BASIC PIANO TUNING

by

Mark Cerisano, RPT

howtotunepianos.com

TRAINING MANUAL
eBook EDITION

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INTRODUCTION

LEARN TO TUNE and REPAIR PIANOS!

MR.TUNER'S SCHOOL OF PIANO TECHNOLOGY

Welcome to Basic Piano Tuning. Learning to tune a piano can be a difficult task but this course is designed to make it as easy as possible. In this class you will learn two basic skills. One easy; the other will take much more time than we have here to master. The easy skill will be where to put the hammer and what notes to tune and when. The hard part will be hearing and comparing the beats. Without being able to hear the beats produced by un-pure intervals, it is impossible to be a great tuner. (We will discuss what beats and un-pure intervals are soon) This class will give you many tricks that should ease the challenge of hearing these beats.

This is a course in aural piano tuning. There are other ways to tune a piano, but if you can tune a piano aurally, you will be a better tuner than if you went straight to an Electronic Tuning Device (ETD).

The course is organized from the beginning of tuning a piano to the end. We will concern ourselves mostly with upright pianos for two reasons. One, uprights are much more prevalent than grands and two, beginner tuners usually tune only uprights until their skills are better. We will talk about grands and try tuning one if it is available at the school.

You will be asked to hear the beats produced by un-pure intervals right from the beginning and you will spend the rest of the course trying to improve your ability to hear these beats. Relax. You will never hear these beats by trying too hard. Stay relaxed and focused. Do not spend too much time trying to hear any one interval's beat. If you are having difficulty, change it up and listen to something else. The skill will come as long as you keep trying to listen. Try to always listen from a relaxed frame of mind. If you are having difficulty, take a break.

Many students report the sensation of time slowing down when they are tuning; many are surprised when they are told the class has finished. Indeed the instructor often goes overtime without being aware; that is how intoxicating tuning can be.

Good luck with the class and I hope you all find the class interesting, your expectations exceeded, and learning new skills; successful.

Mark Cerisano, RPT

GENERAL OUTLINE of CLASS PROGRESSION

This manual and the class will follow this order of topics.

CHAPTER I - GENERAL CONCEPTS

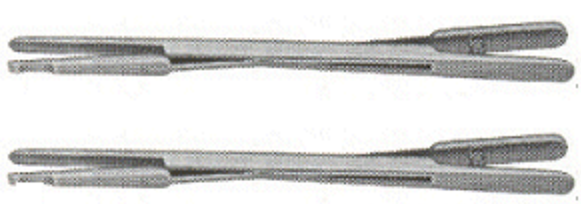
1.1 Tuning Tools

These are the required tools for Basic Piano Tuning.

TUNING HAMMER

TUNING FORK

THREE FELT MUTE STRIPS for muting outside unison strings



2 PAPP'S MUTES for selective muting of strings, especially where there is no room above hammers.

8 RUBBER WEDGE MUTES for muting strings of notes at ends of sections.

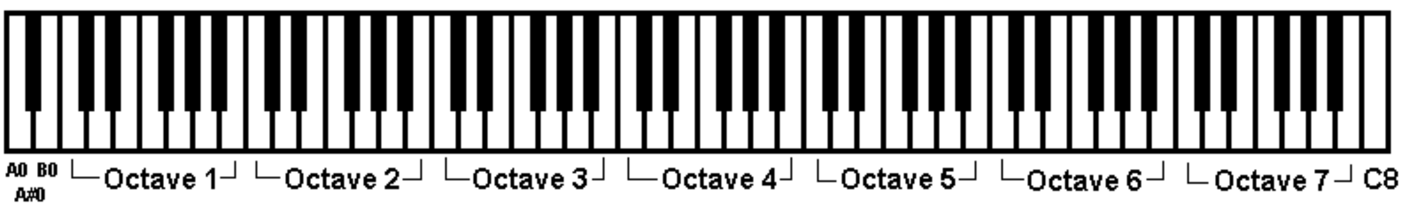
1.2 Note Nomenclature

BLACK KEYS
Tuners generally don't use flats (b) to name the black keys, just sharps (#). This produces some musically unusual combinations, like F – A# for a perfect fourth.

Exception for this text: I will use flats when we are discussing topics that are also common as musical forms. For example: Appendix G - Cycle of Fifths uses flats because the Cycle of Fifths is a common musical form for practicing, composing, and improvisation.

NAMING NOTES
There are two common systems used to name the notes of the piano for tuning purposes:

System 1
Each octave gets its own number.
Octaves are C to B
The bottom three notes and the top note have their own octave number.
The bottom octave is numbered zero (0).
So, the first three notes are A0, A#0, B0
Then the next octave is C1 C#1 D1 D#1 E1 F1 F#1 G1 G#1 A1 A#1 B1
Then the octaves follow up to number 7.
The top note is C8



System 2
Some tuners just name the letter name of the note and add the number of the key.
For example: A1, A#2, B3, C4, C#5, etc…up to C88.

For this book we will use ***System 1***

Some common notes to remember using System 1:

The pitch of the tuning fork A440 is found at A4.
Middle C is C4
Our first complete octave we will tune is the temperament octave, F3F4

Occasionally, I will describe notes with their frequencies if we are discussing frequencies. For example: A4 may be listed as A440, and A3 as A220, etc.

1.3 Pure, Wide, and Narrow Intervals

This can be a tricky concept to grasp but the sooner you do grasp it, the easier other things will be to understand. In order to understand these terms, it is necessary to introduce the harmonic series now. The harmonic series is a concept that we will come back to often, so it too requires effort on your part to really know it inside and out; be able to name all the notes in any harmonic series easily.
(See Appendix A – Harmonic Series and Tone. Worksheet and Answer Sheet)

HARMONIC SERIES
Whenever a note is played, there are actually many frequencies produced. The note we hear is called the Fundamental or 1st Partial. The other frequencies produced are called the 2nd partial, 3rd partial, 4th partial, etc.

The musical intervals of the partials above the fundamental are:

Fundamental or 1st Partial – Unison (The note we hear)
2nd Partial – Octave
3rd Partial – Octave plus perfect fifth
4th Partial – 2 octaves
5th Partial – 2 octaves plus M3
6th Partial – 2 octaves plus P5
7th Partial – 2 octaves plus m7
8th Partial – 3 octaves

Notice:
2,3,4 make a common left hand pattern in piano music (an octave with the fifth inside)
4,5,6 make a major chord
4,5,6,7 make a dominant chord (7th chord)

PURE INTERVALS AND BEATING INTERVALS
(The term *pure* refers to the sound of an interval and must not be confused with the term *perfect.* We can have a *perfect* fifth that is not *pure.*)

In the ideal world, the frequencies of the partials = the partial frequency x the fundamental frequency. I.e. the 3rd partial above A440 is 440 x 3 = 1320Hz
Now, when an interval is played, there are multiple frequencies created above each interval note. These interval notes produce one (or sometimes more) partials that are common to the series of both interval notes. This common partial is referred to as the co-incidental partial. (C.P.) If the frequencies of the C.P.'s are not the same, there will be beating, just like an out-of-tune unison. (See the section on unisons).
WHEN THE FREQUENCIES OF THE CO-INCIDENTAL PARTIALS ARE IDENTICAL, THERE IS NO BEATING AT THE C.P.'s AND THE INTERVAL IS SAID TO BE *PURE.*

WIDE AND NARROW INTERVALS
Beating intervals (un-pure intervals) are either wide or narrow, depending on which way the notes are out.
WIDE INTERVAL: Bottom note is flat from pure or top note is sharp from pure.
NARROW INTERVAL: Bottom note is sharp from pure or top note is flat from pure.

EXAMPLES

Let’s look at the ideal frequencies of the harmonic series above A4 (A440).

Partial	Note	Frequency (Hz)	Calculation
8	A7	3520	440 x 8
7	G7	3080	440 x 7
6	E7	2640	440 x 6
5	C#7	2200	440 x 5
4	A6	1760	440 x 4
3	E6	1320	440 x 3
2	A5	880	440 x 2
1	A4	440	440 x 1

(It is very important that you understand that these frequencies are not the frequencies of the named notes on the piano. They are the frequencies of the harmonics of the fundamental, A4 in this case. Please keep these ideas separate)

Now, let’s consider an interval note a perfect fifth above A440 (A4). The note would be E5.

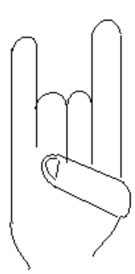
It is a fact that the frequency of E5 at 660Hz is that which produces a pure fifth. And the coincidental partial is found at E6. (660 x 2 = **1320** AND 440 x 3 = **1320**) The 2^{nd} partial of E5 and the 3^{rd} partial of A4 line up exactly at 1320Hz when E5 is 660Hz. I.e. E6 is the C.P. and there is no beating.
(Note: The factor for producing a *pure* fifth is 1.5. e.g. 440 x 1.5 = 660)

Here are some frequencies of E6 and A4 that will produce different sounding fifths.

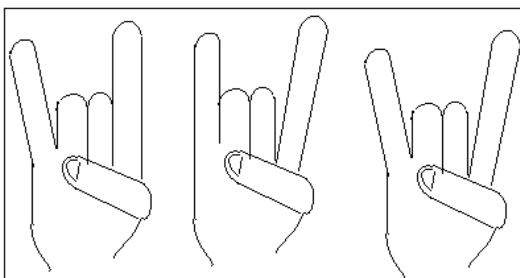
A4	**E6**	**SIZE**
440	660	Pure
440	661	Wide
439	660	Wide
440	659	Narrow
441	660	Narrow
441	659	Narrow
439	661	Wide

It is important that you understand the physical relationship of these different sized perfect fifths. Imagine them as having physical distances. This will help you to be able to analyze your tunings later. We will be constantly concerning ourselves with the size of our intervals when we tune.

