

With the very best wood a soloist-quality 4/4 violin belly will be less than 70 grams, and a back, believe it or not, will be less than 96 grams. More often a finished belly plate on a factory violin will be about 75 to 80 grams, and a back plate about 115 grams.

The ‘reference’ weight of each plate is as follows in Table 2: This includes the standard or reference weight of violin, viola and 4/4 ‘cello plates.

<table>
<thead>
<tr>
<th>Plate Reference Weights: violin &amp; viola Table 2 modified 20 May ‘10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>belly uses relationship:</strong> linear dimension (length) (^<em>) 2.53, back (length) (^</em>) 2.31 rel. to 4/4 violin.</td>
</tr>
<tr>
<td>Back Length mm</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>300 mm (1/2 size)</td>
</tr>
</tbody>
</table>
### Violin Plate Tuning

<table>
<thead>
<tr>
<th>Size</th>
<th>Width</th>
<th>Height</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>328 mm (3/4 size)</td>
<td>12.9”</td>
<td>53.1</td>
<td>91.1</td>
</tr>
<tr>
<td>357 mm (4/4 size)</td>
<td>14”</td>
<td>64.7</td>
<td>109.3</td>
</tr>
<tr>
<td>387 mm viola</td>
<td>15 1/4”</td>
<td>79.4</td>
<td>131.7</td>
</tr>
<tr>
<td>394 mm viola</td>
<td>15 1/2”</td>
<td>83.1</td>
<td>137.3</td>
</tr>
<tr>
<td>407 mm viola</td>
<td>16”</td>
<td>89.6</td>
<td>147.2</td>
</tr>
<tr>
<td>419 mm viola</td>
<td>16 1/2”</td>
<td>97.1</td>
<td>158.3</td>
</tr>
<tr>
<td>4/4 ‘Cello’</td>
<td>~30” (760 mm.)</td>
<td>438.2</td>
<td>627.8</td>
</tr>
</tbody>
</table>

............ And that’s it!

**Footnote:** This model is derived from *Alonso Moral’s paper of 1984*, and also on the data published on *Patrick Kreit’s book and website* that gives the ‘deltas’ between these (A0), A1, B1-, B1+ body resonance’s we should look for in a first rate violin. The 3 coloured areas correspond to a difference in coupling frequencies of some 25 Hz, and set differences between the B1-, A1 and B1+ body frequencies expected. The relationship between coupling frequencies and B1- and B1+ is non-linear. You will need to get *Patrick Kreit’s book* to get more details.

2. See “*The Art of Violin Making*” by Courtnall and Johnson and the chapter on plate tuning.

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*Last update: 2nd. May 2012*
**Tone and Weight**

**Making or modifying a violin for good tone**

In making or modifying a violin or viola for good or better tone you can choose one of a number of methods. These are, in historical sequence:

- **Use craftsmanship!** Get help, get trained, get experience, and make your first dozen violins. There is no substitute for knowledge, craftsmanship and experience, not least in choosing your wood.
- There are **many plate thickness maps available**, and there are many available free on the web. They kind of work, but most platee need to be thicker or thinner than the map, as every bit of wood has different elasticity. **Tune the plates too!**
- If you do choose to use wood tap-tone tuning methods, then adjust the **traditional Tune Mode 5 (Ring tone)** with the back Mode 5 sounding F#, and the front at F (as a ‘raw’ plate). This ‘F’ later becomes F# to G with ff’s bassbar fitted and varnished. **The tap tone must be a full, true ring,** the very best you can get. Mode 2 frequency ‘floats’, and the plate’s weight is ignored. Typically, allied with good practice, very good wood and experience it works very well**.
- **Use the ‘CAS’ method:** Tune **Mode 5 and Mode 2** to be an octave apart (Mode 5 = 2 x Mode 2). This is Carleen Maley Hutchins’ (or the CAS***) method. It works well if you are choosing the best wood. Modes 2 & 5 frequencies of front and back should match.

**Update: this is a major revision March/April 2012.**

After reading Patrick Kreit’s book “The Sound of Stradivari” in February 2011 it seems to me now that all of this work on plate Stiffnesses is interesting, but really all we need to do is make the Mode 5 frequencies of the plates right and we can get the tone we want from a violin without knowing the Stiffness Figures for the plates. What to set the Mode 5 tap tones of the plates for the various choices of tone is explained on the page ‘Platetuning 4 dummies’.

The basics are: make or alter the violin plates so that the Mode 5 frequencies fall within the area in green, brown or purple in the diagram shown right. Click on it, and then right click that screen to save it as a .jpg to print.

The belly Mode 5 should be either equal to, or up to a semitone below the back plate’s Mode 5 in the range 315 Hz to 370 Hz, just as is traditional!

That is when the plate’s Moisture Content (MC) is at 6%, for a heated workshop in winter, or 15 Hz less if done in the summer months with the wood at 12% MC.

You can ..........

- **use Dr. Harris’s method:** Tune **Modes 5 and Mode 2 and take the plate’s weight into account** by making the ‘plate stiffness’ proportional to the plate’s weight. It works well with good nearly standard density spruce or maple. Unfortunately Dr. Harris’ method or theory it does not take into account the effects of the plates’ edges being attached to the stiff and relatively massive bouts.

Or you can .......

- **use a modified version of Dr. Harris’s method.** Here you **Tune Modes 5 and Mode 2** but only drop the tap tone frequencies a little if any plate has turned out rather heavy. I, and number of others who have contacted me via this web site have found that Dr. Harris’ method gives plates that turn out too thin. Only about half a quarter of the ‘extra’ weight of plate needs to be taken into account. So this is in between the two methods shown above - Carleen’s CAS method, and Dr. Harris’s. It takes account of the plate edges, and plate weight and grain stiffness as significant factors in determining the resonant frequencies of front and back plates when in an actual violin.

Looking at the weights of plates given below you may see just how much plates vary in weight: e.g. a belly can be about 54 grams right the way to 101 grams - nearly a 100% range, so, as Joseph Curtin says, we really do need to take weight into account in choosing tap tone frequencies.
Dr. Nigel Harris’s figures.

In his paper Dr. Harris gives Stiffness Figures * of

- 7,255,000 for backs, and
- 4,247,000 for fronts, with the back unvarnished and the front ‘raw’, i.e. with no ‘ff’ holes, bassbar or varnish. I personally have found this belly figure to be rather high, and a stiffness of 4,000,000 is fine if you don’t intend to do any ‘final’ thinning later. Dr. Harris’ violins are presumably intended for ‘solo’ use, so I would expect them to be rather thick.

This figure, Dr. Harris’ “Stiffness Figure” is a simple product. It is the average of the Mode 2 and 5 frequencies (in Hz) squared, multiplied by the plate’s weight (in grams), and is explained too in Joseph Curtin’s Strad article.

The table below (Table 1) shows the way in which the plate Stiffness Figures above are derived, and shows that these figures are all directly derived from Carleen Hutchin’s work with CAS, combined with Dr. Harris’ Stiffness figures: the spreadsheet itself can be seen here. They are given below for each ‘tone’: you can choose which - Student, Orchestral or Soloist. I have introduced the “Stiffness Factor” here too, as it is much easier to work with, and is described next.

<table>
<thead>
<tr>
<th>Plate Stiffness Reference.xls</th>
<th>15 Feb ’10</th>
<th>Table 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stiffness Figures are for fully finished plates with varnish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belly ref. Weight (gms.)</td>
<td>64.7</td>
<td>Belly Stiffness Figure</td>
</tr>
<tr>
<td>Back ref. weight (gms.)</td>
<td>109.3</td>
<td>Back Stiffness Figure</td>
</tr>
<tr>
<td>Weight (gms.)</td>
<td>Mode 2 (Hz)</td>
<td>Mode 5 (Hz)</td>
</tr>
<tr>
<td>Belly</td>
<td>64.7</td>
<td>165</td>
</tr>
<tr>
<td>Back</td>
<td>109.3</td>
<td>165</td>
</tr>
</tbody>
</table>

Derived from Jo Curtin’s Strad violin data

<table>
<thead>
<tr>
<th>Weight (gms.)</th>
<th>Mode 2 (Hz)</th>
<th>Mode 5 (Hz)</th>
<th>Stiffness Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belly</td>
<td>65.62</td>
<td>170</td>
<td>340</td>
</tr>
</tbody>
</table>

330 Hz is E natural relative to Stiffness Figures above
### Violin Plate Tuning

<table>
<thead>
<tr>
<th>Back</th>
<th>111.4</th>
<th>170</th>
<th>340</th>
<th>0.95</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weight (gms.)</strong></td>
<td>Mode 2 (Hz)</td>
<td>Mode 5 (Hz)</td>
<td><strong>Stiffness Factor</strong></td>
<td></td>
</tr>
<tr>
<td>Belly</td>
<td>67.7</td>
<td>180</td>
<td>360</td>
<td>1.07</td>
</tr>
<tr>
<td>Back</td>
<td>116.05</td>
<td>180</td>
<td>360</td>
<td>1.08</td>
</tr>
</tbody>
</table>

Relative to Stiffness Figures above

<table>
<thead>
<tr>
<th>Weight (gms.)</th>
<th>Mode 2 (Hz)</th>
<th>Mode 5 (Hz)</th>
<th>Stiffness Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belly</td>
<td>68.7</td>
<td>185</td>
<td>370</td>
</tr>
<tr>
<td>Back</td>
<td>118.3</td>
<td>185</td>
<td>370</td>
</tr>
</tbody>
</table>

Note that belly & back are heavier for higher tap tone frequencies

370 Hz is F#. Relative to Stiffness Figures above

To simplify things a little and to also take account of an inaccuracy in Dr. Harris' Stiffness Figure (an error due to the effects of the stiffness and weight of the edges of the plates), I define the "Stiffness Factor" as the ratio of $f^2 \times$ corrected plate weight, relative to the Stiffness Figure. This is shown in the formula below, and shows the specific relationship that needs to be in place between the tap tones and the plate weights for a good violin, once the kind of tone you want has been chosen:

It may be interesting to note that a 'good' violin, with 'viable back and front' needs its plates to have a Stiffness Figure within +10% / -15% of the Reference Figures given here. In terms of plate weight, because removing wood changes weight, Mode 2 and Mode 5 all downwards, then the plate's weight needs to be within the small band of -5% / +4% of its 'proper' weight. In fact the plates' weights need to match within ~ 2 or 3% for a good instrument. This explains why factory fiddles have plates that are so wrong (and mostly too heavy) most of the time: it just doesn’t happen by accident.
Time for Examples : Belly plate

So for instance, a good belly or front plate of spruce might have a Mode 2 of 172 Hz, a Mode 5 of 327.8 Hz, and a weight of 71.3 grams in the raw with no ff’s, bassbar or varnish. So the average frequency is \((172 + 327.8) / 2 = 249.9\) Hz. Squared (multiplied by itself) gives 62,450, multiplied by the corrected plate weight as follows: 71.3 actual wt. + 64.7 ref. weight [from table 2 below] / 2, = 68 grams, giving a Stiffness Figure of 4,247,000 or rather larger than the 4,000,000 of a ‘raw’ belly plate. So this belly has a Stiffness Factor of 1.06, and will give a bright ‘Orchestral’ tone. There is a Wiki page giving the relationship between frequency (Hz) and modern pitch here.

It is worth noting that roughly speaking, a belly plate ring tone or Mode 5 will be increased by about 0.7 of a semitone, or be raised by 14 to 15 Hz when the ff holes are cut, the bassbar added (which itself increases Mode 5 by 2 to 3 semitones), and the plate varnished. This is equivalent to a Stiffness Figure increase of \(\sim 12.5\%\).

Back Plate
Similarly, a back, unvarnished, with Mode 2 of 171 Hz, a Mode 5 of 345 Hz and weighing 109.3 grams would have stiffness factor of \((171 + 345)/2 = 258\) Hz, squared = 66,564, x 109.3 grams = 7,255,000. This has a Stiffness Factor of 1.0, for an Orchestral tone. This example has the plate exactly equal to the reference weight (Table 1), so there is no weight correction.

**Table 2** right shows the Reference weights of violin (first 3 rows), and then the larger Viola plates for various sizes.

Note: These weights are a little high for raw plates, as they actually include about 2 gms of varnish!

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* This formula or relationship can be found in Dr. Harris’s paper here.

**Interestingly, F.J.Fetis’s book “A Notice of Anthony Stradivari”, on page 81, is the only one to say that the back, (actually Villaume’s real Strads and Guarnerii violins of 1850, obviously with ff’s bassbar & varnish) should be tuned a tone lower than the belly. Heron-Allen in his “Violin Making, as it was and is”, page 132 says the back should be a tone higher than the belly. Other sources say they should match.

*** CAS = Catgut Acoustical Society, now part of the Violin Society of America, the VSA.

**** I had a good violin with a finished front of 101 grams! This was the third fiddle I ever worked on and though heavy, it produced an excellent tone. It’s an oddity that set me on the road to tap tones... why should such a belly with a Mode 5 at only 316 Hz (final, with ff’s, varnish) make such a good sounding fiddle? A standard front is nearer to 65 - 70 grams with ff’s, bassbar and varnished, and even as low as 57 grams.

David Langsather gives low plate weights of 54 gm front with bass bar, and an incredible 86 grams back. Stradivarius’ bellies, with bass bar & varnish, are also typically low at 58 - 70 gm. Dr. Harris uses heavier plates, typically 65 gm front and 109 gm. back before ff's and varnish.

A Charles Davis has been in touch to tell me (Jun08) about Joseph Curtin’s Strad magazine article on Stradivarius front plates: found at the Strad magazine website. Based on these (obviously) finished Italian violin bellies I suggest the front’s target ‘stiffness figure’ is \(4.5 \times 10^6\) (i.e. just 12.5% or \(-0.7\) of a semitone above raw plates) for a finished belly or violin front plate. Chart 2 (see below) incorporates these figures.

**Matching the plates: Matching Stiffness Factors!**

It’s important that the “Stiffness Factors” of the front and back plates match for a good instrument. The general rule seems to be that the front ‘s stiffness factor should be equal to or not more than 15% less that of the back.
Finished plates: the front or belly with ff holes, bassbar & varnish, and the back varnished.

Based on the good old Italian fronts of Joseph Curtin’s Strad article then final varnished violin fronts should have a ‘Stiffness Factor’ some 12.5% or about 0.7 of a semitone higher than the raw plate, and this is shown in Chart 2 below.

Cutting the ff holes in a raw belly plate lowers Modes 2 & 5 frequencies. Then adding the bassbar and varnish raises them again. If there is no “final tuning”, i.e. thinning the belly a little from the ‘raw plate’ tuning, then typically the plate stiffness would be 10% to 15% higher than the ‘raw plate, tying up with a Stiffness Factor of a raw belly plate (no ff’s, bassbar or varnish) of 4,000,000. Varnish will harden too over the first year an more, raising Modes 2 & 5 slightly with time. The back is only slightly affected by varnish. http://www.platetuning.org/Chart_Plates_final_V3.2.jpg

As before for the ‘raw’ plates before the ff’s are cut and bassbar put in, a similar relationship applies:-

The average of the Modes 2 and Mode 5 tap tones (in Hz) still needs to be modified somewhat to take account of the
plate’s weight, and what sort of ‘tone’ you want from the instrument.

So for an 'orchestral' tone (see below) the final plates need to have a stiffness factor of :-

- about 4,500,000 for the front, with its ff’s, bassbar & varnish, calculated, or a Stiffness Factor of 1.0, and
- 7,580,000 for a good maple back plate that is varnished, calculated as above.: a Stiffness Factor of 1.0 again. javascript:openpopup_3d5c('/..chart_8_final_plates.jpg')

To avoid the maths, use the chart (left) that allows the 'Stiffness Factor' for both a front (belly) and back plates in final varnished state to be derived directly from:-

1. the average tap tone, i.e. the average of Modes 2 & 5, typically 260 Hz, and
2. the plate’s final weight: e.g. 109.3 grams for a back, and e.g. 64.7 grams for a belly with bassbar, ff’s and varnish.
plate weight using the plate weight data of Table 1 left. The two Mode frequencies can be read off the one tap tone recording and its FFT, made with mic & computer as shown here.

The chart above has log graduations on the scales#. To save and print it, just right click it, select ‘Save Link As...’ and save to ‘My Pictures’. Then open it in any picture/photo program and print it out from there.

As before, this chart above has log graduations on the scales#. To use it, just use a ruler’s edge to connect the average freq. (Mode 2 + Mode 5)/2 at the bottom scale, and the plate’s weight at the top, to read off the stiffness factor relative to 1.0 off the middle scale.

The figure 1.0 on the middle line is equivalent to or is scaled to $4.5 \times 10^6$ (4,500,000) for a belly in finished form, and $7.58 \times 10^6$ (7,580,000) for a back.

Different ‘Stiffness Factors’ for different tones.

To summarise, Carleen Hutchins’ figures for higher or lower tap tones for a range of violin tones, she found that both front and back plates with Modes 2 & 5 of 170 & 340 Hz gave a ‘Student or Chamber instrument tone’ that is easy to bow, but doesn’t carry all that well. She also says how to make ‘Solo’ instruments with tap tones of 190 & 380 Hz shown in Table 1 left. Other tap tone frequencies in between gave ‘amateur, ‘Orchestral or teacher’ violin tone.

So start with the ‘Stiffness factor’ of the back. This should be at about 1.1 for a ‘Solo’, 1.0 for an ‘Orchestral’ and about 0.9 for a Student’ tone. The relative ‘Stiffness factor’ is read off Chart 2 above or found with a spreadsheet.

I’ve found it better that the stiffness factor of the front should match the back or be below it: this a similar to what Carleen (CAS) recommends. Never take too much wood off the back plate - it’s better to leave it with a Stiffness Factor not less than 0.95, even for a student instrument.!

You can choose to take the front’s ‘stiffness factor’ anything up to 10% below that of the back for a good tone, but I would not generally recommend more than 5% - 8% below the back. This uses the data from the Strad fronts Joseph Curtin wrote about in his Strad Magazine article. I have modified some instruments with final belly Stiffness Factors of as low as 0.85 (3,800,000), (and indeed many Strads etc. have bellies with a stiffness factor as low as this), and the modified instruments are an absolute delight to play under the bow, but need top quality spruce to have good solo or carrying power as well.

I have found that in a dozen violins so far a Stiffness Factor between 90% and 100% of the figures above (0.9 to 1.0 on the chart) for both front and back plates makes a good violin with Student, Chamber to Orchestral tone.

Plates for ‘Celsos

It has been possible to use data that Carleen Hutchins, Dr. Nigel Harris and particularly John Osnes Violins (Anchorage, Alaska) have provided to estimate the Stiffness Figures required for ‘Cello plates too. Carleen strongly recommends that the plates have matching Mode 2’s, and they are ‘octave’ plates (Mode 5 = 2 x Mode 2) in the range: Mode 2 = 60 to 65 Hz, and Mode 5 120 to 130 Hz.

Not surprisingly the ‘cello Stiffness Figures are very similar to those for violin and viola plates. For normal ‘cello ‘Orchestral Tone’ the belly unvarnished but with ff’s and bassbar should have a Stiffness Figure of $4.03E6$ (4,030,000 ) and the back unvarnished 6.0E6. Varnished this rises to $4.44E6$ for the ‘cello belly (note it is almost identical to the violin figure) and $6.16E6$ for the ‘cello back, which is 19% less than for violins.
You should change the Stiffness Figures say 5% lower to 15% lower for a ‘student’ tone (3.78E6 and 5.24E6) for easy bowing, or increase it by up to 15% for a ‘Solo’ tone (5.1E6 and 7.08E6). Note that plates still need to have matched Stiffness Figures, as for violins! This is summarised in this table: click on it ....