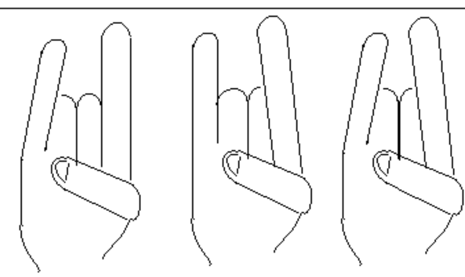
I will use the 2^{nd} and 5^{th} fingers of my hand to show the size of the intervals we will be talking about. Here is how I will show the different sizes:



PURE - Both fingers parallel



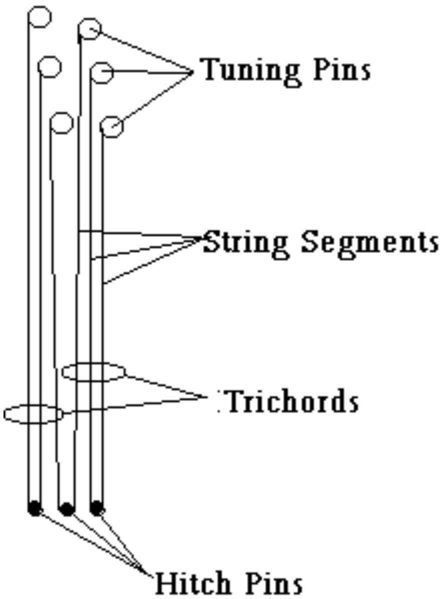
WIDE - Bottom note flat OR top note sharp OR both



NARROW - Bottom note sharp OR top note flat OR both

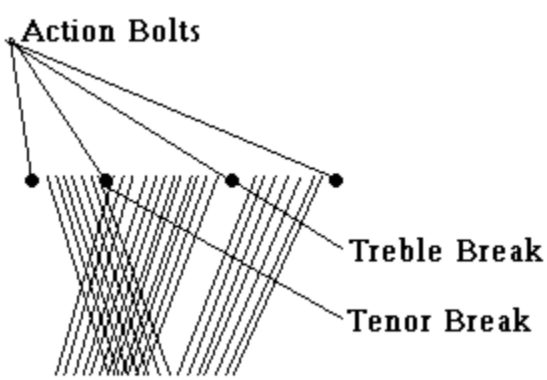
1.4 Design of the Piano

The strings of the piano are arranged in unichords (one string per note), bichords (two strings per note), and trichords (three strings per note). Most trichords are actually string segments, not discrete strings; the string actually starts from one tuning pin, travels down and winds around the hitch pin at the bottom and returns to the next tuning pin, thereby producing two segments. So, it actually takes 3 strings to make two notes.



Usually, the bass strings are unichords and bichords, and the rest are trichords. Bass strings are those to the left of the tenor break.

There are usually two breaks where the strings make room for the action brackets and over-stringing. (Over-stringing is when the bass strings pass over the other strings so they can be longer).



1.5 Basic Tuning Procedure

1. Mute off the piano so there is only one unmuted string per note where possible.
2. Tune A4 to the fork
3. Tune the first octave A3A4
4. Tune all the notes within the temperament octave F3F4
5. Tune all the notes from F#4 up to C8.
6. Tune all notes from E3 down to A0.
7. Remove mutes and tune the unisons.

We will follow these steps and introduce the skills needed to perform each step as we need them.

CHAPTER II - MUTING THE PIANO

2.1 Creating Single Strings (Upright Piano)

The purpose of muting the piano is to have only one string free to vibrate for each note, where possible. (We only tune one string at a time.)

MUTING THE MID-SECTION

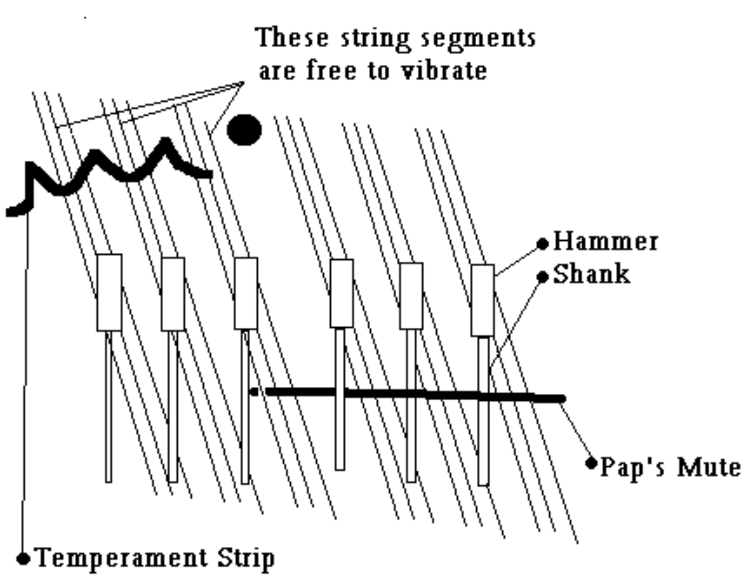
Start with a temperament mute strip and screwdriver or other flat thin object like a Papp's mute, and push the folded end of the strip between the last two notes of the middle section. I.e. to the left of the treble break. If your strip is too wide for these high notes, taper about 6 inches narrower on the end or use a thinner strip. Leave the loose end of the strip dangling to the left.

Continue down, inserting the felt strip between each note until you come to the bichords. This way, you will have the center string free to vibrate on all trichords. (except of course the trichords at the ends.)

BE VERY CAREFUL TO LEAVE ENOUGH OF A LOOP BETWEEN EACH NOTE SO THAT THE MIDDLE STRING IS NOT MUTED. When the loops are small and tight, the felt can actually touch the middle string and cause it to have very poor tone.

ALSO, INSERT THE MUTE AS CLOSE AS POSSIBLE TO THE HAMMERS WITHOUT TOUCHING THEM. When the mute strip is close to the V-bar, the dampening effect of the felt mute strip is inefficient and the vibrations of the other strings will interfere with the middle string's tone.

The first note you muted (just to the left of the treble break) will have two strings free – the second and third string. Insert the Papp's mute between the first and second hammer shank in the treble section and stick it between the first and second string segment of the note to the left of the treble break. Now the third string segment of that note is the only one free to vibrate. (See diagram below)

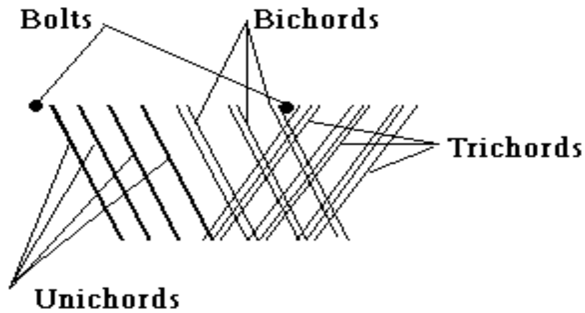


2.2 Muting the Bichords (Upright Piano)

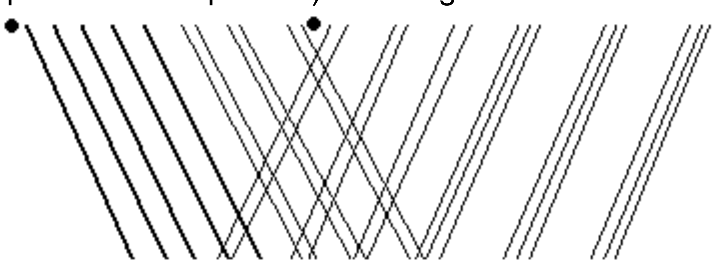
You have some choices on how to mute the strings when you reach the bichords. Your choice depends on how the piano is designed.

There are three ways the bichords of a piano are designed. They always start in the bass section but can end in three different places depending on the design of the piano.

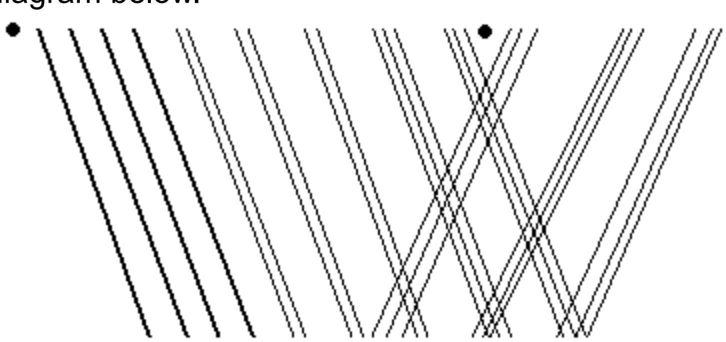
Design #1. The bichords stop at the tenor break. (Most uprights) See below.



Design #2: The bichords go past the tenor break and end in the tenor section. (Most spinets or apartment size pianos.) See diagram below.

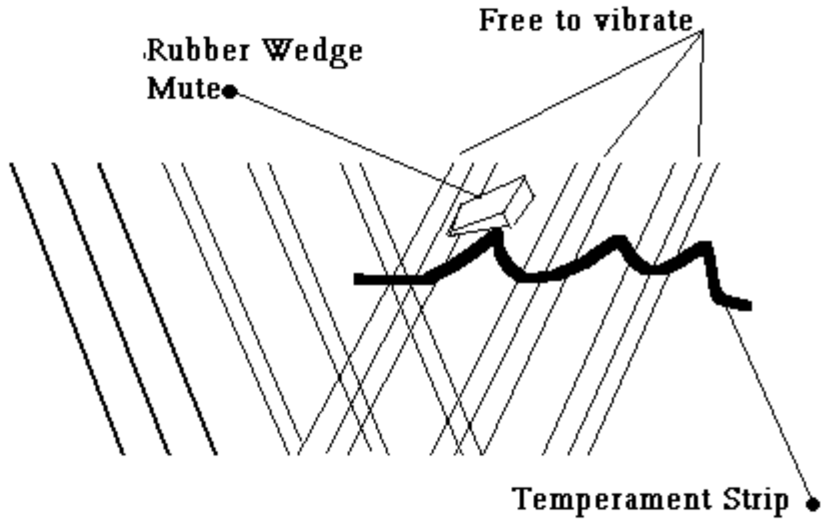


Design #3: The bichords start in the bass section but do not go all the way to the tenor break. (The trichords in the bass section are usually wound and are found in larger uprights and grands.) See diagram below.



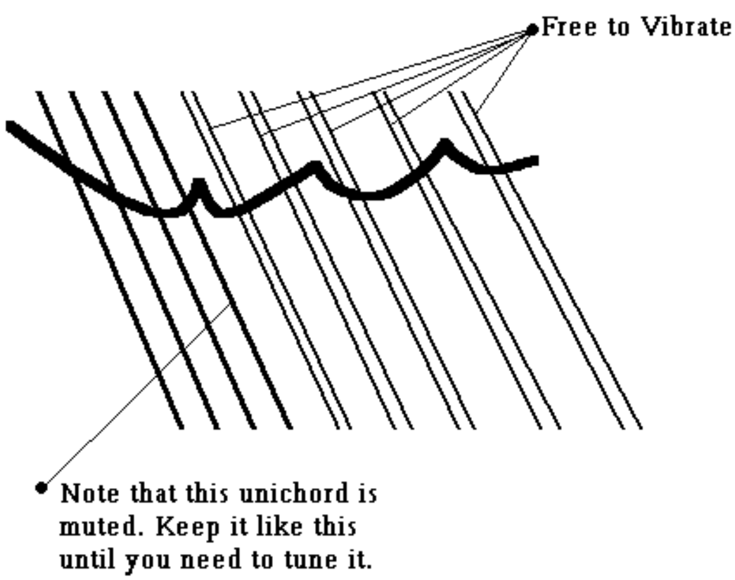
2.2.1 Muting the Bichords When They End at the Tenor Break (Design #1)

The first note of the tenor section will only have its third string segment muted by the mute strip you inserted previously. So, insert a rubber wedge mute between the second and third string segment. Now, only the first string segment is free to vibrate. See diagram below.



Now, the first tenor note only has one string segment free to vibrate, segment #1

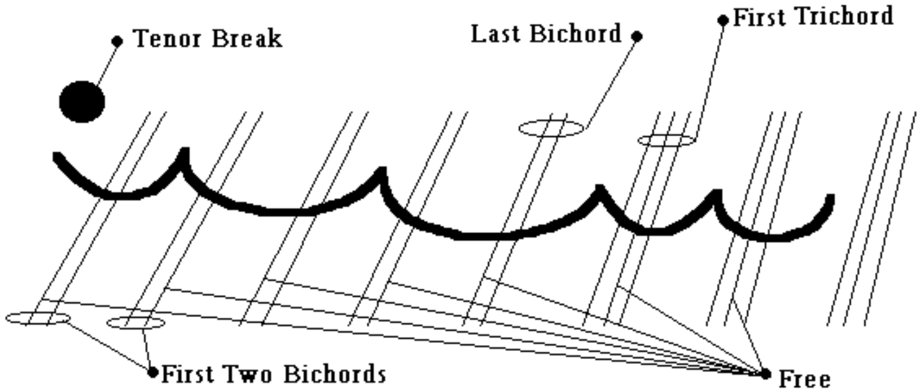
Now, insert the mute strip between every 2nd pair of bichords. This will leave alternating left-right-left-right strings free to vibrate. Hang the loose end, if any, out of the way, or insert it between some already muted bichords pairs.



In the example above, the mute strip ends up between a bichord and a unichord. When the strip ends between two bichords, then each note in the bass will have only one string free to vibrate, which is what we want. In the case above, the last unichord is muted by the strip. Leave it like that. As we tune our way down the piano, we will pull the strip out when we get here and deal with it then.

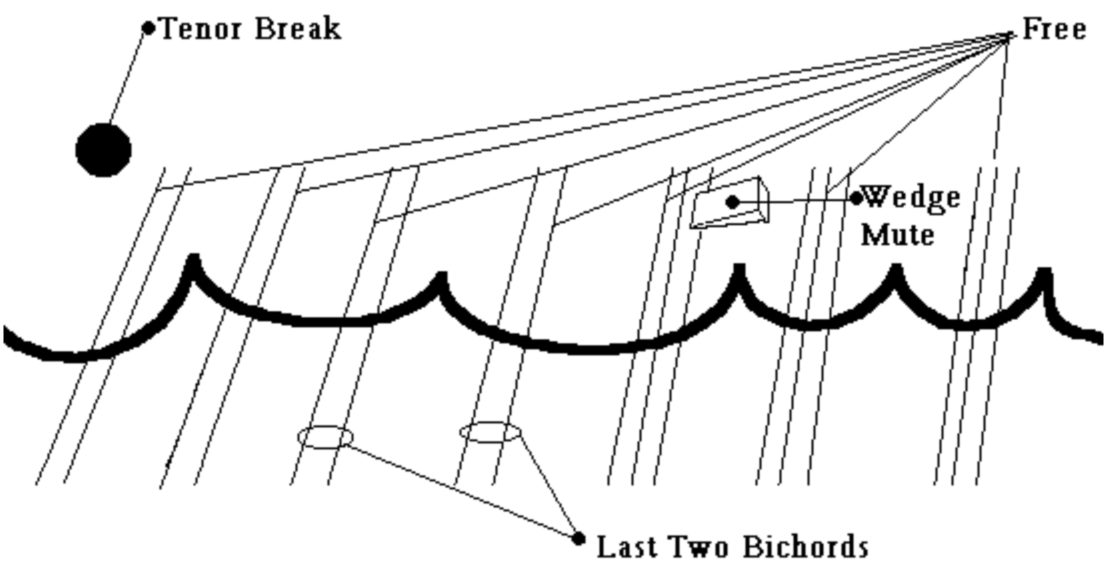
2.2.2 Muting the Bichords When They End in the Tenor Section (Design #2)

Count how many bichords are in the tenor section. If it is an odd number, you can stick the strip between the trichord and bichord and continue down inserting the strip into every 2nd bichord. When you get to the tenor break, each note will have only one string unmated.



Odd number of bichords (5 in this example) results in every note with only one unmated string.

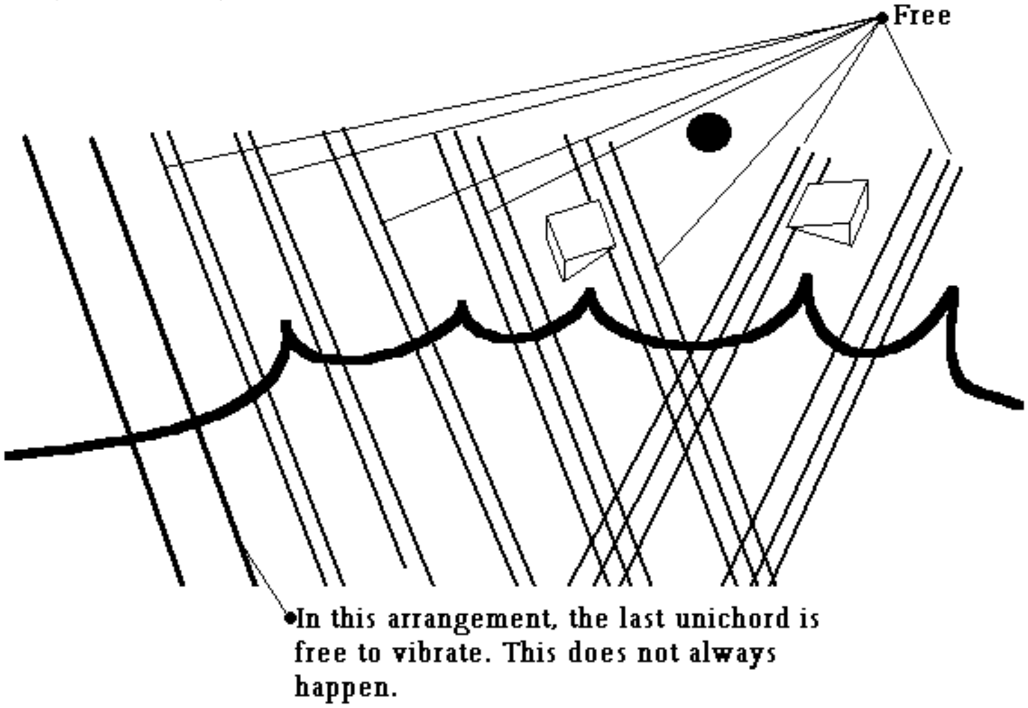
If there is an *even* number of bichords, then do *not* stick the mute strip between the bichord and the trichord. Start with the top two bichords and continue muting every 2nd bichord until you get to the tenor break. Now you will have one unmu ted string for each note *except* the first trichord. That will have string segment #1 and #2 unmuted. To get only one unmuted string segment here, stick a wedge mute between strings #2 and #3. Now #1 is the only unmated string segment for that note.



Even number of bichords (4 in this example) results in every note having one unmuted string when the rubber wedge mute is used in the first trichord.

2.2.3 Muting the Bichords When They End in the Bass Section (Design #3)

In this arrangement, you will have trichords on either side of the tenor break. Use the wedge mutes to leave the string segments close to the break free to vibrate. (#3 on trichord to left of break, #1 on trichord to right of break) Then mute the rest of the bichords as usual.