<table>
<thead>
<tr>
<th>Standard Orchestral Tone Cello plates, summary:</th>
<th>Mode 2</th>
<th>Mode 5</th>
<th>Standard Plate Weight (gms)</th>
<th>Harris Stiffness Figure</th>
<th>Modified Stiffness Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belly, unvarnished, finished</td>
<td>62.5 Hz</td>
<td>125 Hz</td>
<td>439.2</td>
<td>4.33E+06</td>
<td>4.33E+06</td>
</tr>
<tr>
<td>Back, unvarnished, finished</td>
<td>62.8 Hz</td>
<td>126 Hz</td>
<td>628.8</td>
<td>6.0E+06</td>
<td>6.0E+06</td>
</tr>
</tbody>
</table>

In the CAS Journal III there is a particularly interesting example of a ‘factory’ Mittenwald ‘cello that has been rethicknessed. Thomas King did the work under Carleen’s supervision, and the article is here (I strongly recommend you get the full set of CAS articles). The ‘cello has a low but matching Mode 2 in front and back plates (57 Hz): the back has a standard ‘orchestral’ Stiffness Figure, but the belly is 20% low, assuming standard plate weights. The tone apparently is outstanding and is easy to bow.

Plotting the Stiffness Factor for a plate as you go along.

The method I use is as follows: I keep a constant watch on the calculated ‘Stiffness Factors’ of front and back all the time as I even thin the plates from the inside. Back & front have to match subject to the rules above, and don’t take the back too thin!

The wood you have may limit your choice of ‘tone’ perhaps, but you can put in a rather high new bassbar to raise the stiffness factor of the front, and graft (i.e. glue) in a round or oval maple patch (~45 x ~50 mm across) into the middle of the back to raise its stiffness factor.

It took me a week or two to get used to the method, but now I don’t really have to think about it: it’s just habit.

I do calculations at every step (!), but they are simple: find the average of the plate’s Mode 2 and 5 frequencies, and watch the weight of the plate too.

Spreadsheets.

Record the details and the stiffness factor at each step for each plate. I mostly use a simple spreadsheet to do all the calculation on the same PC I’m measuring the Mode frequencies, but you might prefer the chart I’ve given above if you don’t like spreadsheets. Here is an example spreadsheet I created for a JTL ‘Steiner’ violin with finished, varnished plates to show how easy it is. The screen looks like this:

<table>
<thead>
<tr>
<th>Ssheat Steiner violin SFs V1.0.xls</th>
<th>8 Jan ’10</th>
<th>Table 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stiffness Figures are for fully finished plates with varnish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back Stiffness Figure for Reference</td>
<td>4,500,000</td>
<td></td>
</tr>
</tbody>
</table>

Belly Reference Weight (gms.) 64.7
Violin Plate Tuning

<table>
<thead>
<tr>
<th>Weight (gms.)</th>
<th>Mode 2 (Hz)</th>
<th>Mode 5 (Hz)</th>
<th>Stiffness Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belly</td>
<td>162.5</td>
<td>351</td>
<td>1.05</td>
</tr>
<tr>
<td>Back</td>
<td>164.5</td>
<td>374</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Italics = estimated figures relative to Stiffness Figures above

Only the cells shaded yellow need to have your measured figures entered, and the Stiffness Factor can then be read out from cells E7 and E8. It is easy to create a similar spreadsheet that will do all the calculation for you. Use OpenOffice for a good free spreadsheet.

A note on humidity

It is worth noting that tap tones change with the moisture content (MC) of the wood. So in a heated workshop in winter wood will have an MC of ~6% and the figure given on this website will apply. However in summer the wood MC will rise to ~12%, and the Mode 5 tap tone frequencies given on this website will need to be reduced by about 15 Hz! The plate weights also increase with higher MC too.

*I created it using the ‘SmallBasic’ language on a PC.*
Resonance of Violin Body

Violin whole-body body resonances and modes

This is for the brave! Do not attempt to work on finding these ‘main body resonances’ until you are very familiar with using Audacity and finding tap tones on the belly and back plates. It can drive you mad, .... but a good violin needs to have these key 7 resonances below 700 Hz where they should be.

It only takes about 5 minutes to find all the key body modes. These can also be seen at the Strad3D modal view site here.

There is a website - John Schmidt Violins, Laurinburg, North Carolina, USA - that has two .pdf files (“Violin Mode Measurements 1 and 2” by Don Noon). In them you can see how to measure A0, A1, B1- and B1+ body modes on completed, strung up violins: how to do it is also summarised below. And you can also see the Maestronet chat pages about B1+ and B1- for Don and Anders Buen’s discussions that lay out the basics.

How to do it ...

damp the strings and hold the violin at the top block with the left hand. Don Noon suggests you can see the individual body resonances by tapping and mic’ing in different places on the violin body, with the ‘chosen’ peak usually then the highest of several recorded in the recorded FFT, as follows:

For ........

- A0 - close mic at the upper part of an f-hole while tapping anywhere on the body,
- B1- - close mic near the center of the back, and tap at the centre of the back,
- B1+ - close mic the violin top, just above the f-holes, and tap the bridge with a pencil,
- A1 - close mic at the lower eye or the lower ‘O’ of an f-hole, and tap a bout [or the belly next to the tailpiece]
- B0 - hold the violin at the lower widest point, tap the scroll and mic at the centre of the back.
- CBR or C2 - close mic at the edge of a C-bout, and tap the opposite C-bout [on the back]

You’ll then see

- A0 (Helmholtz) peak at about 270 Hz, and
- B1- at about 410 - 460 Hz, and
- B1+ at 510 - 550 Hz, and also
- A1 between B1- and B1+ at 450 - 485 Hz.
- B0 at about 270 Hz if there is a good ebony fingerboard.

javascript:openpopup_3d5c('../bridge_tapped_with_pencil_mic_over_rt_f_hole.jpg')
The example right is an Audacity FFT plot for my red ‘Juzek’ violin, tapped on the side of the bridge with a pencil. There is 50 Hz hum (as always in the UK), A0 is at 265 Hz (a very high peak), ‘B1-‘ is at 449 Hz, there is a little of A1 visible at 465 Hz, and then there’s ‘B1+‘ at 540 Hz. The extract of this plot with these peaks is here.

You can see the exact same Audacity FFT curves/plots in the 2 papers by ‘Don Noon’ on the Schmidt website mentioned above.

To find the important A1 resonance properly (and this is a resonance mostly of the air column along the violin, closely linked to A0): with the strings damped, hold the violin at the upper block and tap the belly next to the tailpiece with your finger or knuckle. Position the mic. so it is right at the lower ‘O’ of the right hand f hole - right in it if possible! Then you’ll see clear resonances at A0 (~270 Hz) and also A1 (~450 - 485 Hz) as distinct peaks.

With this method you can see the very strong A0 at 263 Hz for the ‘Juzek’. If you click on the picture right the A1 mode frequency also shows up as a strong peak at 462 Hz. The extract of this plot can be seen here. The B1+ and B1- mode peaks are at a very much lower amplitude.
If you look at Patrick Kreit’s site (or better, get his book!) you will see he strongly recommends that the relationships between these key body resonances should be as follows for a concert quality violin:

- a delta of 75 to 95 Hz between modes B1+ and B1-
- a delta of 60 to 90 Hz between modes B1+ and A1
- a delta of 0 to 16 Hz between modes A1 and B1-.

But be aware too that when the tailpiece and chinrest are added then B1- and B1+ both drop by 10 to 15 Hz! Their weights affect the body resonances. A1 is unaffected.

* This “CBR” mode was labelled “C2” by Jansson, and “Vertical translation of C bouts” by Marshall.

Using the instructions given in Don Noon’s paper on the Schmidt website you can also easily find the ‘CBR’ or C2 mode which lies between 350 and 420 Hz, but sometimes you may get 2 of them very close! The ‘Juzek’ has the CBR at 370.5 Hz.

Carleen also recommended matching the B0 body resonance to the A0 (Helmholtz) resonance you have measured above. If it is at too high a frequency, reduce B0 by adding weight at the end of the fingerboard. For example, use blue-tack stuck under the end.

Ideally the tailpiece resonance, usually at about 125 to 135 Hz should be at half of A0 and B0.

Oberlin Acoustics has a glossary online of these key terms and
The article *Mode tuning for the violin maker* by Carleen M. Hutchins and Duane Voskuil is rather an advanced paper, but if you can understand it, it covers all the basics on violin body resonances.

Now what do we *do* with this information on body resonances?

Carleen M. Hutchins’ work showed that the difference or ‘delta’ between the frequencies ‘B1+’ and A1 dictate how a violin projects, and quoting from her *CAS paper*:

**A1 AND B1 FREQUENCY RELATIONSHIPS**: It has been found that the frequency spacing (delta) between the A1 cavity mode and the B1[+]
body mode is critical to the overall tone and playing qualities, indicating whether a violin is suitable for soloists (delta 60-
80 Hz), orchestra players (delta 40-60 Hz), chamber music players (delta 20-40 Hz), and below 20 Hz is easy to play but lacks power” (Hutchins 1989).

Amongst my violins I’d say that it is so!

There are discussions among the experts on maestronet on just what the relationships are between the plate tap tones, weights and thicknesses. It is very complex indeed. Anders Buen has come up with a useful relationship I have reproduced here, where he says:

“*The B1+ is slightly more determined by the back plate, while the B1-
is more determined by the top. The [critical] distance between the B1- and B1+ is much determined by the back plate central thickness*”.

So, for the back plate the thickness of the area between the C-bouts, which is most closely tied to and measured by the back’s Mode 2, is very important.

The back is often seen as the sound ‘reflector’ to the belly’s ‘projector’, so do not take too much wood off this critical area between the C-bouts of the back plate, including the area of the channel next to the linings. I recommend 3 mm or more in the channel here, and 2.7 mm for the rest of the channel at the plates' edges.

As mentioned above, Patrick Kreit gives a lot more detail (and I mean a lot) in his book “*The Sound of Stradivari*”. He tells us that the sound, dynamics and clarity of a solo-grade violin, Strad or Guarnerius model, is based on the exact frequencies and ‘deltas’ of the B1+, B1- and A1 body modes, and also on the frequencies of the A0, and the B0 and CBR (C2) modes.

While reading Patrick Kreit’s book I modified a 40-year old, very cheap Chinese ‘Skylark’ violin to put the Mode 5 frequencies of the belly and
back plates where Patrick said they should be, and with their Mode 2’s an octave below. The key body resonances ended up where he said they would be (A0, A1, B1-, B1?). This ‘Skylark’ is now the best sounding and easiest to play violin I have among my 12+ violins, which go up to ~$2.5k each. Apart from putting the Mode 2 an octave below Mode 5, his plate-tuning methods are based mainly on tuning Mode 5 of the plates, and knowing what the wood’s moisture content is at all times.

Testing my violins I can find all of these body resonances / modes as good, clear peaks in their FFT (Audacity) plots, and they are of similar amplitudes.

You can look at Jo Curtin’s papers in the Strad or on his website to see where these key resonances are for some of the world’s great violins! So if you want to copy one - you can try to copy the main body resonances too!

Getting the tap tones of the plates right goes a long way to getting these key body resonances just where they should be for a good violin. We do know that the plates’ tap tones need to be within a particular range for a decent violin: what I’ve found is that matching them, as Carleen Hutchins did, gives a better violin, and taking the plates’ weight into account too is also a step forward!
The Tools

You will need **about £500 ($750) of tools** if you buy the real things, but much can be achieved with very much less

**Computer and microphone**, with free recording and FFT software such as "Audacity", available off the web. Have a look [here](#) to see what the options are and how to do it.

A **thickening gauge** that can reach inside the back when it has the sides or bouts on. This is perhaps the tool, along with the small thumb planes that I use most. It cost about £65 ($130) on eBay, new.

There are various plans for making your own from wood etc, but I found that I just couldn’t get the accuracy with a very crude homemade (wooden) version to reach into the back when it has bouts on. But if you only do thicknessing on new plates then simple home-made gauges using levers can work well. Note that training your thumb + first finger (calibrated digits) is also very useful!

A good set of **chisels**, and/or **gauges** flat and curved.

**Rasps.**

A kitchen **balance or scales**, with better than 1 gram accuracy, shown here with a jap saw.

**Thumb planes:** they give you blisters after a few hours, but it’s an occupational hazard: wear one leather gardening glove! I have only 2 thumb planes at the moment: one flat bottomed, and one with a convex base for thinning the insides of the plates. It has a 10 mm blade. Martin Smith has been in touch and suggests making thumb planes as shown on [dunwellguitar’s web site](#) (a real neat simple design), and there’s detail on how to sharpen scrapers here at [ruttan.com’s site](#). Cheap scraper sheet can be had in UK’s pound shop apparently! Martin wrote

“The harder the metal of the scraper the harder it is to sharpen but the longer it holds the edge. They reckon you need a special burr tool but I use a halfords 3/8 chrome vanadium socket extension bar to round the edge over, it’s much harder than the scraper and is easy to hold. I found that the most important part of sharpening is to ensure a smooth square edge on the scraper before rolling the edge over, this really needs the oilstone to get it right. Getting the curl right took me a while but about a 30-40 degree angle from horizontal seems to work well, that and a fair bit of force with a few passes, you really need to be able to feel the burr sticking out. They work better on the maple than the spruce. The thumb planes are a doodle to make, slightly trickier to make blades for, but again the pound shop scrapers came in useful although cutting the blades was hard work with a hacksaw, a dremel would be better. They clog pretty quickly but I'm not precious about them so I've been modifying them as I go along and they work well enough for me (ignorance is bliss).

A **small flat plane with about 1 1/4” cut:** to tidy up the top of the bouts and blocks. You’ll need a good **oil stone** to keep it sharp too, and a honing guide to get the angle right: you can make a simple one out of hardwood.

**Glue-pot** for animal glue: I use a [Boots baby-bottle warmer](#), about $25 new.

It is set at 55 - 68 deg C, a mid-range setting, as I calibrated this one. Do not boil the animal glue, as it is protein-based and is weakened by high temperatures. Add the pearl glue along with water (about 1:2) as it goes into the small pot - the kind used in hotels for marmalade or jam is good for small jobs. When not in use I keep the mini-glue pot in the top of the fridge to stop mould growing on it. Do not use this glue on toast, it tastes disgusting. Note that a violin front needs to be glued on with **well diluted glue** as it will need to come off again in a few years, and the glue needs to give before the spruce
A wax heater such as this Babyliss one can also be used, but I have not checked that this one can go up to 68 deg C.

**A ‘Dremel’ type hand-held router.** This was a “Power Craft” Combitool sold by Aldi in the UK for less than £25 ($40), with a useful flexible drive shaft. 10k to 35k rpm, but only 160 Watts.

I use this, or its bigger brother to grind down the over-thick bouts (sides) of factory fiddles using a cylindrical sanding head shown.

You can also use this for routing for the purfling with an adapter to keep the distance from the edge and the depth constant [http://books.google.com/books?id=XmFy8PXrY2IC&pg=PA140&lpg=PA140&dq=router+violin+purfling+groove+cutter&source=web&ots=kBOXyZfmj9&sig=VjnZeCWbsd-Q8-CC7MRQtw0HqU](http://books.google.com/books?id=XmFy8PXrY2IC&pg=PA140&lpg=PA140&dq=router+violin+purfling+groove+cutter&source=web&ots=kBOXyZfmj9&sig=VjnZeCWbsd-Q8-CC7MRQtw0HqU), and cutting to a depth of ~1.5 - 2 mm. A Chinese company called ‘music-1982’ sell a ‘dremel and a fixture’ to cut the purfling groove, and a photo of it to be found here.

**A drill press.** A basic model can be bought new for about £60 ($100), and is indispensable. It may be worth paying more - there are some very useful hints here at Pete Shugg’s Power Tool page about drill-presses. He loves the the Safe-T-Planer cutter too: see later.

Mowry Strings uses the Safe-T-Planer cutter (about $50) in such a drill press to carve the external contour profiles of mandolin backs, which are like violin fronts or backs. He calls it a ‘topographic step method’. This is an alternative to using hand gouges for carving. I’ve not tried it yet. The Planer head is apparently also useful for thinning the raw bouts to 1 to 1.2 mm.

**A small Bandsaw.** I bought a 12” (used) Clarke CBS-12WB 3-wheel bandsaw.

It cost about £60 ($100) off eBay. It dates from about 1993, hardly used. This is the older single-speed version with a 6 mm blade, and here is a copy of the handbook / Owner’s Manual for it here as I can’t find it anywhere else on the web. There is a later variable speed version, still available from Machine Mart.

**Scrapers, curved:** see note about thumb planes.

I also use Stanley knife blades too: they have a straight edge and are very sharp, and with grinding they can be used to make knife blades when glued into a wooden handle.

Old carbon steel kitchen knives, if you can find one, are useful sources of good steel for blades and scrapers.

**A pencil gauge:** Derek Roberts is shown using one here.

Here’s an experimental pencil gauge I made last year. It’s invaluable for visualising the arching of the front and back plates by using ‘contours’: like
a map of the countryside with its hills and valleys. It is used when the back surface of the belly of back plate is still flat: i.e. before gouging out the inside of a plate.

The pencil clamped in the top bar marks the top of plate while the top of a bolt beneath keeps it fixed distance from flat side of the plate.

I used an M6 bolt which locates into an M6 nut, which in turn is glued into the bottom bar. A wing nut locks the bolt into position.

A second M6 bolt (with its wing-nut to lock it) allows the gauge to be opened out and then closed up again keeping its calibration when the violin plate is held down on a ‘carving board’ above the workbench. A piece of plastic acts as a ‘hinge’.

**Use M6 nuts and bolts for all such projects. They have a pitch of 1.0 mm:** one turn of the bolt or nut moves exactly 1.0 mm, so adjustments of say 1/2 mm are one half turn - easy!

The gauge works ok but you can see I used the wrong wood: the cheap softwood of the vertical split straight away! Use hardwood or better, metal, say steel or ali’.

**Clamps** (a full set) to hold the front on while it the glue sets, and various sizes of G-clamps too. I made 2 C-shaped clamps shown here to reduce the number of spool clamps needed and make the operation of clamping quicker: it needs to be quick so the glue doesn’t gel while the top or back is glued on.

**A knife to remove the front.** I use a old table knife that I’ve ground down and shortened on a bench grinder. It needs to be quite thin, with edges not too sharp: I’ve cut myself quite badly with this knife a couple of times as a front or fingerboard can suddenly give way and the knife goes out of control. So take great care - always cut away from you left hand. Here are some web pages on opening the violin or viola front (belly) with such a knife - they can be found here and here.

If you have to make or replace a rib or bout you will need to fabricate one either

- by using Bruce Ossman’s method: by laminating layers of maple veneer in a mould, or
- using heat, bend a piece of maple that is 1.0 to 1.4 mm thick and 32 mm wide.

The rib bending is done with a rib bending iron (about $150-$200 new, or less from China), or you could use a household iron as shown by Jonathan McKinley here. Or you can use a hollow metal tube gently heated inside to about 200 degC with a blow torch or heat gun .... But, do take care you don’t burn your hands, clothing or the house.

**A good metal ruler.**
Violin Plate Tuning

Touch-up varnish (not water based!) and good brushes. I use transparent oil paint (e.g. Burnt Umber) to colour the clear varnish, or oil paint mixed with Liquin to lay down a thin glaze between varnish layers.

A good flat file.

Sandpaper, and fine emery cloth from 400 to 1000+ grit. I use water (with a touch of detergent), or baby oil for fine wet-and dry sanding with the emery cloth.

A soundpost setting tool, which can be bought or made.
Violin Plate Tuning

Arching and Thickness

Arching of the front and back, plus f-holes & bassbar

For arching the plates, the best guidance I've found is in Sacconi's book on Stradivarius' violins called "The Secrets of Stradivarius", where he gives the ideal 'contours' of front and back plates, and tells us just where to put the highest point of the plate.

You can use the long and cross 'arching templates' that so many books get you to cut out and use as guides, but I prefer the method that Juliet Barker teaches at CVM in Cambridge that can be found in her book. While the inside of each plate is (perfectly) flat use a pencil gauge to create the arching contours of your choice. This ties up well with Sacconi's 'contours' in his book mentioned above.

I cut elaborate cardboard contour guides (like David Langsather's and Sacconi's) for use with the pencil gauge but in reality? It's really about a feel and look for arching, especially when you've made and handled a lot of violins. The contour guides are just guides.

There's also guidance in any of the various books on violin making in the 'Really Useful Links' page, but I have just discovered that Sergei Murgatov has written a book called "The Art Of The Violin Design" available on the web in English here, and it includes detailed arching (and sixths gauges) on pages 50 to 61. It includes arching for violas and 'cellos too. He uses the the 'Cornu spiral' or 'clothoid' rather than the cycloid as the basis for traditional Stradivarius arching.

Don Morris has published some free plans for a "1720 Strad" violin. If printed on A4 they need enlarging by 65% to get full scale for a 356 mm body length. You can also buy plans of violins and other instruments off his site. Dimensions are in US inches. A copy of his plans are here as a .pdf too.

For belly plate Strad. arching: click on the picture right, and right click to save it in the new window

Other belly arching figures are here, and the belly sixths are here.

For back plate Strad. arching: click on the picture below:

Other back arching figures are here, and the back sixths are here.

The front and back should really have different arches: the front (the belly) has a flatter long arch and cross arching than the back: some say it has a 'platform' the back doesn't have. Some outline and arching templates for a 'Strad.' can be found here as
upper part and lower part.

These can be printed out full size (use the scaling print option for your printer) and then cut and glued together to match ‘X-X’ or the bridge line. The scaling is:

- overall length = 356 mm. Max.
- width for the upper bouts at template #1 = 2 x 82 = 164 mm. Max.
- for lower bouts at template #5 = 2 x 103 = 206 mm. The same arching templates can be used for back and belly without much error for your first violin.

Bruce Ossman in his book on your first violin (see here) has exactly the same the arching, back and front for simplicity, but there is no need to do so as you can alter it as you make it.

Here's how Onnes Violins sets the arching on the back of a 'cello he’s making, using various workshop tools, including power tools!. The same technique could be applied to a violin or viola. He also has an interesting page on thicknessing and tuning the plates of a 'cello here using a laptop and Apple’s ‘Perfect Pitch’ program.

Darren Molnar has some interesting things to say about arching on his site, particularly about using Curtate Cycloids.

The Strad Magazine has a scanned copy of Quentin Playfair’s article on cycloids from The Strad, 1999: you can download: Part 1, and Part 2. I met Quentin again when he taught at Cambridge (CVM, UK), and here’s a picture of him (centre) in the workshop. A skilled craftsman who knows a lot, and can tell it with tact. These cycloid shapes are much easier to create (draw) than to describe, especially in maths, as they use parametric equations. But it's quite easy to create an arching profile using a spreadsheet, and then use the pencil gauge shown on the Tools page. They are (much) easier to create than Murgatov’s clothoids!

Roger Hargrave's site library has an article on Guarneri’s arching and f-holes here.

Thicknesses of the front and back

The New York Times printed an article in 1994 called “Perfect Violin - Does Artistry Or Physics Hold Secret?” which is available on Peter Zaret’s website here as a .pdf file. He has an interesting modification to the standard bassbar and other good stuff on violins. Anyway, the original article is difficult to read as the text is small, so I have reproduced Carleen M Hutchins’ thickness plans from it (see and click left) for a Mezzo violin (an oversize standard violin!), but the thicknesses are all but identical to Sacconi's plate thicknesses for a normal violin. The text of the article is here.
Right click it and use “Save target as ...” to save as a .jpg file. These plate thicknesses are final thicknesses, so your plates may be thicker than these.

The thickness of front and back plates for great Guarnieri ‘del Gesu’ violins can be found here, reprinted from ‘The Strad’ Sept. 2005. Borman Violins also shows some fascinating animations of violin and other plates here.

There are also plans (A3 size) available for the Ole Bull Violin Project (the Ole Bull Guarnieri of 1744) than can be found on the Christophe Landon’s Violins web site. These include the shape, the arching and the plate thicknesses.

Erik Jansson also gives guidance on thicknesses in his articles “Acoustics for Violin Makers”, Chapter 5, Fig. 5.21, page 24.

**Rough thicknessing: back**

![Diagram of violin plate tuning](image)

I have derived Fig. 2 above to shows where to thin a back plate to reduce either Mode 2, Mode 5 or both frequencies. Again, click on it to see the diagrams in detail. Right click it and use “Save target as ...” to save as a .jpg file.

**The thickest point**

There is some agreement between the various reference book and other sources of back thickness data as to where the thickest point on a violin back should be.

Summarising these sources, and ignoring differences in plate shape :-

- Stradivarius put the thickest point ~ 46% down from the top of the back plate [source: Sacconi and Courtnall and Johnson].
- Other sources (e.g. CVM, Juliet Barker and her team) and others) put the thickest point about halfway (50%) of the way down the back, and
Guarneri del Gesu usually put it ~ 55% of the way down, with all distances measured from the bottom of the top block to the top of the bottom block. This ‘thickest point’ then acts as the centre point of the ovals or circles that guide the thicknessing of the central area. It is sometimes slightly offset by ~10 mm. towards the sound post: see the work of ‘Jack’ Fry below.

To get the back to the right kind of thicknesses to start with I use a cardboard ‘pattern’ with cutouts as shown right. It is a quick and remarkably effective technique I copied off others like David Langsather. So choose your model, make your choice.

There’s an interesting YouTube video here showing how to use a ‘graduation punch’ in thicknessing a plate.

If you didn’t over-thin the back it is then ready for plate tuning!

**Rough thicknessing: belly**
I have derived a Fig. 1 above to show where to thin a front plate (the belly) to reduce either Mode 2, Mode 5 or both frequencies.

Click on it to see the Figure in more detail. Right click it and use “Save target as ...” to save as a .jpg file.

This is a revamp of Erik Jannsson’s work referenced earlier, which itself seems to be based on Carleen Hutchin’s work of 1982, published in the CAS (VSA) Journal.

In some forum discussions between Don Noon and Anders Buen on maestronet here one Marty Kasprzyk, a retired product development mechanical engineer, has produced an excellent illustration (click on it, right) of just where to thin a plate to reduce Mode 2 and/or Mode 5.

As an example using this data, I recently needed to reduce Mode 5 of a viola belly without reducing Mode 2, so I took areas marked the colour orange in Fig. 1 above from 3.0 mm to 2.4 & 2.5 mm. This took Mode 5 from 278 Hz to 263 Hz, but left Mode 2 unchanged at 112.8 Hz.

The f-holes
Violin Plate Tuning

The Strad f-hole shape can be taken for example from Stroebel’s book on violin making, or from an article in Roger Hargrave’s site library where the article on the Mackenzie Stradivarius violin has dimensioned drawings with f-holes shown. The Strad ran an article on the detailed positioning of f-holes too, which is here. A 1733 Guarnerius is also described and drawn here, with f-holes and plate thicknesses.

The bassbar

The bass bar should be 5.5 mm thick, or 6 mm if the belly has low arching or has wide-grain. Its final cross-section shape will be a ‘parabola’ (inverted U shape).

The ends of the bassbar should be either 40 mm from the top and bottom edges, or other makers end the bar when it is at the 3/4 way point from bridge line to top and bottom edge.

The outside of the bassbar must sit 1.0 to 1.5 mm inside the left foot of the bridge, i.e. the bassbar must be under the left foot to take the pressure of the strings and pass the forces and vibrations to the belly. The top end of the bassbar (nearer the top block) needs to be ~2 mm closer to the belly centre-line than at the bridge position, or you can use the ‘sevenths’ method text books describe for more accuracy. There was an article by Dominic Excell in The Woodworker, Jul ’96 (which alas is long since out of print) available here as a .pdf file. It shows how to cut f-holes and how to position the bassbar using the ‘sevenths’ rule.

The picture right (click on it) shows the wood for the bassbar being chalk-fitted onto the belly. I use 2 or more thin blocks temporarily glued on with white glue to hold and guide the bassbar wood during fitting and gluing, and I also use brightly coloured chalk on everything but a Strad.: it’s easier to see than white.

There are many shapes of bassbar: the fashionable one is ‘hump shaped’, but Stradivari’s originals were just a low flat bar, the Strad magazine has promoted a triangular shape (Jo Curtin, ‘Trade Secrets’, Nov ’05, available here) with the highest point under the bridge. Patrick Kreit uses a flat bar tapering down a few cm. from each end, so the shaping is easier. Some keep the bar at full height just for the length of the f-holes. Take your pick.

You must now choose where the highest point of the bassbar is: at the bridge position or closer to the mid point of the bassbar, but best is to put it half way between the middle of the bar and the bridge line.

The figure right (click on it) shows the ideal (logarithmic) shape of the top of a humped finished bassbar as it slopes from the highest point towards the ends. There are heights from 11 to 15 mm shown, but start shaping at no less than 15 mm.

This graph needs to be scaled of course, as the bridge position (the ff inside nicks) is closer to the bottom edge than the top! A typical finished bassbar is 12 mm high at its highest point (measured down the the belly on the inside, centre-line side) and is 6.8 mm high halfway (50% of the way) to the end in both directions, and the ‘half height’ point is 56% of the way to the end.

The bassbar’s height needs to be reduced as you tune the belly plate for Mode 5 to get the Stiffness Factor you want. You will need to keep the bassbar’s top shape correct, so there’s quite a lot of measuring, checking, carving and planing (thumb plane work) to do. Note the bassbar needs to be rounded to a parabolic cross-section but is nearly semicircular at the ends. Reducing the bassbar height has little effect on Mode 2.

Raising Modes 2 & 5 in a thin back.

This thickness data is especially useful if you need to add a maple patch to the middle of the inside of a back that is
too thin i.e. has too low a Mode 2 or 5. This is more like ‘doubling’ as it can cover quite and area. I’ve found that a wide patch of say 3 - 4 mm thick (which may be made up of layers of maple veneer) increases mostly Mode 2, and a long (lengthwise) patch of 3 - 4 mm thick increases mostly Mode 5. You will need to shape and then ‘chalk fit’ the maple patch before gluing or use layers of veneer, but I have sometimes used fluid Araldite (2-part resin glue) to stick a patch on a cheap factory fiddle, as the patch can be fitted less exactly - the resin glue acts as a filler, where animal hide glue does not.

There’s first-hand guidance on thicknessing in Sacconi’s book on Stradivarius called “The Secrets of Stradivari”, and in other books to be found on the ‘Really Useful Links’ page.

‘Fiddlehead’ has been working with the famous Jeff Loen on Strad plate thicknesses, and these can be found here for the Harrison Strad of 1693 for front and back.

Have a look too at David Langsather’s website page for a quick and practical approach. He has the thickest point about 55% of the way down the back.

Osnes Violins in Alaska (!) shows how thickness graduation is done here on a ‘cello, and shows plate tuning, cutting the ff holes, and fitting the bass-bar. He uses a power router/cutter to remove the excess wood from inside the back of a cello.

Physicist “Jack” Fry, with the help of violinist Rose Mary Harbison, has been working to rediscover the legendary sound of the Stradivarius violins. William ("Jack") Fry has a lot of interesting things to say about the effects of tiny local thickness differences, especially at the end of the fibres that go over the sound-post (over an area shaped like a ‘tongue’ of thicker wood), and an area at the violin’s edge at and above the right-hand f hole. The video of Jack’s lecture (1 1/2 hrs.) can be found at the website above. His books titled “A Physicist’s Quest for the Secrets of Stradivari” (with DVDs) are available here, and an article on him and his quest is here. Many thanks to Jeff Minniear of Schenectady NY for the links and articles.
Violin Plate Tuning

Trying a Violin's Tone

Evaluating a violin’s tone.

There is no accepted way of evaluating the tone of a fiddle: everyone, including me, has their own idea of what a fiddle should sound like! I bet that helps. But it also depends on what you want to do with it: a bluegrass fiddle needs to be quite brash to be heard over the banjo and various guitars - but is probably not suited to classical at all. A chamber instrument (for quartets etc). needs to be responsive and intimate or it can be overpowering.

Squawkers and squeakers.

Well, there’s a lot of squawkers and squeakers out there among the cheap violins .......... so we do need some way of assessing them with fact rather than opinion.

More objective methods.

A simple way of checking to see how even a violin or viola is across all the strings there is a simple method first used in the early 20th Century before oscilloscopes and computers. It is described in various books on the physics of music, and it’s easy and quick to do these days. You just play every semitone from the bottom G open string upwards as loudly and evenly as possible while recording the violin. Here is an extract from Alex. Woods "The Physics of Violins" (1944) showing response curves for strads. and other violins using this method.

Ideally a sound level meter should be used with the whole experiment done in an anechoic chamber [no echo’s from the walls etc], but a mic and a well-damped room or workshop will do. Here’s how Carleen M Hutchings describes it, and shows what an ideal (i.e a Stradivarius) violin response should look like, and where the key 3 resonances should be. Open strings tend to sound overly loud (see below) so it’s better to use 3rd position for the D, A and E strings.

Play each note for about 1 second standing say 2 feet from the computer’s microphone. Leave a gap of say one second between each note: a silence. You can even say out loud the note’s name, it helps.

Then on the playback waveform, select each note with the mouse and read off the (rough) RMS* amplitude measured in dB, from the meter in Audacity. It works better with ‘professional’ software such as ‘Cool Edit 2000’ however, where the RMS energy can be read off the selected waveform using Analyze => Statistics, directly in dB **.

I then plot the response using these figures (dB, vertical scale, uncalibrated) for each semitone using a logarithmic horizontal frequency scale so that equal octaves are equal distances on the x-axis. Note that I used open strings (D, A, E) which therefore appear about 2dB louder than other notes.

You can see that the response of a fiddle, even a strad., varies by some 10 dB, or about a 10 times ratio of sound power max. between various notes over its range. This seems to be a lot, but this is also where the instruments tone colour comes from too.

What does this tell us?

Well, if you’ve paid $20 k for a fiddle it tells you whether the maker got the fundamentals of the physics right. Note that Carleen was not impressed by the “Peter Guarnerius” of her example, but how a fiddle responds to attack of the bow is more than just how loud it is.
Violin Plate Tuning

This fiddle example is showing less response for ‘G’s, while similarly 2 other fiddles I’ve plotted responses for show less output on ‘D’s. So we can use this technique to find out or to confirm our impressions of a fiddle’s strengths and weaknesses, and put numbers to them. That helps, especially in suggesting what to change and do in the next fiddle!

* RMS = root mean square: a measure of the total energy in a sound wave.

** Select say 500 -1000 mS of waveform, and 0dB = FS [Full Scale] sinewave.
What Will it Take

You will need :-

Courage,

The right tools, and plenty of time.

Be prepared to make a lot of mistakes, so start on a cheap violin. A faint heart ne'er won the maiden. Have a mistake on me.

If your working on the plates of a new fiddle your making, or you have one completely in pieces you're lucky! The weights and tap tones will be there ready for the asking or the measuring.

It takes me about 10 hrs. per violin to take off the front and fingerboard of a 'factory fiddle', modify ** the front and back to appropriate tap-tones and put the fiddle back together. On top of this is any time for any repairs, like a sound-post patch and varnish touch-up: but be warned. This is without having to take the back off the bouts (sides) and glue them back on.

Removing the front - the belly plate

Removing the back can cause a great deal of damage ........, but I have found ways of measuring (deriving) the weight of the back, and also the Modes 2 and 5 frequencies of the free plate while it is still in the bouts with the neck in place.

The Mode 5 of a back plate is reduced by about 15%*, but sometimes splits into 2 frequencies up to 40 Hz apart, usually either side of 300 Hz.

Mode 2 of a back in the bouts is only slightly increased, but the neck (with no fingerboard) has a resonant frequency at almost exactly the same frequency, so we have to move the neck's resonance out of the way!

Use a shortened table knife to remove the front plate (the belly) and the fingerboard, but do be careful. You are trying to ease the knife into the joint and 'lever' the plate off, not to cut into the joint.

Removing the front (belly) is made much easier if you carefully feed into the joint a little warm Isopropyl alcohol mixed with water (50/50). I have used it heated in a baby bottle warmer to 50 degC, and the belly came off in about 10 minutes with very little damage, but it can take a day. Note that the alcohol may well damage or soften some varnishes, so experiment first, and be prepared to touch up the varnish carefully later.

When all the belly is nearly off, feed a small amount of the warm alcohol/water fluid down or via a long bladed knife to get it into the top block joint with the belly held slightly open. And with that the
belly should come off relatively undamaged.

**Dangers**

I've managed to cut myself quite badly doing this on my left hand, as I'm right handed. Always cut away from your left hand, as the knife can suddenly fly out of control as the joint gives way, so using a leather gardening glove on your left hand reduces the risk of a serious wound a lot!

*: Footnote on accuracy: As this method measures Mode 5 indirectly then there is a possible inaccuracy. I estimate that using this method there is a Standard Deviation of ~4.1%. That means that my estimates are 68% likely to be in error by not more than 4.1%, and 95.5% likely to be out by no more than 8.2%. There's more detail on this here on the Wikip'dia page.

** This is by using the thumb plane(s) on the inside of back and front plates, leaving the varnish intact. Obviously you cannot alter the arching at all with this method unless the back is over-thick and you are prepared to refinish the back.
Odd Shaped Violins

Violins & violas of odd shapes

Most string instruments, except the guitar had their shapes and sizes determined by the late 1600's, so for 300 years a violin has been violin shaped.

There have been many attempts to 'improve' on the classical baroque shape. Most have been unsuccessful, and almost all have found little acceptance by the paying, playing public.

There are some notable attempts to change the violin shape, and a few can be seen here at Springers Music. The violin is a complex, difficult shape to manufacture, so it is not surprising there have been attempts to simplify the construction without loss of tone.

People worth mentioning here are Mr Francois Chanot and Nicolo Guseto, who made 'guitar shaped' violins; and Rigat Rubus, a Russian who made novelty violins with the edges and scrolls edges rounded. There are quite a lot of poor Rubus copies of these around, especially on eBay. There is of course also the Hardanger Fiddle with its 8 strings, a left-over of earlier proto-violin forms.

And there's Félix Savart. His Trapezoid or 'box' violin (as well as the Chanot violin) is described by Ed. Heron-Allen in his book "Violin Making as it was, and is" - click on this link for access to the .pdf file of the whole book, courtesy of GoogleBooks. I've extracted the pages (p. 118 ff) here as a .pdf, as what is so surprising is that a 'box' with...
strings on can sound so much like a violin!

Ronald Roberts published a book called *Making a Simple Violin and Viola* in 1975 describing in detail how to make fractional and 4/4 violins, and also violas. Apparently the violas sound particularly good. As the front and back are not carved, and all the sides are all straight it is much easier to make than a classical 'baroque-shaped' violin: a good student project perhaps! Note that Savart put the bassbar right up the middle of the belly (!), but later copyists put it under the left foot of the bridge, as is more usual.

An Ed. G. has been in touch with me from the USA: he’s made some successful violins with the lower corners missing: see right, and Tim Phillips violins.

Da Salo made some early violas like this (Oxford Ashmolen Museum), and I think their appearance is rather elegant!

Tim Phillips makes fine violins, many of which are unusual shapes and colours: have look at his ‘top corner’ or ‘asymmetric’ instruments.

One of the most interesting violas come from David Rivinus: he has designed an alternative viola shape (click on the picture right) to overcome the major difficulties of
playing 17 + inch violas for long periods. I have had to go from a 17” to a 16.5” viola myself, even though my knuckles drag on the ground when I walk.

The ‘ideal’ viola design has a 20 inch body that should be played like a small ‘cello between the knees and not under the chin!

There is also the Maximilian violin (see and click right) to ease playing for normal violinists too.
Violin Viola Examples

Here are more details on some of the instruments I have modified:-

A good modern Chinese violin c. 1980.

JTL Medio Fino, Marked “Steiner”.

German “Bench fiddle”, circa 1800 marked ‘Hopf’, with a ‘transitional’ neck, dating from the early 1800’s. I lengthened the neck at its root.

A 15 1/4” (387 mm) Viola, modified to have low plate stiffness factors, and making an outstanding student / orchestral viola!

A German (transitional *) fiddle with a lions-head scroll, also dating from the early 1800’s. It had such low belly Mode 2 that I needed to add 5 cross-braces to raise Mode 2 and also improve the ring/Mode 5 resonances. An outstanding tone - a delight to play.

A violin labelled “John Juzek, Prague”.