2.2.4 The Treble Section

For the upright piano treble section, all three strings of each note are tuned as you go, using the Papp's mute. (More on exactly how in the unison section)

For grand pianos, you can mute all the strings with the strip and use the rubber wedges at the ends of each section to leave the outside segments free to vibrate.

2.3 Muting the Grand Piano

Since the hammers are under the strings, they do not get in the way of the mute strip, and we can use the mute strip to mute off the entire piano.

Start at the treble and place your mute strip between the top two notes. Continue down, muting between each two notes.

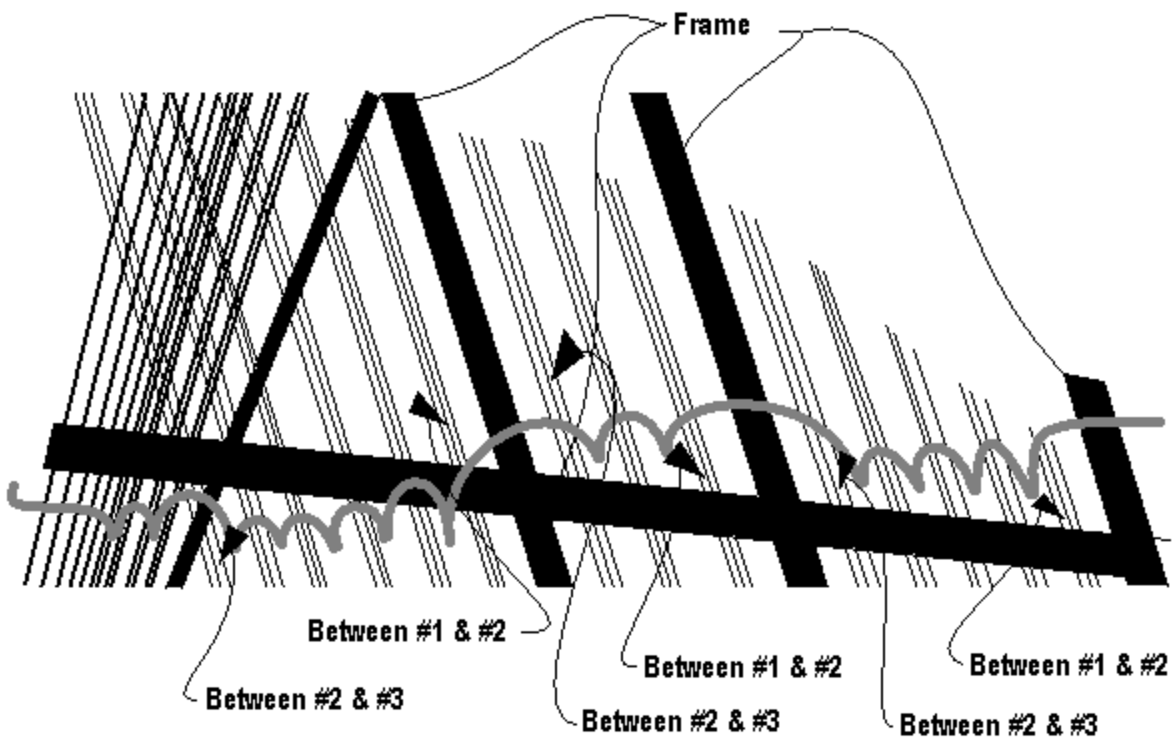
When you get to the end of a section, don’t try to put the strip between the note and the frame, you only put the strip between two notes. Leave the end notes with two free strings for now.

Near the middle, you will find that the mute strip is going farther and farther away from you. At this point, find a convenient place to cross over the frame towards you, and continue muting closer to you.

Only mute every second pair of bichords, as with the upright.

When finished, insert rubber wedge mutes in the notes that are at the ends of each section; the notes where you left two strings free. See the diagram to get an idea where to put them. We want only one string free for these notes. There are two ways to think about how to mutes these strings:

1. Leave the string on the outside of the section free to vibrate.
2. Put the rubber wedge mute between the string muted already by the felt, and the center string.



CHAPTER III - TUNING A4 TO THE FORK

This being the first real tuning exercise, there are a few concepts that we must present in order for you to understand what to do.

First of all, you will need to sound the fork so that an audible tone can be heard. Do this by following these steps .

3.1 Sounding the Fork

1. Hold the fork by the ball at the single end.
2. Strike one of the double ends on a relatively firm surface. It does not need to be hard. Do NOT strike it on the piano cabinet. It will leave a dent or mark. You must not hold it too tight. You have to let it bounce off the surface. You can use your knee, or the lower palm of your hand. Some people use their head. Others have made a small block of wood with a hard rubber surface.
3. Find a good amplifying spot on the piano on which to place the ball of the fork. Try different spots. The top, the cheek blocks (the wood blocks beside the keys), the key slip (the wood rail over the keys), the top of the side. Generally a spot that is hollow underneath or has the fork in line with the grain, are good spots. Some people put the fork in their teeth and bite gently. The sound travels well in the skull. Sometimes you might like to just place the fork near one of your ears.

Now you will play A4 with the fork and tune A4 so that A4 and the fork make an in-tune unison.

3.2 Turning the Tuning Pin

Simply place the hammer on the tuning pin. Make sure you have the right pin. There are three for A4. Pick the one that attaches to the unmuted string, the middle one usually.

Place the handle as close to 12 o'clock as you can. Choose 11 o'clock instead of 1 o'clock. (See Appendix D – Tuning Stability)

Anchor your fingers, wrist or elbow somewhere on the piano for support. Use smooth motions if you can. If the pins are "jumpy", try short jabs at the handle. (See Appendix E - Hammer Technique for a more in-depth discussion of hammer technique) Keep a constant grip on the hammer. You don't want to lose hold of it and have it fall down and damage the finish or chip a keytop!

Turn the pin clockwise (to the right) to tighten the string and raise the pitch. Turn the pin counter-clockwise (to the left) to loosen the string and lower the pitch.

3.3 Unison Concepts

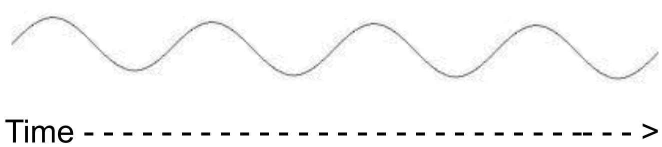
You are trying to hear an in-tune unison. For beginners, it is sometimes hard to even get A4 *near* the pitch of the fork if they are not used to listening to two notes simultaneously. Be careful that you are not so far sharp that you damage or break the string. If at all unsure, play each separately and compare and adjust.

Once you are close, then you must find the tone of the unison that produces the cleanest sound, sometimes referred to as a dark or warm sound. It has no motion, no colour or shimmering.

You may find it useful to try and hear the beats (More on that later) But for now, let’s discuss a bit, what an in-tune unison is, in theory.

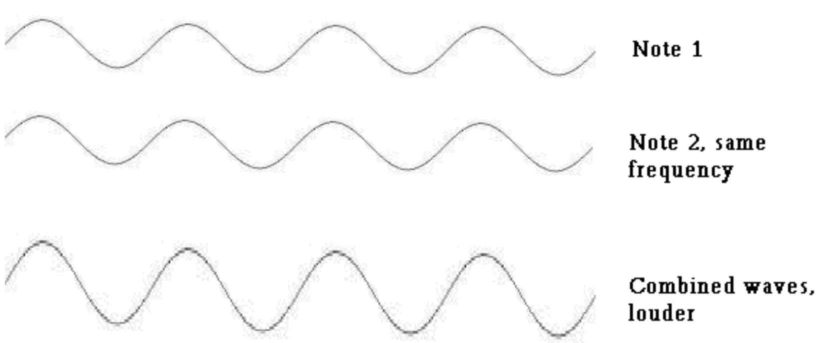
3.3.1 Unison Theory

One string vibrates back and forth like this:



(Think of a spot on the string moving up and down as time passes)

When two strings vibrate together at the same frequency, they add up to one frequency that is just louder

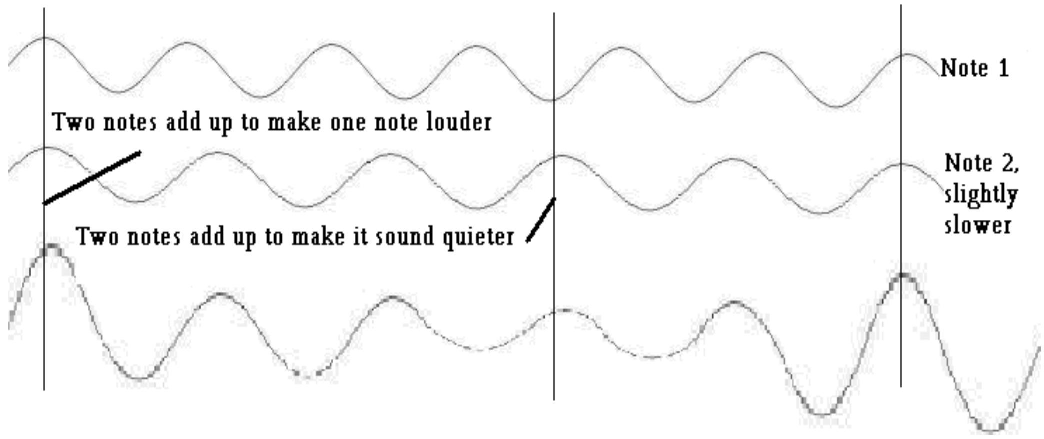


However, if one of the notes is slightly faster (sharper) or slower (flatter) then the waves are said to go in and out of phase. They will add up to give alternating loud and quiet pulses called beats. These beats can be very fast, discernable up to about 15 Hz, or very slow, as slow as zero Hz, which is a *pure unison*. A Pure Unison has no beats (in theory)

3.3.1 Unison Theory (Continued)

So, to tune a unison, you just need to adjust the pitch of one string so that the beats slow down and disappear. If you aren’t sure what a good unison sounds like, ask your instructor to show you.