A German Stainer copy, a 7/8ths Christian Meisel (1930), and a good Mittenwald, with very dark varnish that once had a severed peg-box.

These violins now have a known, reasonably matched ‘stiffness factors’ (which is the ratio of plate stiffness figure to the Reference plate stiffness, as given on this page) on both front and back.

* With a short neck, the kind fitted before ~1820.

There is also a page on the violins and violas at the Ashmolean Museum in Oxford, UK here. This includes the Stradivari “Messiah” violin.
Examples 1

JTL Medio Fino, Marked “Steiner”

This is a JTL “Medio Fino” which is branded “Steiner” (not Stainer!) on the button.

It has a single piece back which is very plain. The front had a great big chunk missing bottom left when I got it, and for my first graft ever, I grafted in some good quality spruce as shown.

I took the front down from the original 3.8 and 4.0 mm thickness all over (i.e. unusually thick!), to 2.6 mm all over - to give me a Mode 2 of 162.5 Hz, and Mode 5 of 351 Hz measured as shown here. I left the original good bassbar in place. A belly at 2.6 mm is rather thin, but this is somewhat dense spruce of the belly, and it has shown no signs of splitting anywhere in 80+ years.

So I thinned the back at the edges a little to make it more even, but the centre is already at a measly 3.3 mm: I didn’t want to take it down any more than that.

The [estimated] Mode 2 of the back is now 164.5 Hz, and Mode 5 at 374 Hz.

The tone of this fiddle is now superb! A very good G string. So far, matching stiffness factors for front and back has always yielded a superb G string tone.

I’ve played this now in quite a few Concerts and its good both at fff and ppp, and its a fine all rounder. Good balance between strings, a nice breathy A string, and it has no noticeable vices anywhere, other than the repair.
JTL Medio Fino violins don't have purfling (the lines are inked in), and that made the repair simpler, as matching purfling is challenging. Colour match to the varnish is ok.

So taking 78 gms. for the front and 100 gms for the back, gives a “Stiffness Factor” of 1.05 for the front and ~1.00 for the back: quite a good match. I hasten to add this was more by good fortune rather than good planning.

There’s a summary of a simple spreadsheet below, and you can download the spreadsheet here if you like. The formulas that do the work are in cells E7 and E8. It can be opened with OpenOffice or MS Excel.

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<tr>
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<td>Back ref. weight (gms.)</td>
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<table>
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<th>Weight (gms.)</th>
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</tr>
<tr>
<td>Back</td>
<td>100</td>
<td>164.5</td>
<td>374</td>
</tr>
</tbody>
</table>

*Italic s = estimated figures relative to Stiffness Figures above*

Here’s what it sounds like: showing G and D strings, “The Day before Easter”. This fiddle has an enormous G-string sound that’s easy to draw out.

The A and E strings are shown in “The Wind that Shakes the Barley”. This is with a cheap mono computer mic, a £10 Chinese bow, and Corelli Crystal strings. Beware however of amateur violinist.

Note that most of the tone of a violin comes from the start or attack of each note, so I don't find the long, legato demo stuff many demos do to be of any use at all. This fiddle has a strong B natural on the A string.

German “Bench fiddle”, circa 1800, unlabelled copy of D
A couple of years ago I asked a friend of mine for his ‘worst fiddle’: I wanted to see how good I could make it sound by matching the stiffnesses of the front and back plates. And it’s turned out rather well, though it does look rather like Humpty Dumpty after his fall!

This is a ‘cottage’ or bench ‘transitional’ fiddle probably made in Germany in the early 1800’s, as the neck was too short by 10mm, but it had the more modern neck angle. No machines whatsoever were used in its making: it is strictly hand-made, and made in a hurry! The arching is somewhat crude.

As you can see right in the picture of the fiddle as received, the front had no bassbar and worse, it had a crack along where the bassbar should be. There were no upper linings at all, no purfling (it’s inked in), and the neck extended into the body to form the upper block, in the German tradition.

I thought I might end up using this as firewood, but with the bassbar crack glued up the front had a good tap tone, so I used it as an experiment, taking the stiffness factors of front and back plates quite low, set the thicknesses right and added a bassbar to the belly (see right).

Then I took the back right out too: it got damaged, but it meant I could set the tap tones and back’s stiffness exactly where I wanted, and confirm the relationships of the tap tones of the back plate (both Modes 2 and 5) in and out of the bouts. Repaired and glued back onto the bouts, onto the sides and onto 6 new blocks it’s quite constructionally challenged.

The bouts were 4 mm thick in places, so I reduced them with a Dremel-type grinder to about 1.2 mm. You can see the back’s thickness contours on the back plate here.

The neck had to be lengthened too with new maple, and set it into the new neck block. Not pretty, but effective. I haven’t got the skills (yet?) to do a peg box graft,
and it wouldn’t be worth the time on this fiddle.

You can see the lengthened neck here on the right.

There’s a summary of the Stiffness Factors for the plates of this Hopf copy in a simple spreadsheet below, and you can download the actual spreadsheet here if you like. The formulas that do the work are in cells E7 and E8. It can be opened with OpenOffice or MS Excel.

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<tr>
<td>Weight (gms.)</td>
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<tr>
<td>Back</td>
<td>96.5</td>
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Relative to Stiffness Figures above

What does it sound like? Great! for Irish or English dance music, with a strong A and stronger E string, with a good ‘bite’ to the sound using hard bowing. The G string is quite good, but the fiddle back is too light to have real G-string grunt, confirming what Dr. Harris says about the ratio of front and back plate weights. The D string is quite acceptable, but like all my fiddles so far, the D string lets the rest of the fiddles tone down: a little weak, and slightly ‘scratchy’ as each bowed note begins.

Recently I put a proper Thomastik Dominant G string on it, and which is much more respectable now - it shows good strings can improve tone.

This fiddle is good enough to use on a recording, so it was used in a set of songs for a charity concert we put onto CD just before Christmas ’07. This a part of Jane Gridley’s ‘Horace goes to London’ with this fiddle doing both the rhythm bowing in the background and the ‘descant’ over the voice.

Here is the response of this fiddle using the bowed ‘semitone loudness’ method described on this page. It shows the 3 main
frequency responses are roughly right, but it's a little weak on ‘G’s on both the D and E strings.
Examples 2

**Good Chinese violin circa 1980, labelled ‘Liberto Planas’**

This is a full size (4/4) “modern” Chinese violin that had a crack on the front that required removing the belly to repair the crack. It also had a thick coat of modern varnish that had craquelled, with thousands of tiny varnish cracks. I sanded much the varnish with wet and dry emery paper and put on several coats of boiled linseed oil to remove the craquelling effect.

So I removed the front (easy, as it had been put on with thinned animal glue) and removed the fingerboard, which was glued on with contact adhesive. My thicknesses for the back are shown in pencil above if you click on the photo.

I thinned the back twice (with 3 years between the thinnings!) as I thought it could be improved: my sister in law borrowed it for a year, but was not that taken with it. I thought last year that there was too big a difference between the Stiffness Factors of front and back, and now it certainly has been much improved by thinning the back and improving the shape of the bassbar.

The spreadsheet showing the Stiffness Factor calculation is shown in the table below, and is available as a spreadsheet (.xls) here.
Stiffness Figures are for fully finished plates with varnish.

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<tr>
<th>Weight (gms.)</th>
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<th>Mode 5 (Hz)</th>
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<td>Back</td>
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First plate thinning: thinning back, belly as received (1996).

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<th>Mode 5 (Hz)</th>
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<tr>
<td>Back</td>
<td>113</td>
<td>181.2</td>
<td>364.3</td>
<td>1.09</td>
</tr>
</tbody>
</table>

Second plate thinning: improved bassbar & thinned back more (2009).

<table>
<thead>
<tr>
<th>Weight (gms.)</th>
<th>Mode 2 (Hz)</th>
<th>Mode 5 (Hz)</th>
<th>Stiffness Factor</th>
<th>Tone evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belly</td>
<td>71</td>
<td>156</td>
<td>335</td>
<td>0.91</td>
</tr>
<tr>
<td>Back</td>
<td>107</td>
<td>178</td>
<td>343</td>
<td>0.97</td>
</tr>
</tbody>
</table>

relative to Stiffness Figures above
I emailed Liberto Planas in Paris to see if he had made this violin, but he mailed me that it was only a repair he had done.

So this is now a good violin - it's not a Strad - but an excellent instrument for someone who will play in a band or orchestra.

**15 1/4" (387 mm.) Viola**

Ken, a violinist friend, wanted me to take custody of a rather sad old 15 1/4" viola he'd been given. It hadn't been played for 10's of years, and had telltale worm holes in the front and a bout.
Violin Plate Tuning

Taking the front off, the belly had an intrinsic bassbar (click picture above) and worm along the centre line. I fitted 5 spruce patches (see below) and increased the gluing area of the land for the top block and thinned the plate to: centre (between ffs) 3.1 to 3.3 mm, sound post area 3.5 mm, top and bottom areas to 2.8 - 2.9 mm thick. This gave a belly that was 88 gms, Mode 2 = 111 Hz, and Mode 5 = 241 Hz. This is very low indeed for Mode 5, but a good tall bassbar might just get it to a useable Stiffness Factor, so I fitted and shaped a 17 mm (max.) bassbar. A Strad Magazine article (Jo Curtin?) in 2009 suggests a tall bassbar can be ok on a viola.

So the new bassbar looks like this ........, and it is shaped according to “The Art of Violin Making” by Courtnall and Johnson instructions for a good bassbar.

The back was thinned to a thickness pattern with a good thick area between the C-bouts to keep Mode 2 up, and the corner blocks were ‘filled in’: see right. The back’s Stiffness Factor was taken really low to 0.93: as low as I dare take it, as the front is at 0.82. I sanded the ribs down to 1.2 mm with a Dremel sanding bit.

The spreadsheet showing how the Stiffness Factors are calculated can be found here, and is summarised in the table below:
<table>
<thead>
<tr>
<th>Weight (gms.)</th>
<th>Mode 2 (Hz)</th>
<th>Mode 5 (Hz)</th>
<th>Stiffness Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belly</td>
<td>96</td>
<td>133</td>
<td>281</td>
</tr>
<tr>
<td>Back</td>
<td>146</td>
<td>148</td>
<td>305</td>
</tr>
</tbody>
</table>

With the viola reassembled - belly and fingerboard put back on, a new 47 mm. bridge, 6.5 mm sound post and strings fitted the first impression was that this is a very very good instrument, and well suited to a student for chamber and orchestral playing. The tone is even between the strings - even the G string where there is often a one-note boom. It has an amazing C-string, considering this is just a 15 1/4” viola! Bowing is so easy that Irish dance jigs etc. sound really good on it, and the notes can be articulated easily.

So even with such low Stiffness Factors this is the best viola I have played outside the BVMA exhibition in London!
Ashmolean Violin

I'm lucky enough to live only 3/4 of an hour from Oxford an [http://www.platetuning.org/Messiah_Stradivarius.jpg](http://www.platetuning.org/Messiah_Stradivarius.jpg)ed the Ashmolean Museum where the single most famous violin, Stradivari's "Messie" or "Messiah" violin is kept in a glass case.

I went there to see the newly opened and improved Museum in Jan. '10 and took some pictures of some of the instruments there - see right. The musical instruments are in Room 39, second floor. The lighting is low in the cases so it's difficult to appreciate the varnishes and detail of some instruments.

With a glass case round it, photographing this violin is problematic, but here are pictures of it from [Wikipedia](http://www.platetuning.org/2622114231_5e233a96ff.jpg) and elsewhere. There is a [special page](http://www.platetuning.org/2622114231_5e233a96ff.jpg) on the 'Cello Heaven web site dedicated to this remarkable violin. [http://www.platetuning.org/As](http://www.platetuning.org/As)

Funny how the most valuable violin in the world (c. £10 M) has no *intrinsic* 'drama': it needs someone there to *explain* how special it is. The value of course is intimidating, and my brother (a philistine, I fear) said it looked just like any of the 1,000,000 copies that have been made of it.

I too enjoyed the other cases more (see right), but that's just me.

[http://www.platetuning.org/As](http://www.platetuning.org/As)

hm_n_violins_viola_1.jpg The other glass cases of instruments have a [Jacob Stainer](http://www.platetuning.org/As), another [Strad](http://www.platetuning.org/As), a [Lupot](http://www.platetuning.org/As), a [Rugeri](http://www.platetuning.org/As), and a [Wamsley](http://www.platetuning.org/As) violins, and a [Forster](http://www.platetuning.org/As)
Violin Plate Tuning

viola. [http://www.platetuning.org/Ashm_n_violins_viola_2.jpg](http://www.platetuning.org/Ashm_n_violins_viola_2.jpg)

I've labelled the instruments in the 4 photos. The camera flash gives some feeling for the arching, but you really have to see these instruments to appreciate them: go and visit Oxford and the Ashmolean if you can.

The **Jacob Stainer** has some drama in its voluptuous arching, above left and the back below, which is noticeably less bulbous than the 10’s of thousands of Stainer copies. It has a stunning back.

The **Forster** viola is a lovely colour (right), and the **Lupot** has an elaborate back. The small **Strad** has exquisite inlay and ornamentation. Click on the pictures to see them.

There's an early **Gasparo da Salo** viola in one cabinet: a vast 'viola' with only 2 corners. A wonderful wood choice on this instrument, and the bridge is set well below the ff holes.

Click on the pictures for the full photos.
Odd examples

Experimental violin: this is a lions head scrolled German (transitional *) fiddle, from the early 1800’s. Originally it had an intrinsic bassbar - that is carved from the belly wood itself - but it had such a low belly Mode 2 that I experimented by adding 5 cross-braces to bring the belly Mode 2 up, and which also improved the ring/Mode 5 resonance. As an experiment - it has been a great success: it has an outstanding tone, and is a delight to play, being easy to bow, and carries very well: much better than I would have expected with such a low Stiffness Factor.

Here is the spreadsheet that gives the Stiffness Factors of belly and back, which has the same data as shown in Table 1.1 below.

<table>
<thead>
<tr>
<th>Ssheet Lionshead violin SFs V1.0.xls</th>
<th>Table 1.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stiffness Figures are for fully finished plates with varnish</td>
<td></td>
</tr>
<tr>
<td>Back ref. weight (gms.)</td>
<td>109.3</td>
</tr>
<tr>
<td>Back ref. weight (gms.)</td>
<td>109.3</td>
</tr>
</tbody>
</table>

With 5 cross-braces added to belly. Has a 1-piece slab-cut back.

<table>
<thead>
<tr>
<th>Weight (gms.)</th>
<th>Mode 2 (Hz)</th>
<th>Mode 5 (Hz)</th>
<th>Stiffness Factor</th>
<th>Tone evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belly</td>
<td>75.5</td>
<td>160</td>
<td>328</td>
<td>0.93 V good G and D strings. Outstanding sound.</td>
</tr>
<tr>
<td>Back</td>
<td>98</td>
<td>181</td>
<td>331</td>
<td>0.90</td>
</tr>
</tbody>
</table>

The neck on this violin was too short by 12 mm, so I lengthened it by adding to the neck root, and put the neck angles right at the same time: it was skewed relative to the body. The pictures below show how the work was done: remember this is not a Strad!

The belly had a very low Mode 2: properly thickened it was at 129 Hz, and I want a minimum of 155 Hz. Worse than that though was the poor ring or Mode 5 tone: no where near strong enough. Adding 5 cross braces improved Mode 5 dramatically, and also brought Mode 2 to 160 Hz, adding about 3.5 grams of weight. The cross braces are each just under 2 mm high by 3.5 mm wide.

I think this fiddle shows that getting a high enough Mode 2 to get a ‘octave’ plates (Mode 5 = ~2 x Mode 2), can noticeably improve the G and D strings.

William (“Jack”) Fry would have some interesting things to say about the effects of these cross braces, as they will couple vibrations sideways into the belly into some critical areas, having the effect of significant local thickness increases - especially at the ends of the bassbar and just above the ff holes. His lecture (1.2 hrs.) is at the website above, and books on “A Physicist’s Quest for the Secrets of Stradivari” (with DVDs) are available here, with an article on him and his quest here. Many thanks to Jeff Minniear of Schenectady NY for the links and the article on Jack Fry.

The belly is 2.5 mm in the top and bottom areas, and nearly 3 mm between the ff’s. The back is 2.9 mm thick in the upper lung, up to 4.7 at the middle of the back, and 3.0 in the lower lung.
About me & this site

Who are we?

My name's Jonathan Rowe, and I've been playing violin as an amateur for some 53 years now, and rebuilding basket-case violins and violas for more than 10 years. Over the last 5 or 6 years the odd violin or two for rebuilding has become the 40 or more - when I discovered eBay. Not one single violin among them was a Stradivarius: the labels in them were telling fibs!

I got a general Engineering Degree from Cambridge in the early 1970's and then trained as a teacher and taught secondary Science, Maths and Physics for several years. Ever since then I've been working in the electronics industry, mostly in telecoms and in sales. I'm at home with most technology.

I retired at the beginning of 2009.

Here's a picture of me and my family. I am very proud of them!
Here I am as a Long John Silver in this year’s Pantomime, trying to look fierce.

I get hair for one week of the year: for the last 10 years it has been yellow hair, as I played the Dame. This year (2012) I tried to frighten small children as the Pantomime villain - but the best I could do is get a laugh, a blank stare, or a boo.

Here’s a picture of my daughter Suzy when she got her BSc at Bangor in July ’08. That’s me and my wife Katie being very proud of her.

So now we’ve 3 children with 3 degrees, all degrees that are better than mine. I’m not really jealous.

Last year I bought a very good, and very expensive Richard Weichold violin bow off Dave Swarbrick (Swarb) as a retirement present to myself. Here’s a picture of the Swarb himself with said bow. I’m hoping that some of his ability will pass to me by osmosis from the bow: it is working a little, as I can now play nearly half of part of the Bach Partita No. 3 ...... so there’s only another 10,000 hours of practice to go.

I couldn’t resist putting a picture of me with Swarb with the Weichold bow: ability by inference rather than evidence.

So what is the basis for claiming that setting up tap-tones in front and back plates works?
Of the 40+ low-cost violins (and violas) I have and had, so far I’ve modified about 28. These are of all sorts, and links to some of those in detail with pictures and Stiffness Factors can be found on the “Violin & viola examples” page.

The changes I have made to these fiddles verify that Dr. Harris’s method of compensating for Mode 2 and for plate weights really works. My minor additions also improve the results when the plates (the wood) is particularly non-standard, i.e. particularly dense or heavy. The method can be applied to any violin or viola (including fractional sizes) to produce a fine sounding, playable instrument with a fairly predictable tone.

I have documented some of them (see Example Violins) to show how the tone and playability was improved. It includes sound files too to give you some idea of the tone. I show what is good, and what is not so good about them. There is still a lot of work still to do.

About this site

I first created this site, www.platetuning.org in November 2007. I had no idea how many people would visit it.

In November 2010 it’s interesting to reflect on who visits the site, and where visitors come from. As far as ‘popularity’ goes, 34%, not surprisingly, are from the US of A. Then comes 12% from the UK, then 6% from Canada, and 3% now from Germany: click on the picture left.

The statistics to mid Feb. 2012 are shown below. The site gets an average of 115 visits a day, and most people stay 2 to 5 minutes, and about 25% of visitors look at 2 or more pages. Some stay for an hour!

I guess that’s pretty surprising in retrospect for such a specialist subject.

Many want the violin plans and articles, and also one ‘popular’ page is the “Books links and Articles” page: hardly surprising I suppose.
Google translation does make this (and any other site) readable in pretty much any language. The greek translation is popular, then the Italian (obviously from Cremona), and then French.

What has surprised me is how few people contact me or visit the blog. I’d hoped that I’d learn more of other people’s experiences as they tell their stories of violins they’ve known, made or modified, but I have had a few great contacts over the last 10 months.

So mail me! and tell me what you’re doing breaking open a violin!

I have some spare space here ..... so here is something totally inappropriate....

I got my son a iPhone for his birthday the other week, and recently got my Daughter a iPod for hers. I was dead chuffed when the family clubbed together and bought me an iPad for father’s day.

So I got my wife an iRon for her Birthday, and that is how the fight started...... she doesn’t realise! The iRon can be integrated into the iWash, iCook and iClean.

WHY MEN ARE NEVER DEPRESSED: Men are just ... happier people

Your last name stays put.
The garage is all yours.
Wedding plans take care of themselves.
Chocolate is just another snack.
You can never be pregnant.
Car mechanics tell you the truth.
The world is your urinal.
You don't have to stop and think of which way to turn a nut on a bolt.
Same work, more pay.
Wrinkles add character.
People never stare at your chest when you're talking to them.
New shoes don’t cut, blister, or mangle your feet.
One mood, all the time.
Phone conversations are over in 30 seconds flat.
You know stuff about tanks and engines. A five-day holiday requires only one suitcase.
You can open all your own jars.
You get extra credit for the slightest act of thoughtfulness.
Your underwear is £9.50 for a three-pack. Three pairs of shoes are more than enough. You never have strap problems in public.
You are unable to see wrinkles in your clothes.
Everything on your face stays its original colour.
The same hairstyle lasts for years, maybe decades.
You only have to shave your face and neck.
You can play with toys all your life.
One wallet and one pair of shoes -- one colour for all seasons.
You can wear shorts no matter how your legs look.
You can 'do' your nails with a pocket knife.
You have freedom of choice concerning growing a moustache. You can do
Christmas shopping for 24 relatives on 24th December in 24 minutes ......
Yes, no wonder men are happier.
Articles, Links, Books etc

Here are some very useful references and books I've found over the last few years on tap tones and violin making in general:-

**Construction of a violin** by Hans Johannsson. The *essential sizes* and dimensions of violins and violas. Wikipedia has an article on violin [construction](http://en.wikipedia.org/wiki/Violin).

**Construction of a Violin**: Joe Sedlak's website showing construction of a violin clearly in its various stages.

He also shows the plate resonances measured using Harry Wake's method with coil and 'speaker magnet: takes time, but some good results. The mode freq's are a bit low due to the weight of the energizing coil. This could have been done with a mic: and with Audacity software with a suitable holding point. Note his front plate Mode 2 is rather low.

I like Otis Tomas's website on making a violin, and he has a page on [varnishing a violin](http://otisatlas.com/violin-varnish/index.html) too.

**Acoustics for Violin Makers** by Erik Jansson. This is a key reference work on acoustics and the violin: and it's free! He used to work with Carleen M Hutchins (CAS) and really knows his stuff. He also gives suitable thicknessing patterns for both front and back plates and the key stuff on acoustics.

There are interesting papers by *John E. McLennan (of UNSW)* where he describes the process of making the violin and taking measurements of Mode 2, 5 and also Mode 1 from the start.

**David Langsather** violin maker. A remarkable man, and a fascinating website, showing how a violin is made in his workshop in full detail. He uses tuning, but uses mostly his ear, and tunes *everything*. Some useful hints too on using UV or sun light to *raise* the tone of a plate.

**Edward C. Campbell** is the Master Violin Maker at *The Chimneys Violin Shop* and has been using plate mode tuning for decades to make consistently good - in fact award winning violins - for several decades. He runs [courses and workshops](http://www.chimneys-violinshop.co.uk/online/violin-making-courses-and-workshops.htm) in Pennsylvania, USA.

**Patrick Kreit** has recently published his book *The Sound of Stradivari*. This book (€ 285) links the Mode 5 frequencies of the 2 plates to the resonant modes of the violin body step by step. It will enable any violin maker who is prepared to embrace technical measurements of resonant frequencies, wood weights and densities with his skills in violin making to make world-class sounding violins every single time. You will have to buy some very good wood to do it though!

He says that :-

- You have to know the Moisture Content (MC) of the wood you are working with all the time, and he shows how to keep the wood from acting like a sponge whenever there is moisture
about.

- He shows how to turn a block of spruce or maple into a belly or back that has the absolute minimum weight to give the 340 to 350 Hz Mode 5 of belly and back plates.
- He tells us that the sound, dynamics and clarity of a solo-grade violin, Strad or Guarnerius model, is based on the exact frequencies and the ‘deltas’ between the B1+, B1- and A1 body modes, and also on the frequencies of the A0, and the B0 and CBR (C2) modes. These are derived all from the plates’ Mode 5 frequencies, the volume of air in the violin and the area of the f-holes.

== ==> So to see if it worked for me I modified a 40-year old, very cheap Chinese ‘Skylark’ violin to put the Mode 5 frequencies of the belly and back plates where Patrick said they should be, and with their Mode 2’s an octave below. This ‘Skylark’ is now the best sounding and easiest to play violin I have among my 12+ violins, which go up to ~$2.5k each.

So I will use Patrick Kreit’s work, based on his experience of over 36 years of violin making to improve all the violins I work on.

Mode tuning for the violin maker by Carleen M. Hutchins and Duane Voskuil. Rather an advanced paper, but if you can understand it, it covers all the basics!

Martin Schleske: Master Studio for Violin making. A, or rather the leading authority on the acoustics of violins and making ‘acoustical copies’.

A Physicist in the World of Violins by William Atwood. A good basic introduction to the awkward relationship of craft and science. Peter Coombe: his workshop, and a very good article on Mandolin plate tuning.

Showing how Peter visualises the plate modes using tea leaves - well actually sawdust, but I do like the idea of reading tea leaves. I fully agree with what Peter says about getting the basics - arching, construction and so on right. Plate tuning increases the likelihood of getting a good tone from an instrument that has perhaps taken 100+ hours! Also have a look at MandoVoodoo ( !).

Here’s Dr. Nigel Harris’s article

Nelle Doak O’Neill, Luthier of Carson Valley, Nevada: showing Mode 2 pattern in a belly/top plate.

James Beatley (in Ireland) shows the patterns of both Modes 5 and 2 in a violin back [plate].

Roche Violins. Making a violin - some pictures and text, but incomplete to date.

Oberlin Acoustics. Here is access to some of the important articles on violin making from the last decade. All free.
Violin Plate Tuning

Violin Society of America (VSA) has stuff.

Sound Animation: Six Modes of a completed violin animated that can hurt your brain.

“Path through the woods” Strad Magazine article on the great ‘del Gesù’ violins. Plate thicknesses given.

“Bridging the Divide” article by Joseph Curtin (Cambridge). Offering some help on bridge cutting. Have a look at the excellent papers on Joseph Curtin’s website here, which will include 1 on installing bassbars soon.

Luthiers Library. Important violin dimensions, thicknesses and photos of Strads, Stainers, Amatis, etc. Some stuff available as a ‘guest’, but membership is $45/year to get at it all.

The Pegbox: online forum(s) that include quite a lot of people being rude about plate tuning. Have a look here at one discussion thread on Dr. Harris’s work on plate stiffnesses.

Michael Allen near Cork, Ireland shows how to use and make some special tools for a recent violin. The Safe-T-Planer ($50) looks specially good, and he uses a Dremel hand-router to cut the purfling groove. Note that ‘music-1982’ sell a ‘dremel + a fixture’ to cut the purfling groove, with a photo of it to be found here.

Mowry Strings also uses the Safe-T-Planer in a drill press to carve the external contour profiles of a mandolin back, which is very like a violin front or back. This is an alternative to using hand gauges for carving.

Have a look at David Ouvry’s ‘Construction’ page. He’s a fine violin maker near Charlbury, Oxon, UK, and he uses Chladni’s tap / plate resonance methods to improve violin tone. Instruments from £3k ($6k) upwards. Simon Stace is also a fine violin maker based near Witney.

There’s also “The Violin Site” which has a violin making page. It’s a site for violin teachers, students and performers.

Doing it by machine

And here’s how a front and back plate of violin or viola is carved or rather copied by a machine ..... a violin, and a viola, and a scroll. A plate can be copied in 1 hour to nearly finished for about $3000 for the carver-copier.

Guys who recommend Dr. Harris’s violins:

    Have a look at the www.violinist.com, The Enso Quartet plays on a matched set of instruments by London-based luthier, Nigel Harris. I really like their version of one movement from the Ravel String quartet on MySpace.

Fourier Analysis: Academic articles stuff, so try this page.
Dictionary of Violin Makers - Reference


Friends, good blokes:

Becky and Jonathan Springall mend and sell violins at Devon Strings in Exeter, Devon (UK) and their website is here. You can get some idea of their skill with this cello repair! Quentin Playfair’s contact details in Canada are here. All outstanding craftsmen craftspersons and tutors.

Article on Dr Nigel Harris from Canterbury, New Zealand.

Recommended Books:

“The Technique of Violin Making” by Harry Wake: His books are way out of date now (1970’s), but this remarkable man could write in a wonderful way about how to make your first violin: makes you want to go and do it now.

It has plans (in inches), and all the basic stuff, and is quite keen on measuring the weights of everything (especially the plates) and setting weight targets. Get it. Quite hard to find in the UK, but quite a few to be had in the USA. Here is his grandson’s website, where the books and DVDs can be bought. Harry Wake founded the SCAVM 40 years ago: some good stuff here too.


I like Bruce’s very practical approach (2000 edition) but there are a lot of compromises to keep the cost of special tools to an absolute minimum. In particular, he uses the same arching for belly and back and there’s no need to do so at all. The belly should have a ‘table’ top shape while the back should have a rounder arch. He suggests too that the garland (bouts + blocks) is detached from the form or mold before the front or back are glued on: risky. It can easily get damaged and is prone to warping too when on its own. A simple thicknessing gauge is easy to make: I’d suggest making one, and then using it to help when tuning those plates!

You may need someone with know-how to answer questions that arise as you go along, such as on grain orientation. You can get the book for about £10/$15.

“Violin - Making: as it was and is” by Ed. Heron-Allen. Published 1885-6, some 123 years ago. Can be got in various versions, hard or soft-back for £15 ($30) upwards. Fortunately GoogleBooks have scanned in all of it, and it is available here as a .pdf file etc.

This classic book on (Victorian) violin making has been in print most of that 123 years. Ed. Heron-Allen studied with one of the Georges Chanot’s, and published much of this material in ‘practical magazine’ form originally. It has fold-out plans for violins with arching, thicknessing and external and internal moulds, and lots of stuff on history. References are to books of 150 years ago! Written in somewhat verbose and florid late-19C English (with a smattering of Latin), there are some contradictions and mistakes (especially on belly tap tone frequencies), but do get a copy. It is also avail. here.
Amazingly, re-reading it the other day I found a reference to Modes 2 and 5 tap tones visualised using sand, and a rosined bow drawn across the edge of the plate to excite the modes. This is on pages 132-133. He refers to Mode 2 as the “normal tone”, and believe it or not, refers to “nodal lines” in the tech. footnote on page 133. As a reality check, this is from 123 years ago. What’s new under the sun?

“You can Make a Stradivarius” by Joseph V. Reid (1955). Dates from Noah’s time, but fun. A classic: show it to a luthier and watch him* throw toys out of his* cot. Used as a reference by some - someone I feel a kinship with too ......

Henry Strobel’s books on violin, viola and cello making are well known.

Highly recommended both for starters and the very experienced. They are at the violinman’s store too. In Violin Making: Step by Step ($30) he gives good basic info on tap tones, but frustratingly does not give the weights of plates, front and back. It would be particularly interesting to know the weight of the light (low density) Engleman Spruce he used for a belly. Some of this type of spruce can be 0.30 gm/cc rather than European spruces at around 0.45 gm/cc !

Sacconi’s book on Stradivarius’ violins called “The Secrets of Stradivari”. Get the paperback version: a must have. Try here too: about 120 Euro / £90 / $160.

“The Art of Violin Making” by Courtnall and Johnson. Get it. THE reference on everything for me, and it is less than £50 in hardback.

“The Art of Tap Tuning” by Roger H. Siminoff: $25 to $35 for the book with its DVD. Mr. Siminoff is coming from a quite different direction, but his work is practical and inspirational. He has an enormous amount of experience. He recommends setting up instrument plates in the bouts or with the plate edges held on a frame: this is much more like the conditions found in an actual instrument. And there’s a chapter on tap tones in his “Ultimate Bluegrass Construction Manual” too.

Violin Making Schools

I’m a real fan of Juliet Barker and her wonderful team at Cambridge Violin Makers, ‘The Violin Workshop’, not surprisingly in Cambridge, UK. I spend a week each summer there (when money allows) trying to make a viola from scratch. What Juliet doesn’t know about fiddle (and viola) making could be written on a postage stamp. She has published a superb book: “Violin Making a Practical Guide”, and “The Violin Explained” by James Beament is a useful handbook on the physics of violins too.

Hardangers .......

The Norwegian Hardanger fiddle, with its 8 strings is a fiddle with its own unique and haunting tone, a leftover from the days of mediaeval instruments with sympathetic strings: have a look here at some hybrids .

* Oh for more hers.
And finally bit of wittering ..........

Lastly, I suspect that deep down we all want violin tone to be the result of the knowledge, that touch of a really special secret magic that only the luthier knows, passed down by his father, and his father’s father before him, not to be the result of some new technology or formula. We want living wood fibres not carbon fibre.

In an article in the NY Times (Nov’06) Andrew C. Revkin called “String Theory: New Approaches to Instrument Design” Joseph Curtin is quoted as saying “There’s a kind of a nervousness that the mystery will go out of it, the bubble will be pricked and it’ll all just be ordinary. It’ll be technology. There’s almost a cultural sense that the violin is the last repository of mystery. The fact that we don’t understand the violin adds to its allure.”

There’s an article of interest too in The Times about ‘online amateurism’. I really do hope that I’m not contributing. At least most of the weblinks on this site are to other sites! So many “experts” with so little expertise! I quote “Professor Brabazon’s concerns echo the author Andrew Keen’s criticisms of online amateurism. In his book The Cult of the Amateur, Keen says: “To-day's media is shattering the world into a billion personalised truths, each seemingly equally valid and worthwhile.” Lord, keep us from the ordinary.

Jonathan.
Violin Plate Tuning

Chladni patterns for violin plates


Chladni patterns show the geometry of the different types of vibration of violin plates. This site has an introductory explanation of modes of vibration and a library of photographs of the Chladni patterns of the bellies and backplates of two different violins (one mass-produced and one hand-made). It also has photographs of plates with regular geometries which assist in understanding the violin modes. For some related history, see Chladni's law. For some Chladni patterns on metal plates, with sound files, see Acoustics of bell plates. To make your own Chladni patterns, try this site (http://www.animations.physics.unsw.edu.au/labs/oscillations/oscillations_lab.html)

- Modes of vibration
- Why are there nodes?
- Modes of violin plates
- Naming of modes
- How are Chladni patterns formed?
- Why are Chladni patterns useful?
- More Chladni patterns

Modes of vibration

(See also the explanations of How a violin works, Bows and strings and Strings, harmonics and standing waves.) A mode of vibration is just a way of vibration. Think what happens when you strike a xylophone bar in the middle and set it vibrating. The bar is supported at two points towards the ends. The simplest mode of vibration is this: when the middle of the bar goes up (as shown by the solid lines in the figure) the ends of the bar go down. When the middle goes down (dashed lines), the ends go up. The two points that do not move are called nodes and are marked N in the diagram. (If "modes" and "nodes" sound confusing, remember that the node has no motion.)

Here is a sketch of a simple mode of vibration of a bar. Think of it as a xylophone bar, which would be supported at the nodes, and you would excite this mode by striking it in the middle. This first mode of the bar is rather similar to one of the modes of vibration of a simple rectangular plate, one that is called the (0,2) mode (the naming convention is explained below.)

Now let's look at photographs of the Chladni patterns of (left) mode (0,2) of a uniform rectangular aluminium plate and (right) mode 2 of a violin back plate.
In these pictures, the lines are formed from sand that has collected at the nodes, but has been shaken off the moving regions. The violin back is more complicated in shape, and so the nodes also have a more complicated shape. White sand was used for the black-painted aluminium plate, and black sand for the violin back.

**Why are there nodes?**

The supports of the xylophone bar do not cause the nodes, rather they are placed at the positions which are nodes so as to facilitate this vibration. In an object which is not firmly clamped, a vibration cannot easily move the centre of mass of the object. It follows that, if some part is going up, another part is going down. In the simple motion at resonance, the point(s) that divide(s) these regions are nodes. When a violin or an isolated part is vibrating, the centre of mass doesn't move much, so once again it can be divided into parts that are going up and others that are going down. In these simple modes of vibration, the motion of different parts is either exactly in phase or exactly out of phase, and the two regions are separated by nodes. The nodes are points for a quasi one-dimensional object like a string, or lines for a quasi two-dimensional object like a plate. (There is more explanation in *Strings, harmonics and standing waves*.)

**Modes of violin plates**

The violin plate has many modes of vibration, and in general each one occurs at a different frequency. About seven of them (those with lowest frequency) are well studied and are included in this document. Of these, three or more are considered useful in the process of shaping the plates by violin makers. For several different types of plate, the mode with the lowest frequency has two node lines, both approximately straight, which intersect at about ninety degrees.

The three photographs below show the lowest frequency mode for a violin back [mode 1], a uniform rectangular plate [mode (1,1)] and a uniform circular plate [mode (2,0)].
In this mode, opposite sectors of the plate are going up together, while adjacent sectors (separated by one node) are always moving in opposite directions. In the animation, the mode of the circular plate is shown, with the vertical motion both slowed and exaggerated to make it clear.

This sketch represents (with exaggerated amplitude) an instant in the motion of the mode for the rectangular plate which is shown in the second photo above.

The following links take you to a library of Chladni patterns for the first seven modes of the belly and back plates of two violins. One is a mass-produced "Lark" model from China. The other is a hand-made German violin from about 1870. For further comparisons between Chladni patterns of simple plates and violin plates, follow this link.

Naming of modes
The modes of plates of different geometries have different systems of naming. For a rectangular plate, they are identified by two numbers \((n,m)\) where \(n\) is the number of modes running parallel to the long axis and \(m\) the number in the perpendicular direction (see the examples above). For a circular plate, they are called \((n,m)\) too, but in this case \(n\) is the number of nodes that are diameters (straight lines) and \(m\) is the number of circular nodes. For the violin plates, the modes have more complicated shapes. They are numbered in a way that, for most violins, corresponds to increasing frequency. That is why the modes in the photographs shown above have the names given in square brackets.

Mode 5 for the violin (called the ring mode) is comparable with the \((0,1)\) mode of a circular plate. For a free plate, the centre of mass does not move, so when part of the plate moves up, another part moves down. In this mode, the
central region moves in the opposite direction to the perimeter and only a ring remains motionless, as the animation shows.

The modes for the belly are complicated by the presence of the f-holes (which make the plate more flexible to bending of the short axis) and the bass bar (which makes the plate less flexible to bending of the long axis). Compare the second mode, in which the modes of the top plate could be considered to have rotated by 90 degrees. (see the photographs below) The bass bar also breaks the symmetry for most of the modes of the belly.

How are Chladni patterns formed?
There are at least three different methods.

- The plate can be made to resonate by a powerful sound wave which is tuned to the frequency of the desired mode.
- The plate can be bowed with a violin bow. This is easiest if one chooses a point that is a node for most of the modes that one doesn't want, but not for the desired node.
- The plate can be excited mechanically or electromechanically at the frequency of the desired mode.

For the photographs on this site, a small (0.2 g) magnet was fixed to the plate. An oscillating magnetic field (provided by a coil connected to an audio amplifier and a signal generator) is used to provide an oscillating force whose frequency is tuned to the resonance of the mode. Experiments using different masses showed that the mass of the magnets caused us to underestimate the frequency by about 1 Hertz.

In all cases, some finely divided material is placed on the plate. The material used in the photos on this site is fine sand. When the plate resonates, the motion becomes large over most of the surface and this causes the sand to bounce and to move about. Only at or near the node is the sand stationary. Thus the sand is either bounced off the plate or else collects at the nodes, as shown in the photographs. We used white sand from Coogee Beach to the East of the campus, and black sand from Rainbow Beach on Fraser Island. Emmanuel and Renaud are now leaving on a "research" trip to bring back supplies of diverse colours from Rainbow Beach.