NOTE: Because each unison note has a series of frequencies sounding above each fundamental, there are a series of beats sounding at each partial. Each of these beats will have a slightly different beat speed. (Generally the higher ones beat faster). What this means is that you cannot hear a clean beat speed when you are trying to tune a unison. It sounds more like "Wha-ga-la-wha-ga-la-wha-ga-la" (Sorry, but that is the best I can do at describing it in text). Just tune the unison so there is no "Wha-ga-la-wha-ga…" (You get the idea)



3.4 Equal Temperament Brief Introduction

This is not the time to explain equal temperament and how it applies to piano tuning, but we do need to introduce some basic ideas about it. For now, understand that, because of the physics of sound, there are very few pure intervals after a piano has been tuned. In fact many are wide or narrow from pure.

For the sake of tuning A4, we must remember that the M3 in equal temperament is a *wide* interval. You will see how we use this fact next.

3.5 Using the A4 Check Note to Improve Your Tuning of A4

Without getting too theoretical, you can greatly improve the accuracy of your A4 by using the check note F2. Now F2 makes a compound M3 with A4, and in the equal tempered tuning system, the system 99.9% of pianos are tuned to (more on that later), the M3 is wide. (Remember the discussion of un-pure intervals above).

So, tune F2, if you can, so that there are no beats with A4. (i.e. *pure*) Then lower it slightly so that you have a wide M3 and you can hear the beats. Not too fast, not too slow. About 7 beats per second. (7 beats per second is about as fast as you can tap your finger). This will produce a wide M3 in F2A4. Note: F2 might already be close enough to give good beats with A4. Just make sure F2 is beating because it is making a *wide* M3 and not a *narrow* one.

You will hear a beating pitch near the frequency of A4. Listen for a pure tone that seems to come from behind the piano. Turn your head slowly back and forth, side to side, if you have trouble.

Considering the perspective of F2, we can say that A4 is now sharp from a pure M3 with F2. That is why it is beating.

When you play F2 with the fork, it should beat as well, if it is close to A4, because both A4 and the fork are making wide M3s with F2.

Now, if the beat speed of A4 with F2 and the same as beat speed of the fork with F2, then F2Fork and F2A4 are the same wideness, and by comparison, A4 = The Fork.

When A4 and the fork are only slightly out, the difference in beat speeds is quite large and easy to hear. That is why using a check note is so accurate. (We will use other check notes later on.)

If they are not the same, raise or lower A4 until they are.

If F2A4 is faster than F2Fork, then lower A4.
If F2A4 is slower than F2Fork, then raise A4.

NOTE: See Appendix B for another completely confusing attempt at explaining this technique

3.6 Techniques for Hearing Beats

Trying to hear the beats produced by F2A4 and F2Fork may be difficult depending on the piano, the room, and/or your ear. Use these tips to help. (See Appendix C – Tips for Hearing the Coincidental Partial Easier for more explanation) These tips are for hearing F2Fork and F2A4 beating.

1. Know approximately at what note the beating is taking place. (A4 in this example)
2. Listen for a pure pulsating sound coming from behind the piano
3. Try to mentally filter everything else out.
4. MOST HELPFUL: Turn your head slowly side to side and back to front and tilt it until the beating is the loudest. WHAT'S HAPPENING? There are different "hot spots" in a room where different frequencies are easier to hear. Moving your head around helps to find those spots. Also, the angle of your ear canal affects which frequencies are filtered before they reach your ear drum. Tilting your head helps you find the best angle for the frequency you are trying to hear.

3.7 Stability

If your hammer technique is poor, the note will not stay where you put it; it will drift usually flat. Unstable unisons are the #1 reason why tuners are called back to fix their tunings (if they are called back at all!) Appendix D has a more detailed explanation of hammer technique and stability, but for now, know that most tuning pins will be stable if you approach the pitch from above. If you find that the pitch drifts flat with this technique, try approaching the pitch from below.

CHAPTER IV - Tuning the First Octave, A3A4

After tuning A4, the next step is to tune A3 from A4. The reason for this is that we will be tuning the temperament octave next, which is F3F4 and A4 is not in that octave, so we tune A3 as a reference for the temperament octave. Also, all the M3s, m3s, and M6s beat in Equal Temperament and beat faster in the higher octaves. We tune notes in the F3F4 octave first because this is a lower octave and the speeds of these intervals are easier to hear in this octave.

1. Different Octave Sizes

You should be aware that an octave is just double the frequency. For example: A440 is an octave above A220. Also, you should know that the harmonic series is obtained by multiplying the fundamental frequency by 1, 2, 3, etc. Example: A220 has the series 220Hz, 440Hz, 660Hz, 880Hz, etc.

However, you may not know that the physical limitations of a piano string render the harmonic series as not ideal. In our ideal example of A220, a more realistic picture of its harmonic series would be something like: 220Hz, 441Hz, 663Hz, 885Hz, etc. The stiffness and thickness of the strings mean the upper partials are *higher* than they would be in an ideal world.

This results in a bit of a problem when tuning octaves. If the higher partials were ideal, we could just tune octaves as double the frequency and all the partials would line up evenly, like this:

A110: 110, 220, 330, 440, 550, 660, 770, 880, etc
A220: 220 440 660 880, etc

Now, consider the two following notes of an octave and their realistic partials which are higher than the ideal ones above:

A110: *110*, 222, 334, 446, 558, 668, 780, 893, etc
A220: *220* 448 672 899, etc
(These partials are quite audible, especially for these specific notes.)

We can see that the fundamentals are pure octaves but none of the coincidental partials are in tune. This octave would sound horrible. What's more, there is no way to tune this octave so that all the coincidental partials are in tune. In short, we have to find a compromise that results in the least amount of out-of-tuneness.

Let's look at some different octave sizes that may help us to reduce the out-of-tuneness of the higher partials:

Option 1: Tune the first coincidental partials beatless. This would mean tuning the **2nd** partial of A110 to be in tune with the **1st** partial (fundamental) of A220. It might look something like this:

A110: 110, *222*, 334, 446, 558, 668, 780, 893, etc
A220: *222* 450 676 905, etc

Again, note the **2nd** partial of A110 is in tune with the **1st** partial of A220.
That is why this size octave is called a 2:1 octave.
Notice also that the other coincidental partials are still out of tune, especially the top ones.

Let's try tuning the *top* coincidental partials beatless. The series might look like this:

A110: 110, 222, 334, 446, 558, 668, 780, *893*, etc
A220: 210 440 664 *893*, etc

Now the top coincidental partials are in tune (**8** and **4**) but the 2:1 partial is bad.
This is called an 8:4 octave.

Piano tuners seem to agree that the best size for the octave is between a 4:2 and a 6:3 in the middle of the piano. (6:3 for the bass and 4:2 for the treble, and even some say 2:1 for the high treble)

A good octave might look something like this: (Between a 4:2 and a 6:3)

A110: 110, 222, 334, 448, 558, 668, 780, 898, etc
A220: 224 449 667 896, etc
Differences: 2 1 1 2

Please see and use Appendix M: Octave Templates as another way to help you visualize how the partials line up for different octave sizes.

Now, I realize that this is all mathematical mumbo jumbo. (Even to myself when I reread it), so the real object here is how to tune the best sounding octave.

2. How to Tune a Proper Octave for A3A4 using Check Notes

This is the first octave you will be tuning so it is fairly imperative that you get it right. By now you should have experimented with the octave template sheets in Appendix M. If you haven't, do it now. (You will have to cut one of the sheets out)

There are basically two techniques you can use to get the octave sounding good:

1. Tune by ear. If you understand that the best octave is one which minimizes the beating in the higher coincidental partials, and you hear these partials well, then you can just tune the octave so that it sounds good, keeping an ear to those higher partials and minimizing their beating as much as possible.

1a. You can also ghost the 4:2 coincidental partials and the 6:3 coincidental partials.
(For an explanation of ghosting, see Appendix C – Tips for Hearing the Coincidental Partial Easier)
The coincidental partials you are listening for are A5 (4:2) and E6 (6:3)
They should beat slowly and the same speed.

3. Use a check note. A check note is a note that produces beats with *each* of the interval notes separately. (See Appendix H – Check Notes) By comparing the speed of each interval note with the check note, we get an idea of the size of the interval we are checking. This comparison will tell us if the interval we are checking is narrow, pure, or wide.

We will use the check note for the 4:2 octave. By confirming that A3A4 is a slightly wide 4:2 octave, we can be fairly sure that it is a good size.

3a. Play A3A4 and tune A3 so that the octave sounds clean
3b. Play F3A3 and tune F3 flat so that F3A3 beats about 7bps.
(This has the double benefit of producing an easy to hear beat speed in F3A3 and also puts F3 very close to where it should go since, in ET, F3A3 beats about 7bps.)
3c. Play F3A3 and F3A4 back and forth and compare the beat speeds. F3A4 should beat ever-so-slightly faster than F3A3. This means A3A4 is a wide 4:2 octave

4.3 Stretch and Inharmonicity

Consider the theoretically ideal octave listed previously in Chapter 4.1 Different Octave Sizes.

A110: 110, 222, 334, 448, 558, 668, 780, 898, etc
A220: 224 449 667 896, etc
Theoretical Ideal Octave Size

You can see that the higher A (A220) is actually sharper than pure theory would dictate. It has a frequency of 224Hz. This is because the higher partials of piano strings are sharp. This is called *Inharmonicity*. And the higher octaves need to be sharp from ideal in order to be in tune with the higher, sharper partials of the lower notes.
Similarly, the lower octaves are flat from ideal so their sharp partials will be in tune with the higher octaves.