Why are Chladni patterns useful?
The shaping the back and belly plates is very important to the properties of the final instrument. Chladni patterns provide feedback to the maker during the process of scraping the plate to its final shape. Symmetrical plates give symmetrical patterns; asymmetrical ones in general do not. Further, the frequencies of the modes of the pair of free plates can be empirically related to the quality of the completed violin. Many scientists have been interested in the acoustics of violins, and many violin makers have been interested in science, so a lot has been written about the acoustical properties of violins and their parts. See:

Violin Plate Tuning

- Mode Tuning for the Violin Maker by Carleen M. Hutchins and Duane Voskuil CAS Journal Vol. 2, No. 4 (Series II), Nov. 1993, pp. 5 - 9
- How do bell plates work? -- a question that is answered using Chladni patterns.

More Chladni patterns

- A library of Chladni patterns for a hand-made violin.
- A library of Chladni patterns for a mass-produced violin.
- Chladni patterns of violin plates compared with the analogous modes for simple rectangular and circular plates.
- Chladni patterns of a guitar top plate.

Some explanatory notes and related pages on this site

- John McLennan's research papers on violin acoustics.
- How to do Chladni experiments, including a high precision oscillator to download.
- How does a violin work?, and
- Some more detailed information about our work on violin acoustics.
- Some transfer functions measured on violins and violin plates.
- Bows and strings.
- Strings, harmonics and standing waves.
- What is a sound spectrum?
- What is a decibel?
- How do woodwind instruments work?
- Flute acoustics.
- Other research projects in musical acoustics at UNSW.
- The Science of Music.
- An interactive introduction to the orchestra.

Some links to related sites

- List of violin resources.
First seven modes of the top and back plates of a hand made violin


This violin was made in Germany in about 1870. The modes shown are in numerical naming order.
First seven modes of the top and back plates of a "Lark" violin

This is a cheap, mass produced violin made in China. One reason for choosing it for study is that it makes it easy and cheap for other researchers to obtain relatively similar instruments for comparison. The modes shown are in the normal order of naming.
Violin Plate Tuning

Mandolins

See also: http://www.petercoombe.com/Construction.htm

Mandolin Plate tuning

- http://www.petercoombe.com/Tuning_the_plates.htm
- http://www.petercoombe.com/Construction.htm

- http://www.machineconcepts.co.uk/mandolin/mando6.htm
- http://www.smithguitars.com/Plate_tuning.htm


Book

- Art of Tap Tuning How to Build Great Sound into Instruments Book/DVD
  Roger H. Siminoff

Mandolin String Tuning

- http://www.stevesgifts.com/Music/Tuning_Mandolin/Mandolin_Tuning_Instructions.htm

Mostly Violin


General Mandolin URL

- http://www.labraid.ca/
Tuning the plates

http://www.petercoombe.com/Tuning_the_plates.htm

Firstly the top is graduated. This involves thinning the top in little steps with a finger plane until it starts to feel right in the hands, and sounds right when tapped. Sorry, no pictures because this is a 2 handed job. This is where experience comes in. By "right" I mean from experience I think it is likely to sound good. I feel the stiffness of the top in my hands and tap it. I do not tune the top to a particular frequency because I think that is a complete waste of time. Final tuning is done by measuring the Chladni patterns. Usually what happens is I stop graduating and just measure, there is no more adjustments made to the thickness of the top. The tops end up 6-7mm thick in the centre and about 3mm on the recurve. With this top, the stiffness feels about right, but it feels a bit heavy in the hand so I am a bit suspicious it might not be the perfect top. no matter, plough on.

This is my measuring equipment. 140watt power amp on the right and digital signal generator (I built these). On the left is a high powered 8 inch speaker. The method is to sprinkle sawdust on the plate and scan the frequencies until a pattern emerges. There are 4 main modes, but mode 2 is usually not visible. For more information on Chladni plate tuning read my paper.
This is mode 1 at 164Hz. Not very distinct, but that is unusual because with unbraced tops often mode 1 and mode 2 are very close together in frequency so you don't get a strong pattern.

This is mode 3 at 287Hz

This is mode 4 at 365Hz. This is the most important mode. The positions of the modes are marked in pencil.
Next the position of the bridge posts (if it was a Gibson style of bridge) are marked on the inside of the top.

I mark the position of the X braces according to what is measured in the Chladni patterns. I try to position the X so it falls close to the position of Mode 1 and goes directly under the bridge posts. In this case mode 1 is indistinct so I have to guess.

X brace position marked.
Here is my stash of Red Spruce brace wood.

Cutting the brace wood to size in the bandsaw.

Thickness to 7mm thick on the finisher.
Violin Plate Tuning

Mark the length of the brace.

Cut to length on the bandsaw.

A compass is used to mark the shaped of the brace.
Mark the positions of the end of the brace.

Shape the brace on the finisher.

Dry fitting the brace to the top. Easier said than done because a close fit is required.
Gluing the first brace.

Marking the position of the X join.

Cut on the marks
and then chisel out the groove.

Dry fit the other brace and mark.

Cut the groove on the other brace and chisel it out.
Dry fit the second brace. Should be a snug fit. If too tight, a bit of fine cutting with a sharp blade should get it fitting snug.

Glue the second brace and wait 24hrs for the glue to dry.
Shape the braces down to nothing on the ends and scallop in front of the soundhole.

Round off the tops of the braces with a finger plane and then sand smooth.
All finished. Now measure the Chladni patterns.

Mode 1 at 192 Hz.
Mode 3 at 308 Hz. I don't like the look of this.

Mode 4 at 393Hz. Mmm I don't like the look of this either. The pattern is not very sharp and mode 4 is the most important mode and the sawdust should jump around more than what I am observing. I am now seriously considering not using this top for this mandolin. It is a special order for a local musician who is very particular about sound. No matter, let's continue on and see how the back turns out.
Graduating

and sanding the back.
Mode 1 at 160Hz. Very nice.

Mode 3 at 318Hz. Also very nice.

Mode 4 at 402Hz. Excellent. Absolutely nothing wrong with this back. Sounds good when tapped, nice and stiff and light in the hands.

Ok, now need to re-consider the top. Top is so so, and mode 4 is at 393Hz, a bit low to match the back. Big breath, this top is really not good enough for this customer, I will use it on another mandolin, probably not a special order. .... 3 months later I have another top ready. This is why the mandolins take so long to make and why I never get paid enough! However, they do sound exceptional so the extra care is worth it.

In the end, this turned out to be a really good decision. This instrument turned out to be exceptionally nice, whereas the mandolin I eventually made with the original top sounded disappointing.

Here are the Chladni patterns for the new top. This top is excellent.
Mode 1 at 169Hz.

Mode 3 at 301Hz.

Mode 4 at 400Hz, nice sharp lines, strong amplitude and very close to the back. Excellent.
Modern mandolin construction is similar to violins in that the belly and the back of the instrument is carved. This method of construction for mandolins was pioneered by Orville Gibson late in the 19th century and further developed by the Gibson Company in the early 20th century. F5 Gibson mandolins manufactured in the 1920's and signed by Loyd Loar are considered by many to be the finest mandolins ever made.

Although the construction of the modern Gibson style of mandolin is similar to a violin there are some important differences. The most obvious is the different shape. The instrument is plucked rather than bowed, which changes some of the desirable acoustic characteristics, and the other important difference is there is no soundpost. There are 8 steel strings rather than 4, so the instrument needs to be constructed strong enough to withstand the greater string pressure. Also, a mandolin is unlike a violin in that the top (or even the back) can be braced in any way you like so long as the bracing adds enough additional strength to prevent the instrument from collapsing under the pressure of the strings. In mandolins with an oval soundhole, Gibson used a single cross brace placed just behind the soundhole. In instruments with F soundholes, Gibson used two longitudinal braces which went under the feet of the bridge. After much experimentation I have settled on an X brace, although that is not necessarily the ideal bracing method for all tonal characteristics demanded by musicians.

Acoustics of violins and the violin family of instruments has been relatively well researched. Since one could described a mandolin as an 8 stringed violin (without a soundpost) that you pluck rather than bow, at least some of this research should be relevant to mandolins. I have spent a lot of time developing a method of tap tuning, but tap tuning is an imprecise method and requires a lot of experience to master. However, tap tuning does give useful information to an experienced Luthier. The absolute frequencies indicate the strength to weight ratio and the sound of the tap tone gives information about overtones and internal damping (Q factor).

If you make enough instruments, just on a probability basis you are bound to make some outstanding sounding instruments. The big difficulty is to understand why those outstanding instruments sound outstanding and to be able to repeat that process consistently. This was the driving force behind the research on violins, and is the driving force behind the results in this paper. The other driving force was to use a technique that could be useful and could be used by a Luthier with limited resources. Laser interferometry is a much more sensitive method of measuring modal patterns, but this technique is not practical for the average Luthier. What follows is my experience on free plate tuning of mandolins, and as far as I am aware, is the first time anything of this nature has been published on mandolins. Cohen and Rossing (2000 and 2003) have published pioneering papers on normal modes of vibration in assembled mandolins, and I would urge anyone interested in mandolins to read these papers. This report is based on my experience of building approximately 70 mandolins over a period of some 7 years. It is certainly not the end of the story.

At this stage it is important to point out that the techniques described in this paper are only a tool that can be used to tune the free plates of a mandolin. The tone of a mandolin depends on many factors, some of which will have a much bigger influence on tone than plate tuning. Other factors that can affect the tone of a mandolin are species of wood, arching, graduation, bridge, tailpiece, strings, varnish, neck and of course other acoustic resonances not measured by free plate tuning. Free plate tuning has a somewhat controversial history, and I certainly do not pretend that on it's own the technique will produce great sounding instruments. In fact I often advise beginners to forget about tap tuning or Chladni plate tuning and concentrate on other things such as getting the arch and gradations right, and after having built a few instrument then think about it. This is likely to have a bigger influence on the sound of the resulting instrument than concentrating on plate tuning or tap tones. Just build to the dimensions and listen and note. However, once arching and graduations have been mastered, I have found plate tuning to be very useful in helping to maintain consistency. If I make a mandolin from the same timbers and tune the plates to identical frequencies, the resulting instrument will sound near enough to identical. A musical instrument is the sum of all it’s parts so a Luthier has to consider the effects of everything that goes into the construction of the instrument. However, add up a lot of small improvements and you end up with a big improvement. It has taken a large amount of my time to get to the stage
where I can start to predict some things about tone from the way the free plates have been tuned. Wood is a highly variable material and often does not do what you want it to do, so the process can be frustrating at times.

If one scans the discussion groups on the Internet, it would appear that mandolin makers are obsessed with gradations, whereas violin makers are more concerned with arching. My experience tells me that arching is very important in mandolins as is the species of timber (see Coombe 1996, 1999, and Bourgeois 1994 for guitars), and the bridge design and material can also profoundly affect tone as well (Coombe 2003). Plate tuning is only a small part of the whole picture.

I do not intend to give a detailed description of the techniques. This information can be obtained from other sources (e.g. Hutchins 1981, 1983, Carruth 1992). Alan Carruth’s (1992) excellent paper on violins and guitars has been published in the Big Red Book of American Lutherie Volume 3 (available from the GAL) so is now readily accessible.

Methods

A mandolin free plate (i.e. carved top or back) is placed over a speaker with the concave (i.e. inner) surface facing upwards. Four blocks of foam support the plate. The plate is then sprinkled with sawdust and a sine wave applied to the speaker. Christmas glitter is the usual method of measuring Chladni patterns rather than sawdust, and it does give more precise patterns, but glitter is difficult to remove completely. I chose to use Jarrah sawdust since it doesn’t matter if there is a bit extra of sawdust in the workshop, and Jarrah is more visible on Spruce bellies. Glitter is horrible stuff because it tends to stick to everything, and the last thing I need is a piece of glitter stuck under a varnish finish.

The speaker is a 120 Watt high power 8” woofer, the amplifier a 140 Watt Hi Fi power amplifier driven by a digital sine wave generator. All electronics were purchased from Jaycar as kits and built by the author. The total investment necessary was about $900. Sound levels necessary to generate the patterns are quite high so ear protection is absolutely essential.

It is important to store the plates before measuring the Chladni patterns together. Changes in relative humidity will change the modal frequencies (Hutchins 1982, Thompson 1979), so ideally the free plates should be stored at a constant relative humidity and tested at the same humidity at the same time.

Results

As in violins and guitars, there are a large number of Chladni patterns (i.e. modes) that can be measured, and there are quite significant variations between individual plates. Also, not all modes may be measurable on a particular plate. However, there are usually 4 modes that can be measured which I have named Mode 1, 2, 3 & 4. These are illustrated in Figure 1. These 4 modes can be clearly heard as tap tones, and Figure 1 illustrates how one can listen to the tap tones. If the plate is held in position A and tapped in position B, one can hear the mode as a tap tone. Mode 2 is often difficult or impossible to measure as a Chladni pattern, and over time I have stopped trying to measure it since I believe it is unimportant to the final tone of the instrument. Modes 1 and 2 are more often than not very close together in frequency, and in this case mode 1 will dominate and mode 2 disappears in the Chladni plate measurements. Mode 4 is usually, although not always, the strongest mode as measured by how much the sawdust dances on the plate. Comparing these patterns to what has been measured in Violins and Guitars, it is clear that mandolin mode 1 corresponds to mode 2 in Violins and Guitars (the “X” mode, the first bending mode), mandolin mode 2 corresponds to mode 1 (a twisting mode) in violins and guitars, and mode 4 is the so called “ring” mode. Mandolin mode 4 is very similar to the open ring mode that has been measured in classical guitars (Carruth 1992). Mandolin modes 1 and 2 can be very close in frequency or sometimes they are reversed, with mode 1 at a higher frequency than mode 2 as is observed in violin and guitars. I have called the “X mode”, mode 1 because it is always the lowest frequency on an X braced mandolin top, and is often the lower frequency in backs. I have only ever measured a closed ring pattern on one mandolin back that I eventually decided was not suitable for a mandolin because of wild figure and excessive runout. In every other case, mode 4 was the open ring pattern, and without exception was easily measured. There are other modes that can be measured at higher frequencies, but these are almost invariably multiples of these 4 modes.
so normally I do not measure anything beyond mode 4. In any case, my speaker starts to drop off in frequency response after about 2 KHz.

Figure 1 is not typically what occurs in real wooden mandolin free plates. It is meant to be a guide to identify the modes rather than an indication of what you are likely to see when measuring carved mandolin plates. Figure 2 shows some real Chladni patterns of Coombe mandolin #95. The shape of the patterns will change depending on the physical characteristics of the wood, so are not always symmetrical as shown in the Figure 1. Wood that is perfectly quarter sawn, free of knots and perfectly straight grained, and carved perfectly symmetrical, is more likely to produce patterns similar to Figure 1. This seldom happens. For example, King Billy Pine is particularly problematic because the quality of the wood varies so much. Embedded small knots is very common, and it is difficult to get wood that is perfectly quarter sawn. However, the instruments sound great, so it is not necessary to have perfectly symmetrical Chladni patterns for good sounding instruments. Mandolin #95 is one of the best sounding oval soundhole mandolins I have made, so Fig 2 is a good guide what to aim for. Very recently I have made another mandolin from the same woods and tuned almost identical to #95 and the resulting tone of this instrument is near enough identical to #95. Fig 3 is a Blackwood back from an earlier mandolin made some years ago (#34) and I have included it because it shows all 4 modes. Nowadays I would consider it to be rather poorly tuned.

**Figure 2:** Free plate Chladni patterns measured for mandolin #95. Top is European Spruce, back is Tasmanian Myrtle.
Figure 3: Free plate Chladni patterns measured for a Blackwood back from mandolin #34
So now we have the modes, how can we use them? This is the big question, and I don’t pretend I know the complete answer, and will not go into great detail in this paper, but I can give some clues based on my experience to date. This is a continuing project, and I learn something new from every instrument, so this paper has been a long time coming and there will be others as I gather more information. I have mostly used free plate tuning to improve consistency from instrument to instrument. Once a combination has been found that sounds good then that can be repeated in another mandolin and the two instruments should sound very similar if made from the same woods. In practice I have indeed found this to be the case, with mandolins made from identical woods and tuned the same sounding near enough to identical. Unfortunately wood is not consistent, so usually the tunings are not the same, even if the wood comes from the same trees, and the resulting instruments all sound different. It is a real challenge to make instruments that sound near enough to identical, but I have achieved this on a limited number of occasions.

A good place to start is the data available from the violin research. If one could use this as a starting point, then we may have some clue how to use the mandolin modes. Firstly, it is impossible to do double octave tuning in mandolins. Modes 1 and 2 are usually quite close together and I have never observed a difference of anything like an octave. It is possible, however to have modes 1 and 4 an octave apart, and it is also possible to match modes 1 and 4 in the top and back. However, from about 70 mandolins I have only ever been able to match modes 1 and 4 in the back and top and also to have modes 1 and 4 an octave apart in 2 instruments. These were both oval hole mandolins, King Billy Pine top and Blackwood backs. I have never managed this combination with a Spruce topped instrument. Both of these 2 mandolins were truly exceptional sounding instruments, so at least this does indicate that the principles are similar in mandolins and violins. It is not all that uncommon to find F hole mandolin tops with modes 1 and 4 an octave...
apart, but it is very difficult to find a matching back. The backs are invariably tuned higher, and cannot be tuned any lower without risking structural failure. The obvious thing to do then is to tune the back and top in F hole mandolins an interval of 1/5th apart. I have tried this and the resulting instruments had such a huge sustain and ring they were difficult to play. Usually in F hole mandolins I aim to tune mode 4 in the back 4 semitones above the top since it seems to make an instrument that sounds sweeter and the sustain is controllable. This is not always possible and in these cases you just do the best you can. More recent instruments have been tuned differently with very encouraging results, but it is still too early to make any sort of generalisation.

Oval hole mandolins are much easier to match mode 4 in the top and back, because the top tunes higher than F hole tops (they are carved thicker), but once again this is not always possible and you just need to do the best you can. In my opinion, I do believe it does make a difference when these modes are matched, particularly if you can also get mode 1 close to matching as well. The resulting mandolin is louder and more responsive, and if the neck mode (see below) can also be matched to the soundbox resonance (A0), the instrument becomes extremely responsive, and with a long sustain. The soundbox of these mandolins will resonant audibly without the strings on just by moving it around in the air. A0 (sometimes called the “Helmholtz” mode, but Helmholtz resonators have rigid walls, whereas musical instrument soundboxes do not) is a function of the volume of air in the soundbox, the surface area of the soundholes, the thickness of the soundhole edges (small in mandolins), and the stiffness of the plates and ribs. Thus one can control the frequency of A0 by controlling the stiffness of the top and back so long as the other factors remain constant. More easily said than done! It is not necessary to match mode 1 if mode 4 is matched in mandolins. Mandolins certainly do not exhibit harsh gritty tone if mode 4 is matched, but mode 1 is not matched within 1.4% in frequency as occurs in violins. One can speculate that this may be due to the absence of a soundpost.

The other observation I have made is that the better sounding instruments sometimes have a weaker mode 3. In some cases I cannot measure mode 3 at all. An X brace will tend to raise the frequency of mode 3 and lower the amplitude because it crosses the node line of mode 3. It may even be possible in rare cases to raise mode 3 enough so that it is the same frequency of mode 4. Tone bar bracing will also do this, but to a lesser extent.

How else can we utilize Chladni patterns? Since mode 4 is probably the most important, as indicated from violin and guitar research, I try to maximise the amplitude of mode 4, and get the node lines as sharp as possible. The sawdust should dance the most where the bridge position is. Also, mandolins can be braced however you like. There is no bass bar as in violins and no hard and fast rule on bracing. Usually the top of F hole mandolins is braced with parallel tone bar bracing or an X brace and the back is unbraced, although there is no reason why the back cannot be braced. In fact I have braced the back in some of my mandolins to raise mode 1 without raising mode 4 too much and the resulting instruments sound fine. Indeed some sound exceptionally fine. Perhaps the biggest plus I have got from the huge amount of time I have invested in measuring Chladni patterns, was to change the way I was bracing the tops of my F hole mandolins. The logic of my decision to change the way they were braced was to position the braces in order to interfere with modes 1 and 4 as least as possible. The first mandolin braced in this manner sounded so much better than anything else I had made previously that I continue to use the modified X brace.

“Neck” mode

If a completed mandolin is held at about the nut position and tapped at about the 12th fret position, one can hear a resonant mode. The nodes are at about the nut position and in front of the bridge. It is very likely this is the equivalent to the B0 mode in violins (Hutchins 1985). If the frequency of this “neck mode” is matched to A0, the resultant instrument is very likely to have a big sustain. This may or may not be a good thing, depending on how the Luther wants the instrument to sound. In some cases the sustain is so huge, it is difficult for the player to control, so may not be desirable particularly in F soundhole mandolins. In oval hole mandolins, the instrument becomes more “vibrant” (to quote Hutchins 1992) if these two frequencies are matched. Just moving one of these mandolins around in the air without the strings on will cause the soundbox to resonate audibly. Unfortunately, there is very little that can be done to adjust this frequency, so it is to a large amount a matter of luck where this resonant frequency ends up. Shaving wood off the neck will lower it, but there is a definite limit to how much wood can be taken off before the neck starts to feel uncomfortable or becomes a structural risk. This phenomenon has been well documented in violins by Hutchins (1985, 1990), and Bissinger and Hutchins (1985).
Violin Plate Tuning

The main conclusion I have come to is that mandolins are similar but different from violins. They are also similar, but different from guitars. The assembled mandolin is more like a guitar (Cohen and Rossing 2000 and 2003). This of course comes as no surprise. The important thing to know is how are they different and how are they similar to violins or guitars, and to be able to use this information in the construction of the instrument. Listening to tap tones is basically the same as measuring Chladni patterns, except Chladni patterns are more precise and will give you more information in the spatial and frequency domain. However, it is important to still listen to tap tones.

The important question to be answered is, are Chladni plate modal patterns useful? Once the ribs are glued to the plate, this fundamentally changes the stiffness of the plates and the model patterns will change. This will change again once the plates are incorporated into a finished instrument. The leap from free plate modes to a fully assembled instrument is a great leap. Wilkins (2001) has attempted to follow free plate modes from the free plates to an assembled violin, and Atwood (1996) has measured modes in free plates and plates clamped to a heavy frame around the edges. Unfortunately the mass of the wooden frame does affect the results so this is probably not a good method, as shown by Wilkins (2001) who glued the plates to ribs. The main conclusion made by Wilkins is that it is possible to follow free plate modes after the ribs are glued, but the ribs do affect the top and back modes differently so that the relative relationships change. Also, it is possible to find some links between free plate frequencies and those in finished violins, but the relationship is not simple.

It has been argued by many that because assembly of the instrument changes the modal frequencies, that free plate tuning is not a very useful technique at all and is a waste of time. In fact Schleske (2000) found no correlation between the free plate eigenfrequencies and the corpus eigenfrequencies and questioned the meaning of free plate tuning. Unfortunately, there was no evaluation of the sound of the instrument being played in this study. Perhaps (or perhaps not) the conclusions may have been different if he had evaluated tonal qualities. I would be astonished if thinning the plates had absolutely no affect on the sound of the instrument as implied by this paper.

I would argue that so long as the design of the instrument is consistent - i.e. same shape, same internal volume, same soundhole, same ribs and neck, same glue, same varnish, bridge etc, then the changes should also be consistent, and it does not matter that things do change when the instrument is assembled. Once a relationship is found that works, then so long as everything else is consistent then it should give similar results in the next instrument that has the same relationships in the free plates. The method is empirical, and basically is what most Luthiers do anyway but by using different techniques. Everyone tries to repeat that fluke instrument that sounds fantastic, but usually one does not know why it sounds fantastic. By measuring as many things as you can as each instrument is built, there is a much better chance of being able to repeat that fantastic sounding instrument. I have done it, but it is not necessarily because of something I discovered using free plate tuning! One example is with arching. I now make my mandolins with a higher arch because they seem to sound better with the arch higher than in my earlier instruments. This has the effect of raising the frequencies of the free plates, which may or may not be a good thing. Now I know I can consistently predict the likely frequency of A0 in my mandolins from the Chladni plate modes I measure in the free plates. The frequency of A0 does have a very significant influence on the tone of a mandolin (this I will attempt to address in another paper), so I can to some extent predict the likely effects the measured modal frequencies will have on the tone of the instrument and can aim for something I know will produce the required effect. Unfortunately it is not all that easy, because wood is such a variable material, so in practice one aims to stay in a certain envelope and to make adjustments in other areas (e.g. bracing) to compensate.

It is certainly possible to make very fine sounding instruments without resorting to free plate tuning, whether that be via tap tuning, Chladni plate tuning, laser interferometry or FFT. It is still very important to use the usual techniques of flexing the plates in one’s hand, looking and feeling the arch and thicknesses, listening and tapping etc, even if you are doing some measurements, but measurements may just give you that little bit of additional information that gives you that idea that results in a better sounding instrument. It has certainly worked for me. Instruments that come back for frets occasionally have proven that significant progress has been made. Now whether that is directly due to free plate tuning is a debatable point, but I think it has certainly helped. It unquestionably does help in maintaining better consistency.

As with many things in musical instrument making, there is so much to do and learn and so little time. Many makers who have tried measuring free plate modes give up either because they don’t understand what is happening, or believe that the technique is not useful, or it takes up too much time. As with many difficult techniques it is necessary...
to spend sufficient time on it before the benefits are realised. As already pointed out by Carruth (1992), it takes time and experience to really learn these techniques, and the “typical” plate tuning problem is like the typical piece of wood: a statistical entity rarely encountered in the real world. This is how Fig 1 must be interpreted - a statistical entity rarely encountered in real pieces of wood.

This paper has been a long time coming and I apologise to the editor of the journal for taking so long to prepare it. Hopefully more will follow as I get more data. Research on plate tuning and other physical characteristics of musical instruments is extremely time consuming, and there is always more information that one would like to get. The ideal situation would be to make a large number of musical instruments with randomised physical characteristics and correlate these with the sound qualities of the finished instruments. This is completely impractical, and the sample of instruments is necessarily strongly biased because no one wants to waste their time making dud musical instruments just to prove a point. Biased samples are not well suited to scientific evaluation. Added to this is the difficulty of evaluating musical instruments consistently and objectively over a long period of time. Ideally one should have all the instruments in the same room, setup with the same strings etc, at the same time for subjective evaluation. But once again, this is completely impractical. Any form of objective measurement is also not practical because we don’t know what to measure in mandolins and don’t know what to look for as “good” characteristics because the research has not been done. Many experienced music instrument makers have already worked out how to make a fine sounding instrument through trial and error, learning from other instrument maker’s experience, and application of educated guesswork (i.e. Intuition). Dan Bourgeois (2000), I believe, puts it very nicely - Voicing does not really control the tonality of a guitar. The range that you have (with voicing) is that it can either sound well balanced and have power or not. To manipulate the tone of the guitar, I would work with design elements. Change the woods. Change the bracing. Those are the big factors. Bourgeois (1994 and 2000) considers that voicing (i.e. Tap tuning) allows you to optimise the design. In my experience this principle is exactly the same in mandolins. The design elements are a little different because the dimensions are not as variable as a guitar, and graduations and arching are not relevant to flat top guitars, but the principles are exactly the same.

**Bibliography**


Bourgeois, D (2000), Still voicing, still dreaming. American Lutherie #61


Violin Plate Tuning


Mandolin Comparisons

http://www.petercoombe.com/jaamim8.html

Introduction

In a previous paper published in this journal (Coombe 2005), I outlined a method of using Chladni patterns to tune mandolin free plates. In that paper I indicated that the method was most useful for maintaining consistency from instrument to instrument. However, there is very little hard evidence to indicate that the method is actually useful in violins, let alone mandolins where much less research has been done. For example, Atwood (1996) and Wilkins (2001) both failed to demonstrate any strong correlation between modes of vibration of free plates in violins, and the modes in a completed instrument. There is a big gap between measuring free plate modes and the tone of the completed instrument. Once the instrument is assembled, everything changes. The topic of plate tuning is very controversial among violin makers, and often discussions on Internet forums between the two protagonists end up in a slanging match. Fortunately that is not usually the case amongst mandolin makers, and the topic often comes up on Internet discussion forums. In this paper I have tried to examine this question and to test the hypotheses that Chladni plate tuning (or tap tuning) is somehow correlated to the tone of the completed instrument, and is therefore of some use to Luthiers. It does not matter if the modes change, and it is not necessary to understand what happens as an instrument is assembled, if there is a significant correlation.

Testing this hypothesis is very difficult because of the difficulty of getting a large enough statistical sample of instruments together at the same time. Ideally the instruments would need to be identical except for the plate tuning so they would need to be made from the same species of wood, be made by the same maker, and also would need to be made at about the same time, since it is well known that the sound of a mandolin will change with age. Impossible to do unless one has access to a music instrument factory or a sizeable research grant! However, it is a much easier to disprove the hypothesis. If it is possible to make two identical mandolins that have the free plates tuned identical, and the resulting sound of the completed instruments are completely different, then the hypothesis is likely to be false. Conversely, if identical mandolins made with very different free plate tuning end up sounding identical or very similar, the hypothesis is once again likely to be false, although this is not as convincing. This type of experiment is fine in principle, but very difficult to do in practice. Wood is so highly variable in its physical properties, that rarely is it possible to tune free plates exactly the same. Even if the wood comes from identical trees, it is possible that the resulting free plates will tune differently, but at least if the wood does come from the same tree you are in with a chance. Unfortunately it is not always possible to get wood from the same tree. Other factors that are difficult to ensure are exactly the same (e.g. arching, neck stiffness) can also influence the result. Thus probably the best we can do are instruments that are close to identical, but not quite identical. In addition to this, is the very real practical problem of customers wanting their instruments delivered on time, and made according to their individual preferences. The end result is mostly a matter of pot luck (to have two instruments with similar free plate tuning at the same time) so direct comparisons can be made. One method of getting around the timing problem is to have a reference instrument against which the instruments in question are evaluated. My experience has been that mandolins with the free plates tuned similarly do in fact sound similar, but this has only been an empirical observation which required a more rigorous test, hence this paper.

Method

3 pairs of mandolins were made over a period of about 18 months (amongst others ordered by customers). Pair (1) were European Spruce/Myrtle (#95 and #97) oval hole mandolins with the top and back made from wood from the same trees. Pair (2) were F soundhole mandolins with the top made from Red Spruce (#101 and #102) from the same tree, but the back was Tasmanian Myrtle from a different tree. Pair (3) were oval hole mandolins made from King Billy Pine and Blackwood (Acacia melanoxylon) from different trees (#103 and #105). Pairs (1) and (2) were tuned as close as I could practically manage, but pair (3) were tuned completely differently. I was able to keep pairs (2) and (3) together for some time, so I could compare the tonal qualities in some detail, but pair (1) were subject to customer delivery demands so I was not able to make direct comparisons. However, I was able to compare both of the mandolins from pair (1) to my reference oval hole mandolin (#87) for some days so had a good impression of the
characteristics of both instruments as compared to the reference. The reference mandolin was similar (but slightly different) sounding and was made from the same woods. There was only a short time lag of a few days from when one mandolin was sent to the customer, and the other mandolin was strung up, so I am reasonably confident of the appraisal. My appraisals were checked by my partner, and where possible by another instrument maker. In every case they agreed with my appraisal.

Chladni plate tuning frequencies of modes 1, 3 and 4 were recorded over a period of about 7 years for all the mandolins I have made. Comments on the tone of each mandolin were also recorded. In order to maintain consistency as much as possible over a period of time, each new mandolin was compared to a reference instrument.

**Results**

The free plate modes of a mandolin are shown in Figure 1 (from Coombe 2005). I normally do not try to measure mode 2, so that is missing. Mode 2 is usually fairly close to mode 1 and although mode 1 and mode 2 can be clearly heard as two distinctive tap tones, mode 1 dominates and for mode 2 it is usually difficult or impossible to get a Chladni pattern to form (see also Coombe 2005).

The frequencies of the free plate modes of the pairs of mandolins (top modes are after the braces had been glued) are shown in table 1. The percentages are the differences expressed as a percentage of the lower value. Tuning of pair (1) is very close and the sound of pair (1) were as far as I could determine identical. Both had exactly the same tonal characteristics when compared to the reference instrument. Pair (2) are F hole mandolins, unlike all the other
mandolins in this paper which have an oval sound hole. I was able to play this pair for extended periods of time and my partner was also able to listen to the two mandolins one after the other. My impression as a player was that they sounded very similar, but not quite identical, with #102 having a slightly better sounding E string and being a bit more responsive. However, this difference was so small that I was able to repeatedly fool my partner which instrument I was playing when she was not able to see the instruments. I also managed to fool myself during one session in a darkened room. After swapping from instrument to instrument for a while I needed to turn the light on to work out which mandolin I was actually playing. Conclusion was that this pair of mandolins had tonal characteristics that were very close indeed, close enough to fool most people. Note that this pair were not as closely matched as pair (1). The tops were closely matched, but mode 4 of the back of #102 was 28Hz higher than #101 (6.7% difference).

Table 1

<table>
<thead>
<tr>
<th>Top</th>
<th>Mandolin #</th>
<th>Mode 1</th>
<th>Mode 3</th>
<th>Mode 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td>95</td>
<td>163 0%</td>
<td>321 1.9%</td>
<td>419 0.2%</td>
</tr>
<tr>
<td></td>
<td>97</td>
<td>163</td>
<td>315</td>
<td>420</td>
</tr>
<tr>
<td>Pair 2</td>
<td>101</td>
<td>175 0.6%</td>
<td>367 1.09%</td>
<td>420</td>
</tr>
<tr>
<td></td>
<td>102</td>
<td>176</td>
<td>360</td>
<td></td>
</tr>
<tr>
<td>Pair 3</td>
<td>103</td>
<td>148 11.4%</td>
<td>304 0.7%</td>
<td>400 22.5%</td>
</tr>
<tr>
<td></td>
<td>105</td>
<td>165</td>
<td>308</td>
<td>490</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Back</th>
<th>Mandolin #</th>
<th>Mode 1</th>
<th>Mode 3</th>
<th>Mode 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td>95</td>
<td>164 0%</td>
<td>332 2.1%</td>
<td>420 0%</td>
</tr>
<tr>
<td></td>
<td>97</td>
<td>164</td>
<td>339</td>
<td>420</td>
</tr>
<tr>
<td>Pair 2</td>
<td>101</td>
<td>174 1.7%</td>
<td>362 1.9%</td>
<td>445 6.7%</td>
</tr>
<tr>
<td></td>
<td>102</td>
<td>177</td>
<td>369</td>
<td>417</td>
</tr>
<tr>
<td>Pair 3</td>
<td>103</td>
<td>145 11.4%</td>
<td>306 17.6%</td>
<td>401 11%</td>
</tr>
<tr>
<td></td>
<td>105</td>
<td>161</td>
<td>360</td>
<td>445</td>
</tr>
</tbody>
</table>

I was able to keep pair (3) long enough for extended playing sessions. This was not really necessary since the sound of these two mandolins was so completely different it was obvious to everyone which one was being played. I was not able to fool my partner when she could not see which mandolin I was playing, nor was I able to fool myself, nor the other instrument maker. #103 sounded to me to be by far the better sounding instrument, and everyone who heard the two mandolins agreed with me. #103 had a much cleaner tone and was more evenly balanced across the strings whereas #105 was louder and had a strong booming G string.

Having evaluated these pairs of mandolins, it was thought that maybe my order book should be examined for more evidence. The examination was confined to mandolins with oval sound hole, top European Spruce, back Tasmanian Myrtle and my so called Goldfinch model (oval sound hole King Billy Pine top, Blackwood back) since these are in the greatest numbers. There are a few other oval hole mandolins made from different timbers, but the numbers are too small (1 or 2) to make any meaningful conclusions. The timbers do have a significant effect of the sound of the instruments (Coombe 1996 and 1999), maybe a bigger effect than tuning the free plates. F soundhole mandolins were not examined because of small numbers made from the same timbers, and also because the situation appears to be more complicated because it is seldom possible to match the top and back tunings. Mandolins made earlier than #75 were not examined because this was the first mandolin made from European Spruce sourced from Switzerland. All the Spruce topped mandolins have been made with this Spruce.

A table of the free plate modes and the comments about the tone of the resulting mandolins is shown in Table 2. The comments have been taken direct from my order book with just a few minor re-wordings. Note that #75 was used as a
reference for mandolins from #75-#86, and #87 was used as the reference after that. There was a change in the bridge configuration (see Coombe 2003), and the neck wood was changed to Queensland Maple on and after #87 (not on the Goldfinch mandolins which all have Blackwood necks). #80 and #89 have been excluded because of differing bridge configurations, and the bridge does affect the sound significantly. The percentage values are the difference between the top and back modes expressed as a percentage of the lower value.

Most of the mandolins were excellent instruments, but one of each wood combination were somewhat disappointing (#104 and #105, highlighted in bold in table 2). Note that the tunings are not random. Each instrument was deliberately tuned so the top and back mode 4 was as close as physically possible because experience told me that this produced the best sounding instruments.

What is consistently different about #104 and #105? Both do not have mode 4 matched between the top and the back. The difference between the top and back modes are 12% and 14.1% which is much higher than any of the other mandolins. The next closest is 4.7% in mandolin #78 which was a very successful instrument. #104 and #105 were different because of the physical properties of the wood did not enable me to tune the top and back mode 4 as close as I would have liked. This is something I am not likely to repeat because I would like my instruments to sound consistently excellent. Both mandolins also do not have mode 3 matched either, although the difference for mode 3 for #104 is not unusual so it is probably not significant. Other tests have shown that mode 3 becomes smaller or disappears, and mode 4 becomes by far the strongest mode after the ribs are glued (Coombe, in preparation) so mode 3 is most likely not as significant as mode 4. From this data, the probability of the two poorer sounding mandolins matching up with the larger differences in mode 4 purely by chance is less than 1% so is statistically significant.