The lower notes are lower than theoretical, and the higher notes are higher. This is what is referred to as *stretch*. Each piano has a different amount of stretch that makes it sound good and some tuners prefer a different amount of stretch when tuning.

NOTE: For most students, when they are aware that we tune octaves to minimize higher partial noise, and they focus their ears higher when tuning an octave, they intuitively create an acceptable amount of stretch needed for the piano they are tuning.

CHAPTER V - Tuning the Temperament, F3F4

Now that we have A3 tuned, we can use it to begin to tune the notes in the temperament octave, F3F4. The purpose of tuning the temperament octave is to create acceptable interval sizes that allow us to play in all 12 keys with no one key sounding better or worse than another.
(See 3.4 Equal Temperament Brief Introduction and Appendix F – Equal Temperament)

5.1 Different Temperaments
Temperament, as it refers to tuning, has two meanings.

1) The sizes of the different intervals which may or may not create different colours for different keys. Examples: Equal Temperament sometimes referred to as E.T. (no colour variation), Mean Tone Temperament, Historical Temperaments, Well Temperament, etc. Historical temperaments refer to all temperaments except E.T.

2) When tuners tune their temperament octave, they play intervals and use check notes to confirm and refine interval sizes. The order of intervals and check notes they use is also referred to as a *Temperament.* Examples: Randy Potter Temperament, Defenbaugh Temperament (both from the Reblitz text) and others.

An interesting fact to note is that knowing a temperament order like the back of your hand, is a great way to speed up your tunings. However, most tuners stray from it early on while tuning the temperament octave, as they find notes that need refinement and throw in different check notes to try and improve where possible, instead of waiting until the order is finished. This can only be accomplished with a thorough and complete understanding and knowledge of all check notes and their application and uses.

There is no way to side step this requirement. You will not be a good tuner until you realize that you need to understand how to use check notes and be proficient at knowing which ones to use and when.

5.2 Cycle of Fourths and Fifths Temperament (Basic Temperament)

The easiest temperament to use is the cycle of fifths; it is such a useful musical device that most musicians already have it memorized. We start at A3 and proceed through the cycle making intervals of fourths and fifths as we go. We must keep the notes within the F3F4 octave. While the cycle gives us the note names we need to know, putting those notes within the F3F4 octave sometimes produces musical fourths instead of fifths. We still end up hitting each note before returning to A3.

There are two ways you can go about using the cycle of fifths to tune your temperament.

Method 1: The Peanut-Butter-on-Toast Method

1. Tune all the fifths pure as you did in the section Aural Examples of Musical Commas You Can Produce on the Piano in Appendix F – Equal Temperament.
You can use this chart or the musical notation in Appendix J – Basic Temperament by Fourths and Fifths.

E4 A3	E4 **B3**	B3 **F#3**	**C#4** F#3	C#4 **G#3**	**D#4** G#3	D#4 **A#3**	A#3 **F3**	**C4** F3	C4 **G3**	**D4** G3	D4 A3

Use this chart to tune the pure cycle of fifths

Notes:
- The notes in **bold** are to be tuned. (The regular, or un-bolded notes have already been tuned in the previous step)
- The last interval should sound horrible. (Wolf tone)
- You may want to use check notes to get these intervals pure (See Appendix H – Check Notes) but it is not critical that they are exactly pure. They just need to be close, since we will refine in the next step.

Tuning all the fifths/fourths pure, has left the last interval sounding horrible. Think of moving through the cycle as if you are spreading peanut butter on toast. When you make all the intervals pure, you end up with beating on the last interval. It's like when you spread peanut butter on toast – the first spread leaves you with a blob of peanut butter on your knife at the end of the toast.

Now, you need to reverse the cycle and go backwards, retuning all the intervals so that they are not quite pure. You can follow the chart below, if it helps.

D4 A3	D4 **G3**	**C4** G3	C4 **F3**	**A#3** F3	**D#4** A#3	D#4 **G#3**	**C#4** G#3	C#4 **F#3**	**B3** F#3	**E4** B3	E4 A3

Use this chart to help you tune the cycle backwards and end up back at the beginning

Notes:
- The notes in **bold** are to be tuned. (The regular, un-bolded notes have already been tuned in the previous step)
- Each interval should sound less and less horrible before you tune it. And when you get to the last interval, it should fit, with just the right amount of out-of-tuneness left over.
- If you end up with too much wolf still on the last interval, that means you passed pure on some of the previous intervals or left them pure or too close to pure.
- If you run out of wolf before you get back to the beginning, it means you left some fifths too narrow and/or some fourths too wide. i.e. you didn't get close enough to pure.

Note: In ET, the fifths are narrow and the fourths are wide. When we tune the cycle backwards, trying to tune out the wolf, but not completely, at each interval, it just turns out that we leave the fifths narrow and the fourths wide. Good for us. Just remember not to pass pure on the way back or you will end up with wide fifths and/or narrow fourths.

Continuing with the peanut-butter-on-toast analogy, after making the first pass forward with the knife, you need to turn the knife and return back to the beginning, but don't press so hard, leave a little peanut butter at each step.

Pressing too hard on the way back is analogous to leaving the intervals too close to pure; you will be left with peanut butter still on your knife when you get back where you started. i.e. A3E4 will be beating too fast.
If you don't press hard enough on the way back, that is analogous to leaving the intervals not close enough to pure; you will run out of peanut butter (wolf) before you get back to the beginning; you will have pure intervals at the beginning of the cycle and too wide fourths and too wide fifths in the later intervals.

Try to leave the fourths wide and noisy, and the fifths; narrow and rolling.

You may have to make multiple passes back and forth, before it sounds good.

Play chromatic fifths up and down, and chromatic fourths up and down. The fifths should all have the same amount of rolling, and the fourths; the same amount of noise.

Method 2. Using Check Notes to Tune Narrow Fifths and Wide Fourths Right Away.

By trying to tune out the wolf, but not completely in the toast method above, we end up leaving the fifths narrow and the fourths wide. Using check notes, we can confirm if the intervals are pure in using the toast method above, or we can go right to tuning the intervals their proper size right away

Use the same order of notes, (use the charts above or the music in Appendix J), but each interval is tuned using a check note. (See Appendix H – Check Notes. This must be memorized)

For example, start with A3 and tune E4. The check note is C3 (Appendix H). Play C3A3 and C3E4 over and over. Listen and compare the beats, tone, colour, or emotion. Think of whatever helps you hear well. Since A3E4 should be a narrow fifth, C3A3 should be slightly faster than C3E4. (See How to Tell if an Interval is Wide or Narrow in Appendix H – Check Notes)
When C3A3 is slightly faster than C3E4, move on.

See Appendix K – Interval Size Worksheets for worksheets on hearing wide, narrow, and pure fourths and fifths in the temperament octave. Your instructor will confirm your answers. If you are not taking the course, use this sheet with a mentor or Electronic Tuning Device.

5.3 Wide Noisy Fourths and Narrow Rolling Fifths and What They Sound Like

Many students complain that they don't know how much faster the check intervals need to beat in order to have the right size intervals.

I will give you some direction on this, but first I must mention two things.
One, the right size is the one that fits the interval in with all the others so that no one fifth stands out from the other fifths, and no one fourth stands out from the other fourths. And you won't know that until they are *all* tuned. So, don't waste too much time fretting over the correct amount of narrowness or wideness of a single interval. Try to tune them all quickly, and *then* analyze and refine. This is the secret to tuning fast and accurately.
Two, in general, the healthiest and most efficient approach to tuning is not by concentrating on setting the proper interval sizes, but rather, finding and correcting the intervals that don't fit or sound bad. And you can only do that after you have tuned all the intervals!
So you can see, my suggestion is not to focus on perfection. Well, that will just drive you crazy anyways. Don't you have other areas of your life where you have experience extreme frustration trying to be perfect?
The irony is, after you have cleaned up all the bad sounding intervals that don't fit, what are you left with? Why, a temperament that is pretty darn close to perfect! Well, as close to perfection as you are able to hear at your particular level anyway. As your ability to find out-of-tune intervals improves, so will the level of temperament you leave after the clean-up. That's it.

Now, what about those interval sizes.

Fifths. They are rolling, which means about one beat every four seconds. In other words; very slow. Even though check notes exaggerate the interval size, with the proper size fifth it is still hard to hear a difference. So, I say, make the bottom check interval beat faster than the top, but just enough faster that you are not quite sure if it *is* beating faster. Almost like you think it is beating faster, but you are not sure; it might be a figment of your imagination.

Fourths. They beat a bit faster than fifths and are described as noisy. They beat about once per second. When using the check notes, the difference in the beat speeds of the check intervals is easy to hear. But, when you go back to playing just the fourth, it should still sound acceptably good. If you made the top check interval too fast, the fourth will sound ugly, not noisy.

I hope this helps. Of course the best way to know is to have a good tuner do it for you and listen to it.

5.4 Basic Refining Techniques

After you make the first few passes through the temperament, and you think it sounds ok but you can’t get it better by just tuning fourths and fifths with check notes, now is the time to refine. No matter what technique you use, refining is just the process of playing many intervals and listening to their colour (beat speed). The colour should be the same for all fourths (noisy) and all fifths (rolling) and the thirds and sixths should be slowly increasing in speed as you move up chromatically. What you do when you find an interval that doesn’t fit, is another secret to getting a great temperament.

Basically, this is what you do:

Found an interval that doesn’t fit?

Well, one of the interval notes must be out of tune.

Choose one interval note, and then hypothesize whether it is sharp or flat. (You should be able to do that depending on what intervals you are checking.)

Now, look for other intervals that don’t fit and confirm the sharpness or flatness of the interval note in question. If you can’t find any, check the other interval note the same way.