Table 2

<table>
<thead>
<tr>
<th>Mandolin #</th>
<th>Mode 1</th>
<th>Mode 3</th>
<th>Mode 4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>#75 Top</td>
<td>162</td>
<td>300</td>
<td>381</td>
<td>Beautiful, even, sweet and clear sounding instrument. More lively and a bit brighter and louder than #74. Love it and will keep as a reference. <strong>REFERENCE</strong></td>
</tr>
<tr>
<td>Back</td>
<td>155</td>
<td>279</td>
<td>381</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>4.5%</td>
<td>7.5%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Back</td>
<td>144</td>
<td>289</td>
<td>365</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>4.7%</td>
<td>0.8%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>#78 Top</td>
<td>173</td>
<td>309</td>
<td>401</td>
<td>Beautiful rich, smooth tone. Probably best so far. Treble has great clarity, sweetness and smoothness.</td>
</tr>
<tr>
<td>Back</td>
<td>164</td>
<td>309</td>
<td>383</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>5.5%</td>
<td>0%</td>
<td>4.7%</td>
<td></td>
</tr>
<tr>
<td>#81 Top</td>
<td>172</td>
<td>296</td>
<td>392</td>
<td>Beautiful sweet sounding mandolin. Very responsive. Very nice sounding E string. Mary Shannon’s mandolin, it suits her well.</td>
</tr>
<tr>
<td>Back</td>
<td>167</td>
<td>320</td>
<td>392</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>3%</td>
<td>8.1%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>#82 Top</td>
<td>159</td>
<td>299</td>
<td>377</td>
<td>Similar to #81, but not quite as sweet sounding. Has been mistaken for a Loar in a blind listening test recording (Ha!).</td>
</tr>
<tr>
<td>Back</td>
<td>137</td>
<td>293</td>
<td>385</td>
<td></td>
</tr>
</tbody>
</table>
Difference 16% 2% 2.1% #86 Top 167 298 390 Very sweet. Very good treble. Similar to #75 but with a bit of boom on the G string. Nice.
Back 153 310 390
Difference 9.2% 4% 0% #87 Top 173 320 410 Very nice, probably best Spruce top so far. Unusually even sound across strings and up neck. Very good clarity. REFERENCE
Back 170 315 411
Difference 1.8% 1.6% 0.2% #95 Top 163 321 419 Superb mandolin. Best oval hole to date. Even balance, very sweet and clear treble. Unusually rich tone, very loud.
Back 164 332 420
Difference 0.6% 3.4% 0.2% #97 Top 163 315 420 Loud, responsive, evenly balanced, smooth. Very similar or identical to #95
Back 164 339 420
Difference 0.6 7.6% 0% #108 Top 169 301 400 Very nice, one of the best. Nice well balanced tone.
Back 160 318 402
Difference 5.6% 5.7% 0.5% #111 Top 155 320 420 Nice mandolin, I like it. Not the loudest, but very even tone, very well balanced. In comparison to #87 is similar but marginally a better instrument. Better balance, slightly finer tone. Much better than #104
Back 167 340 422
Difference 6.3% 0.5% #104 Top 192 308 393 Very clear treble, sweet and excellent clarity. Bass a bit thin. Lacking character. Big sustain. Somewhat disappointing.
Back 167 333 440
Difference 15% 8.1% 12% #117 Top 161 276 391 Remarkably similar to #87, just a bit more responsive and louder. Nicely evenly balanced, almost identical to #87. A bit more ring and sustain compared to #87. One of my favourites, I like it a lot.
Back 149 303 391
Difference 8.1% 9.8% 0% #111 Top 155 320 420

King Billy Pine/Blackwood (Goldfinch model)

<table>
<thead>
<tr>
<th>Mandolin #</th>
<th>Mode 1</th>
<th>Mode 3</th>
<th>Mode 4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>#88 Top</td>
<td>155</td>
<td>339</td>
<td>419</td>
<td>Very lively, clear and sweet. Loud and sharp. Good projection.</td>
</tr>
<tr>
<td>Back</td>
<td>149</td>
<td>325</td>
<td>426</td>
<td></td>
</tr>
</tbody>
</table>
Most of the mandolins I make are made from Australian native timbers, not the traditional timbers of Spruce and Myrtle. The question now arises as to whether this method of tuning is useful for traditional timbers. Table 3 shows the results from three Maple backed mandolins, two of which were tuned to match Mode 4 in the top and back. These two instruments I regard as some of the best sounding Spruce topped mandolins I have made, particularly #106. #106 was made from European Spruce and European Maple, and #115 was made from Engelmann Spruce and Birdseye Maple (i.e. Rock Maple). Also included is #92 which is made from Engelmann Spruce and quilted Big Leaf Maple. I was so disappointed in the sound of this mandolin that I have not used Big Leaf Maple again, although now I suspect the problem was the low tuning of the back relative to the top.
Table 3

<table>
<thead>
<tr>
<th>Mandolin #</th>
<th>Mode 1</th>
<th>Mode 3</th>
<th>Mode 4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>#106 Top</td>
<td>190</td>
<td>320</td>
<td>426</td>
<td>Bright, very responsive and resonant. Excellent clarity and clean sound. Different from Myrtle. I think it will be a superb instrument once broken in.</td>
</tr>
<tr>
<td>Back</td>
<td>159</td>
<td>343</td>
<td>427</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>19.5%</td>
<td>7.2%</td>
<td>0.2%</td>
<td></td>
</tr>
<tr>
<td>#115 Top</td>
<td>176</td>
<td>295</td>
<td>383</td>
<td>Sounded roughly equivalent to #87 at first, but after a month or so sounded much better. Really nice mandolin, good volume, excellent clarity, well balanced, lovely sweet and clear treble, warm sounding bass. Excellent instrument. I did not like it quite as much as #112 Goldfinch.</td>
</tr>
<tr>
<td>Back</td>
<td>160</td>
<td>289</td>
<td>385</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>10%</td>
<td>2.1%</td>
<td>0.5%</td>
<td></td>
</tr>
<tr>
<td>#92 Top</td>
<td>170</td>
<td>301</td>
<td>416</td>
<td>Sweet and delicate sounding. Not as much bite as #87. Light and responsive. Relatively quiet. Not up to my usual standard and definitely not as nice as #87.</td>
</tr>
<tr>
<td>Back</td>
<td>156</td>
<td>303</td>
<td>339</td>
<td></td>
</tr>
</tbody>
</table>

One particular mandolin that was excluded from the above tables because of a non standard bridge configuration is particularly interesting. This mandolin was disappointing at first, with an overly mellow weak sound and with a bass that was overpowering. However, the problem was solved by replacing the ebony bridge saddle with a Blackwood saddle. Blackwood saddles give a much brighter and sweet sound (Coombe 2003). Examining the plate tunings, one notes that this mandolin did not have mode 4 in the top and back closely matching.

Table 4

<table>
<thead>
<tr>
<th>Mandolin #</th>
<th>Mode 1</th>
<th>Mode 3</th>
<th>Mode 4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>#89 Top</td>
<td>165</td>
<td>308</td>
<td>439</td>
<td>Overly strong bass with Ebony saddle. With Blackwood saddle well balanced, sweet and clear.</td>
</tr>
<tr>
<td>Back</td>
<td>171</td>
<td>370</td>
<td>339</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>3.6%</td>
<td>20.1%</td>
<td>29.5%</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2 shows the data presented in tables 2 – 4 pooled into graphical form. Note that on the X axis R indicates the reference mandolins, and * indicates the relative poorer sounding mandolins. It is clear from these graphs that there is no correlation with mode 1 or mode 3 and sound, but the correlation between the differences with Mode 4 and sound is clear. It does not matter if mode 4 of the top is tuned higher or lower than the back, what matters is the difference. This supports the contention of many mandolin makers that it does not matter what absolute frequency the plates are tuned to. What does matter is the relative relationship of mode 4 between the top and the back. This is a little different from violins where the recommendation is to match mode 2 (equivalent to mandolin mode 1) in the top and back, and to keep mode 5 (equivalent to mandolin mode 4) within a tone (Hutchins 1983). In mandolins, it does not appear to matter how mode 1 is tuned.
Figure 2
**Discussion and conclusion**

Examining table 1, it can be seen that the free plate tuning of pair (1) is near identical. Tuning of pair (2) were identical for the Red Spruce tops, but slightly different for the backs. Free plate tuning of pair (3) was completely different. This is in close agreement with the tonal qualities of the mandolins, with pair (1) sounding identical, pair (2) sounding very close to identical, and pair (3) sounding completely different.

The results presented in Table 2, and also the evidence from the mandolin pairs does support the hypothesis that the relative tuning of the top and back free plates, particularly that of mode 4, does influence the tone of the completed instrument. Overall, taking into account table 4 and the 3 Maple mandolins, the evidence is convincing. Note that these are all oval soundhole mandolins, so this conclusion does not necessarily apply to F soundhole mandolins, but it does appear to be relevant for mandolins made from the traditional Spruce and Maple combination, although due to low numbers and differing woods is not as convincing. It appears that so long as the frequency of mode 4 of the top is within 4-5% of the back then the resultant finished instrument is a fine sounding mandolin. My experience with mandolins also gives some indication that it may be relevant to mandolins as well since the one any only mandola I have made that had mode 4 of the top and back plates closely matched is easily the finest sounding mandola I have made to date.

It is interesting to note that one commonly repeated comment about the "well tuned" mandolins is that the sound was "well balanced" – i.e. even tone across the strings and up the neck without any obvious changes in volume or tonal qualities. The disappointing instruments were all unbalanced. Thus at least the technique does greatly increase the probably of a well balanced even sounding instrument even if it does nothing else.

Mandolin #89 is particularly interesting because it illustrates the limitations of the technique. It was certainly consistent in that the plates were not matched for mode 4 and the resulting sound was disappointing. The fact that I was able correct the deficiencies in the sound when changing the wood in the saddle indicates that the results presented here really can only be considered relevant to the mandolins I make, in the standard configurations I use. If I had used Blackwood saddles in all my mandolins, then the conclusions of the paper probably would have been quite different. The optimum free plate tuning probably would have been similar to mandolin #89, and all the other mandolins would have been disappointing because they sounded too trebly and bright. Extending this to mandolins made by other makers where the bridge configuration will be different and other configurations will also be different, if these makers tune the free plates the same as I do, then they may be quite disappointed with the results because the tunings are not optimal for the way they make their instruments. This could explain why free plate tuning is so controversial. A particular tuning may work for one Luther, but not another Luthier because the instruments are not made the same, and will have quite a different sound. Thus I would caution readers of this paper that they may not get the same results as I have with the mandolins they construct themselves. Blindly copying the tunings and expecting wonderful results would be unwise, because that probably won't happen.

The small piece of evidence presented in this paper represents a huge amount of effort on my part. Unfortunately there is precious little evidence from other makers. The only evidence I have seen has been one other report on an Internet forum of a pair of mandolins made by another maker that were tuned identically and ended up sounding identical as a finished instrument (unpublished). The evidence available to date certainly does not disprove the hypothesis, which is an important point to make. As for predicting the tone of a completed instrument, I think the best we can hope for is if you can repeat the free plate tuning in two mandolins of identical construction, the resulting tone is very likely to be identical or at least very similar – i.e. consistent, which is what I was arguing in my previous paper (Coombe 2005). In addition, if the free plates are tuned such that mode 4 in the top and back are very close in frequency, then the completed instrument is likely to have a pleasing and well balanced tone. This is a significant conclusion from the data presented in this paper. It is something that can be applied in practice by any Luthier who makes a mandolin.

However, the sound of a completed mandolin is dependent on a host of other factors, not just plate tuning, so these need to be constant if the instruments are to sound identical or close to identical. Note that a pleasing tone has been achieved in my mandolins, other makers may change some other factor that alters the tone so it is no longer pleasing when mode 4 is matched. Matching mode 4 does not necessarily guarantee a "well balanced" and pleasing tone, but if a mandolin is constructed similarly, there is a high probability the completed instrument will sound good. The results presented here certainly merit further investigation by other makers.
Violin Plate Tuning

Bibliography


Coombe P.E., Use of Australian Native Timbers in Mandolins. Journal of the Australian Association of Musical Instrument Makers Inc., Volume 15, Number 4, p.6-11, December 1996, ISSN: 0815-9793


Mandolin Plate tuning using Chladni patterns
http://www.machineconcepts.co.uk/mandolin/mando6.htm

Equipment used

There are 5 things that you will need to enable you to use this method.
1) A sine wave generator that allows the frequency to be changed smoothly.
2) An amplifier to boost the signal from the sinewave generator
3) A loudspeaker mounted under a flat surface.
4) Some small, soft foam blocks to support the plate.
5) A couple of tubes of Christmas Glitter. (this is in the form of tiny, shiny, flat plates and is used as a decoration on Christmas cards and the like by sprinkling it onto a glue shape on a blank card). Sand, salt or sugar will also work but not so well.

I have a 6" loudspeaker mounted under my workbench as shown. It is quite a fragile item so a cover for it should be made for when it is not being used. The 4 foam blocks are used to mount the plate over the speaker and should be set to the minimum height that doesn't allow the plate to touch the benchtop (even when vibrating) I try to set this to about 3/32" max.

The Sine wave generator and the amplifier are contained in the rather crude package shown here and work well despite the appearance. The big dial (from an old radio) sweeps the frequency of sine wave. The top dial (marked "signal") sets the amplitude of the signal and can be left set. The dial marked "amp" controls the volume at the loudspeaker and should be set to give a good level of vibration to the plate.

The knob at the bottom sets the frequency to either high, medium or low range.

In order to measure the actual frequency I use my Boss electronic tuner (the same one I use when tuning up to play) This is sufficiently accurate for this purpose and is a cheap way of getting the required accuracy. I have also used a "Quiktune" tuner that cost only $20 and I find it useless for tuning the instrument but quite OK fo reading the frequency of the sine wave - probably because the sine wave doesn't have the complex wave form that a string produces.
Tuning the plates - some examples

The pictures below show the final state of tune of the front plate of the A5L copy that I am making. I didn't take any pictures of the patterns during the thicknessing of the plate but most of the effort is done at the early stage, before the bars are fitted or the sound holes cut. The Chladni patterns are much more coherent then.

One thing that does have a significant influence on the quality of the patterns and the activity of the plate is "lumps" by this I mean sudden local changes in thickness. These will show up as an imbalance in the shape of the Chladni pattern. Uneven arching will produce the same effect.

I hope to have the camera available when I thickness the back of this instrument and, if all goes well, I will update this page to show the way the thicknessing effects the Chladni patterns.

With the plate mounted on the foam blocks over the loudspeaker, I sprinkle the surface with a light dusting of the "Christmas Glitter" before starting the sinewave generator.

sweep the frequency until the glitter on the surface starts to dance. I should then be possible to fine tune the frequency until the maximum activity is observed and the line of no movement becomes well defined.

The glitter will then migrate to the parts of the plate that are moving the least and away from the parts that are moving the most.
There are a number of different modes that the plate will vibrate in each corresponding to a different frequency. Only a few of them can be found easily using this powder migration method and only 2 of these are strong enough to give the clear patterns I have shown here.

If you hold the plate between thumb and fingertip, exactly on one of the node lines, close to your ear and tap the plate at one of the areas where the glitter has moved away from you should hear the plate ring at that frequency. You can see how the place where that plate is held and the place where it is tapped will significantly influence the amount of ring that the ear will hear. The picture at the left shows the lowest strong frequency. In the case of this instrument is 5 cents above the F below middle C.

NOTE 1 cent is equal to 1/100th of a semitone. I will add the actual frequency as soon as I have worked it out.

The picture at the right shows the pattern at 15 cents below middle C. Of course I have no evidence so show if these frequencies are good or bad. Only time and experience can show that.

I have read that one maker of considerable repute (Ray Dearstone) tunes the front and back a tone apart with the back the higher.

The following is a quote from an interview located on his web site. Follow the link for more information.

Ray: Yeah, that's right. I normally tune the top to a C-note and the back to a D. I had a couple of mandolins where the spruce I used for the tops was pretty hard. I had carved the top down to a C#, but I didn't want to go any thinner because of the structural aspect. So I decided to leave it at C# and make the back tune to a D#, to maintain the same relationship. These mandolins ended up sounding great. I think the relationship of the frequencies, how they all work together, are more important than tap-tuning to a particular note.

More information can be found at Tuning violin plates. This site gives a lot of real information about the process of plate tuning. I recommend a visit.

There is also a library of pictures showing all the modes of vibration of a free violin plate Chladni patterns of a handmade violin.
Chladni patterns for guitar plates

Chladni patterns show the geometry of the different types of vibration of the guitar top plate. This site has an introductory explanation of modes of vibration and a library of photographs of the Chladni patterns of a guitar top plate and an intact guitar.

The results reported on this site are part of a practicum project by:

Thomas Erndl
Musical Acoustics Group
School of Physics
The University of New South Wales

Thomas is a student at the Fachhochschule Regensburg in Germany.

Modes of vibration
(See also the explanations of the guitar, and Strings, harmonics and standing waves.) A mode of vibration is just a way of vibration. Think what happens when you strike a xylophone bar in the middle and set it vibrating. The bar is supported at two points towards the ends. The simplest mode of vibration is this: when the middle of the bar goes up (as shown by the solid lines in the figure) the ends of the bar go down. When the middle goes down (dashed lines), the ends go up. The two points that do not move are called nodes and are marked N in the diagram. (If "modes" and "nodes" sound confusing, remember that the node has no motion.)

Sketch of a simple mode of vibration.

This first mode of the xylophone bar is rather similar to a mode of vibration of a simple rectangular plate which is called the (0,2) mode (the naming convention is explained below.)

Photographs of the Chladni pattern of mode (0,2) of a uniform rectangular aluminium plate:
Violin Plate Tuning

In this pictures, the lines are formed from sand that has collected at the nodes, but has been shaken off the moving regions. The top plate of a guitar is more complicated in shape, and so the nodes also have a more complicated shape. White sand was used for the black-painted aluminium plate, and black sand for the guitar top plate.

Why are there nodes?

The supports of the xylophone bar do not cause the nodes, rather they are placed at the positions which are nodes so as to facilitate this vibration. In an object which is not firmly clamped, a vibration cannot easily move the centre of mass of the object. It follows that, if some part is going up, another part is going down. In the simple motion at resonance, the point(s) that divide(s) these regions are nodes. When a violin or an isolated part is vibrating, the centre of mass doesn't move much, so once again it can be divided into parts that are going up and others that are going down. In these simple modes of vibration, the motion of different parts is either exactly in phase or exactly out of phase, and the two regions are separated by nodes. The nodes are points for a quasi one-dimensional object like a string, or lines for a quasi two-dimensional object like a plate. (There is more explanation in Strings, harmonics and standing waves.)

Modes of guitar plates

One of the modes is comparable with a mode of vibration of a rectangular plate. In this mode the nodal lines separate the plate in three parts, so it can be compared with the (0,2) mode of the rectangular plate, with the middle part moving 180° out-of-phase with the ends.

The modes for the guitar plate are complicated by the presence of the sound hole and the bracing.

More guitar Chladni patterns.

How are Chladni patterns formed?

There are at least three different methods.

- The plate can be made to resonate by a powerful sound wave which is tuned to the frequency of the desired mode.
- The plate can be bowed with a violin bow. This is easiest if one choses a point that is a node for most of the modes that one doesn't want, but not for the desired node.
- The plate can be excited mechanically or electromechanically at the frequency of the desired mode.

For the photographs on this site, a small (4g) magnet was fixed to the bridge. An oscillating magnetic field (provided by a coil connected to an audio amplifier and a signal generator) was used to provide an oscillating force whose frequency is tuned to the resonance of the mode. Experiments using different masses showed that the mass of the
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Magnets caused us to underestimate the frequency by about 10 Hertz in some cases. But there were also patterns obtained with a magnet which could not be obtained without a magnet (e.g. by a speaker). That means, that the vibrating system has changed qualitatively by adding the magnet to the plate.

In all cases, some finely divided material is placed on the plate. The material used here is fine sand. When the plate resonates, the motion becomes large over most of the surface and this causes the sand to bounce and to move about. Only at or near the node is the sand stationary. Thus the sand is either bounced off the plate or else collects at the nodes, as shown in the photographs.

Why are Chladni patterns useful?
The adjustment of the top plate is important to the properties of the final instrument. The most important adjustments are thinning the wood towards the edge of the plate, and thinning the braces. Chladni patterns provide some feedback to the maker during the process of adjusting the plate to its final shape. Symmetrical plates give symmetrical patterns; asymmetrical ones in general do not.

It is very difficult to relate the frequencies of the modes of the isolated top plate to those of the modes of a finished guitar. Fortunately, adjustments can be made to an intact instrument: thinning the top plate close to the edge, and adjusting the bracing by reaching through the soundhole with specially shaped tools. The "tuning" of plate resonances is less formalised in guitar making than in violin making. Over the centuries, violin makers have discovered empirical relations between the modes of free plates and the properties of the finished instrument. Many scientists have been interested in the acoustics of violins, and many violin makers have been interested in science, so a lot has been written about the acoustical properties of violins and their parts. See:

- Mode Tuning for the Violin Maker by Carleen M. Hutchins and Duane Voskuil CAS Journal Vol. 2, No. 4 (Series II), Nov. 1993, pp. 5 - 9
- The Catgut Acoustical Society home page

More Chladni patterns
- A library of Chladni patterns for a guitar top plate
- A library of Chladni patterns for a hand-made violin
- A library of Chladni patterns for a mass-produced violin
- Chladni patterns of violin plates compared with the analogous modes for simple rectangular and circular plates

Some explanatory notes and related pages on this site
- A simple overview of the operation of the guitar, and
- Some more detailed information about work relating to guitar acoustics
- Strings, harmonics and standing waves
- What is a sound spectrum?
- What is a decibel?
- Violin acoustics
- How do woodwind instruments work?
- Flute acoustics
- Other research projects in musical acoustics at UNSW
- The Science of Music
Violin Plate Tuning

- An interactive introduction to the orchestra

Some links to related sites

- The Catgut Acoustical Society
Chladni Patterns of a guitar top plate:

Chladni images made by Thomas Erndl / thomas.erndl@gmx.de (a practicum student from the Fachhochschule Regensburg in Germany).