When you find an out of tune note that you can confirm is sharp or flat multiple ways, you should be able to adjust it and fix two or three problems. This is the key: when refining the temperament, you can’t just change a note to fix one problem; you must confirm that changing the note in a certain direction will fix two or more problems. In this way you move forward towards a great temperament.

In the next two sections we will discuss how to do this with fourths and fifths, and then with thirds and sixths.

5.5 Using Fourths and Fifths to Refine.

There is a simple technique to find and fix bad notes when tuning a temperament using fourths and fifths, but in order for it to be useful YOU MUST TUNE THE FIFTHS NARROW AND THE FOURTHS WIDE! Even if they are not close to the proper size. In fact, on a first pass, they seldom are.

After one pass, you should have intervals of the following sizes:

FIFTHS – Horribly narrow, narrow rolling, or pure. NOT WIDE!
FOURTHS – Horribly wide, wide noisy, or pure. NOT NARROW!

At this point, use check notes to check the intervals again to ensure you have NO WIDE FIFTHS and NO NARROW FOURTHS!

Now, you can check each note by listening to the fourths and fifths it makes with other notes.

Example: F3 can be checked with F3C4, F3A#3.
The fifth should sound narrow and rolling. The fourth should sound wide and noisy.
If F3 is slightly sharp → F3C4 will be horribly narrow and F3A#3 will be pure.
If F3 is slightly flat → F3C4 will be pure and F3A#3 will be horribly wide.

In fact, whenever we are checking notes with fourths and fifths, and we find a horrible fourth or fifth, the corresponding fourth or fifth should be pure. If you can't find a corresponding pure fourth or fifth when an interval is too wide or too narrow, then the temperament is too out-of-tune or you have wide fifths and/or narrow fourths. Either way, you need to go back to your temperament and work on hearing check intervals better.

Example:

C4 is slightly sharp

Therefore:
G3C4 will be horribly wide AND F3C4 will be *pure.*

Now, both these intervals confirm that C4 must be lowered, and when it is
IT WILL FIX TWO INTERVAL SIZES! It will make G3C4 just noisy and F3C4 rolling.

Note: Out of tune C4 was found by first
1) finding a bad sounding interval (G3C4), and
2) Corroborating it with a pure fourth or fifth (F3C4).

This brings up three absolute rules for refining your tuning:

1) When you find an out of tune interval, pick one interval note, assume it is sharp or flat as the case dictates, and look for corroboration by anticipating its affect on the sound of other related intervals. (You thought C4 was sharp and corroborated by anticipating F3C4 would be pure.)
2) Find two or more reasons to change a note in a common direction. (Lowering C4 would make G3C4 less noisy *AND* F3C4 rolling narrow)
3) Fix two or more intervals by changing in the common direction. (G3C4 became just noisy and F3C4 became rolling). By using this technique, you know what note to change, in what direction, and by how much.

When you find a bad interval, that means one, or the other, or both interval notes are out of tune. You need to analyze each interval note and find the pure corroborating interval.

1) Find bad (ugly) interval. NOTE: Bad fifths are too narrow, bad fourths are too wide. Pure intervals are out of tune from ET as well, but tuning philosophy focuses on reducing the ugliness instead of searching for perfection, so we look for the ugliness first.
2) Analyze each interval note by asking "If this interval is out of tune, then one of the notes must be sharp/flat (depends on interval and note). If this note is sharp/flat then what interval will be pure?"
3) When you find the pure interval, you can change the note to fix both intervals.

Here is a list of notes you can use to check each note of the temperament with fourths and fifths.

NOTE	FOURTH	FIFTH
F3	F3 A#3	F3 C4
F#3	F#3 B4	F#3 C#4
G3	G3 C4	G3 D4
G#3	G#3 C#4	G#3 D#4
A3	A3 D4	A3 E4
A#3	A#3 D#4	A#3 F4
B3	B3 E4	F#3 B3 (*)
C4	C4 F4	F3 C4
C#4	G#3 C#4	F#3 C#4
D4	A3 D4	G3 D4
D#4	A#3 D#4	G#3 D#4
E4	B3 E4	A3 E4
F4	C3 F4	A#3 F4

(*) There is no fifth within F3F4 with B3. But we can use two fourths to compare, F#3B3 and B3E4. They should both be wide and noisy. If B3 is slightly sharp or flat, one of the fourths will sound horrible wide and the other will sound pure.

You can also use chromatic fourths and fifths. Just keep looking for something that sticks out and doesn't fit with the other interval colours.

5.6 Using Thirds and Sixths to Refine.

Tuning using fourths and fifths is easy to hear and explain and that is why this course started using these techniques. Tuning manuals and texts usually jump right into tuning using thirds and sixths because they can give a superior tuning with more precision, but the theory can be hard to understand and the beat speeds of thirds and sixths are sometimes hard to hear at first.

You have already been exposed to these intervals in the process of using check notes. Notice that check notes for fourths and fifths produce thirds and sixths with the interval notes.

Example of thirds and sixths produced with check notes:
Interval F3C4
Check Note: Ab2
Third (plus octave) found at Ab2C4
Sixth found at Ab2F3

Now, the beauty of thirds and sixths is that they beat fast and that means we can easily hear beat speed differences. And it is a fact that thirds and sixths beat faster as we go up the keyboard. These differences in speed are very slight but audible with practice. Also, you must memorize:
MAJOR THIRDS and MAJOR SIXTHS ARE WIDE IN EQUAL TEMPERAMENT, ALWAYS!

The best way to use thirds/sixths is after you have used fourths and fifths to refine your temperament. At this point, start playing ascending thirds beginning at F3A4, F#3A#4, etc. You should hear a huge difference in beat speeds from one third to the next (because your temperament needs improvement). Some faster, some slower, none smooth. (If you do have a smooth increase, you can go home now) These uneven beat speeds show how much more refining is possible to improve our temperament.

Use the same absolute rules defined in 5.5 Using Fourths and Fifths to Refine.

1) When you find an out of tune interval, or one that doesn't fit, pick one interval note, assume it is sharp or flat as the case dictates, and look for corroboration by anticipating its affect on the sound of other related intervals.
2) Find two or more reasons to change a note in a common direction.
3) Change the pitch of the note in that direction and that will improve two or more intervals.

Now we can add thirds and sixths to the collection of intervals that can sound “bad” and those that can be improved.

Example of using thirds to find a note that can be improved:

As you check thirds, you find the third Ab3C4 beating too fast compared to the others.

(IMPORTANT: These comparisons must always be done against a large number of intervals in order to get the big picture. Knowing the exact speed a third must beat at is not as important as being able to fit it in with the others, no matter what speed it is beating.)

So, Ab3 is too flat *or* C4 is too sharp, *or both*.

(Remember, thirds and sixths are always wide, and the faster they beat, the wider the interval.)

Ab3 too flat? Check for too noisy fourth above and pure fifth above.
(You can check below if those notes have already been tuned.)

C4 too sharp? Check for too noisy fourth below or pure fifth below.
(You can check above if those notes have already been tuned.)

Let's assume the Ab3Db4 fourth was a bit too noisy and the Ab3Eb4 fifth was pure sounding.
(Very easy to tell when comparing the sound quality of the two intervals.)

This confirms Ab3 is flat and…

raising Ab3 *very slightly* will
1) slow down Ab3C4, (good, Ab3C4 was too fast, remember?)
2) make Ab3Db4 less noisy (good, Ab3Db4 was too noisy, remember?) and
3) make Ab3Eb4 slightly narrow and rolling. (Great, Ab3Eb4 was pure!)

INTERVAL	WHAT WAS FOUND	EFFECT OF RAISING Ab3
Ab3C4 third	Too fast, compared to other neighbouring thirds	The third slows down
Ab3Db4 fourth	Too wide and ugly	The fourth gets less ugly; just noisy
Ab3Eb4 fifth	Sounds pure-ish	The fifth begins to sound narrow and rolling.

Here, we knew which way to adjust, and by doing so, fixed three intervals.

This is the secret to tuning a very refined temperament in a short amount of time.

5.7. Important and Useful Considerations for Tuning the Temperament

So far, we have discussed tuning the temperament on our first pass using the cycle of fourths and fifths. While this is an easy order to remember, it has one big problem. You really don’t know how well you are setting the interval sizes until you complete the cycle. For example, with the method where we use check notes to try and set the interval sizes right from the start, we really don’t know how well we’ve done until we complete the cycle and check how the final interval fits with the note we started on. That’s TWELVE intervals before you know how well you are doing! That is a huge opportunity for accumulated error. It would be much nicer if we could know how well we are doing along the way, without having to wait until we have gone through the entire cycle. Here are some techniques to check our work along the way.

5.7.1 The White Anchor

The white anchor works with the cycle of fourths. We start tuning the temperament by going through the cycle of fourths as show below.

D4	D4	**C4**	C4	**A#3**	**D#4**	D#4	**C#4**	C#4	**B3**	**E4**	E4
A3	**G3**	G3	**F3**	F3	A#3	**G#3**	G#3	**F#3**	F#3	B3	A3

Notice that after four intervals we end up at F3. Now we started at A3 and it is a fact that F3A3 beats about 7 bps, about as fast as you can tap your finger. Another way to get an idea of the speed of 7bps is to look at the second hand of a watch and think “At-lan-tic to pa-ci-fic”. (7 syllables) Yet another way is to set a metronome at 105 beats per minute and think 16^{th} notes between the clicks.
So, if you end up tuning the first five intervals and F3A3 is faster or slower than 7 bps, then your intervals are not good enough. Go back and re-listen and you will find some intervals to refine. Even the smallest deviation from good interval sizes will result in a drastic difference in the speed of F3A3. That is why thirds and sixths and other fast beating intervals are more precise in setting the temperament. For example, if you tune all the intervals a bit too close to pure, D4 will be a little flat, G3 will be a little flat, and so on until F3 is so flat that F3A3 beats so fast you can’t even hear the beats.
You can also start by setting F3A3 as close as possible to 7 bps. Now all you have to do is fit D3, G3, and C3 into the first four intervals. After that, you can be much surer of these notes than if you waited until you finished the cycle. And now there are only seven notes left to tune.
These first five notes of the cycle of fourths are called the *White Anchor* and is basically the F pentatonic scale.

5.7.2 The Skeleton

The Skeleton is the notes F3A3C#4F4A4. Each neighbouring pair is a Major 3rd. The Lower Skeleton is F3A3C#4F4 and the Upper Skeleton is A3C#4F4A4. This course has been taught in the past using the methods in Appendix N – Different Skeleton Procedures. However, I believe this method that I am about to explain, is faster, easier to understand, and more precise. I call it:

Tuning the Skeleton Using the Even Tonal Change Method

I use the term "Tonal" because the tuner listens to the "tone" of the M3's, not the beats. Of course, there really is no difference, except that, at these fast speeds, many people complain that they can't hear the beats. But, if I ask them to compare the "tone" of the intervals, for example, which interval sounds noisier, or more angry, they usually can say they hear a difference.

The beat speeds of all M3's in ET must increase slightly as you go up chromatically, and decrease slightly as you go down. So, the M3's in the skeleton must do the same. Since they are not chromatic, i.e. each one is a M3 away from the previous one, not a semi-tone, the difference in speed (tone) is easier to hear. And the goal is to have them changing tone evenly. Here's how to do it:

1) Tune A3 to A4. This is very important. This octave must be as clean as possible. Make it a wide 4:2 and a narrow 6:3. Or just use your ears and listen to the treble, and get rid of the noise up there. It is possible to set a good octave that way. Using check notes and checking the 4:2 and the 6:3 does give a person more confidence.

2) Tune F3 to A3 so that F3A3 is approximately 7bps wide. Here is the beauty of this method. You actually do not need to be close at all. Anything from 2bps to 11bps will work.

3) Tune F4 from F3. Same thing here as with A3A4. Get the best octave possible.

4) Tune C#4 so that the M3's in the Lower Skeleton, F3A3C#4F4, all change in tone evenly. Note: you may have decreasing speeds, or the same speeds, instead of increasing speeds. That is ok. This step produces a very accurate C#4, depending on how clean your octaves A3A4 and F3F4 are, and how evenly changing your M3 tone is.

5) Now, tune F4 so that the M3's in the Upper Skeleton, A3C#4F4A4, all change in tone evenly.
- These must be increasing.
- You may find that they are changing evenly and increasing evenly, already. That is because you choose a good speed for F3A3, and your octaves are good.

6) If you find that you have to change F4 to get all the M3's in the upper skeleton, A3C#4F4A4, changing tone evenly, that is ok. After you have fit F4 into the Upper Skeleton, retune F3F4 clean.

7) Check all the M3's in the Skeleton. They should all be increasing in speed (tone) evenly.

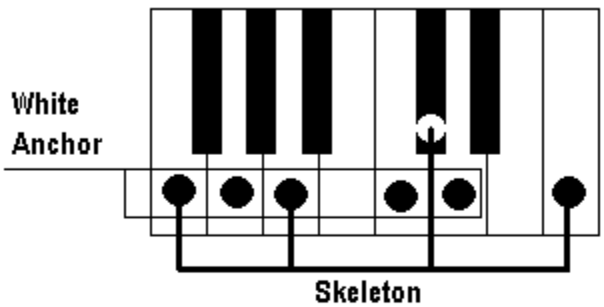
8) If you cannot get all the M3's to fit evenly, check your octaves. They are probably not as clean as you could get them.

5.7. Important and Useful Considerations for Tuning the Temperament, P.3.

5.7.3 Landmarks along the Way

As mentioned at the beginning of 5.7. Important and Useful Considerations for Tuning the Temperament, just using the cycle of fourths or fifths leaves you with opportunity for huge accumulated error. The white anchor and the skeleton are two ways to check your accuracy early on. And checking for smoothly increasing beat speeds of thirds and sixths will help you refine some notes after you finish the temperament. But, if you are aware of the notes you have already tuned, and you are quite sure of their accuracy (because they were tuned using the white anchor or skeleton, for example), then you can check the speeds of the thirds and sixths “on the fly” so to speak.

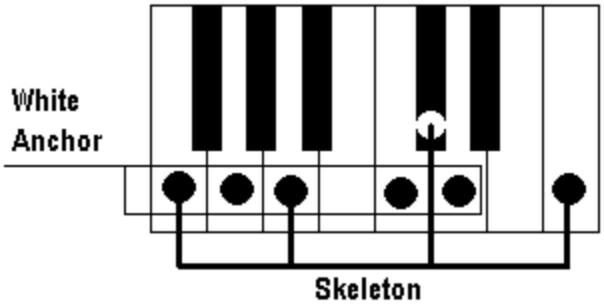
Example:
After tuning the white anchor and the skeleton, you will have tuned the following notes within F3F4:



F3, G3, A3, C4, C#4, D4, and F4

It shouldn’t be too hard to imagine that there are some notes that, if you were to tune them next, would make a major third or major sixth with a chromatic neighbour.

5.7.3 Landmarks along the Way (Continued)



Example: If you were to tune E4 next, it makes a third with C4, but has a chromatic neighbour at C#4F4. (Both have already been tuned) After you tuned E4 using A3E4 perhaps, you could then check C4E4 with C#4F4. It should be ever-so-slightly slower. *Not* faster. It may be hard to tell if it is the same, but you should be able to tell if it is faster, and then you will have to find one of those notes in there somewhere to improve.

Note, you could also check F3D4 with G3E4. The latter should beat a little faster than the former. Yes, but by how much faster is really tricky to tell. The real value in this test comes if G3E4 is *slower* than F3D4. If so, time to refine somewhere. Maybe E4 is too flat. Check A3E4 again. Is it too rolling, maybe a bit noisy? If so, there is room to raise E4 and recheck the thirds and sixths. Don't forget the fourths and fifths as well. Sometimes we can get the thirds and sixths smooth at the sacrifice of the fourths and fifths. They *all* have to fit!

This was just a small example of what a good aural tuner might be thinking. So you see, to really move quickly through these intervals, you have to have a strong understanding of interval theory and spatial understanding of wide/narrow intervals and their sharp/flat notes.

CHAPTER VI - Extreme Octaves

After tuning the temperament octave, you then work your way up and down, tuning octaves using notes from the temperament octave.
For example, if you are working your way up first, tune F#4 using F#3 and other intervals below F#4. (B3F#4, C#4F#4, etc). Continue all the way up. (Up to C8 on the grand, and only up to the last mid note on the upright. See 7.1.2 How to tune the Unisons – Upright Piano Treble for an explanation of how to tune octaves in the treble)
Working down, tune E3 using E4 and other intervals above. (E3A3, E3B3, etc) Continue down to A0. You might have to pull out the mute strip to tune the top unichord. It may have been muted by the mute strip when the piano was muted.

6.1 What Octave Sizes and Where.

As was explained in 4.1 Different Octave Sizes, the ideal octave size seems to be between a 4:2 and a 6:3.This size is a good compromise between the out of tune partials that are audible. As we go up the piano into the high octaves, the higher partials are less audible and the out of tune 8:4 partial created by making a 2:1 or 4:2 octave, is not that prominent. For this reason we say we can tune 2:1 octaves in the top octave. Using check notes for a 4:2 octave produces beats that are too fast in the top two or three octaves of the piano anyway. If you just continue to make the best sounding octave, while still listening to the higher coincidental partials that are produced, you will start making smaller octaves anyway.

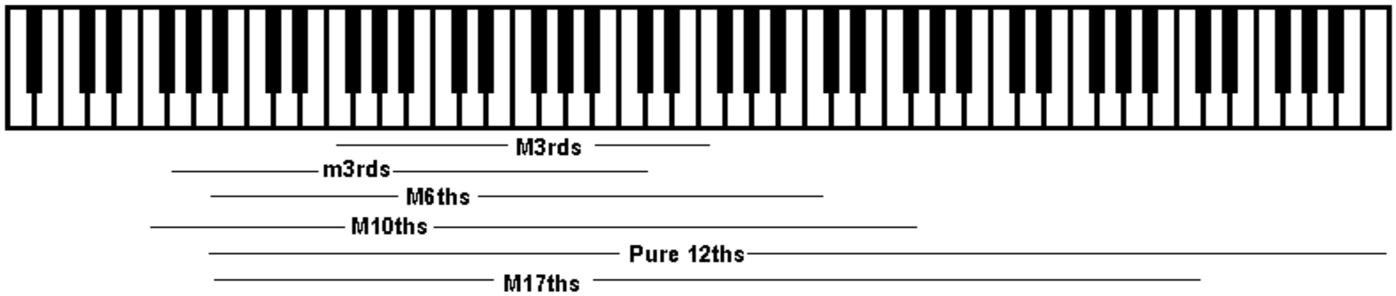
Similarly, but with opposite effect, octaves in the lower part of the piano have more and more audible higher partials. I.e. we begin to hear the 10:5 coincidental partials beating, or even higher on a good grand. For that reason, many texts advocate tuning the lower octaves as 6:3's. Again, you can use the 6:3 check notes but if you concentrate on minimizing the beating in the higher coincidental partials that you can hear, the octaves will be getting bigger anyway.

6.2 Speed of Thirds, Sixths, Tenths, 12ths, 17ths.

We have seen in Appendix F – Equal Temperament, that using narrow fifths to make possible the playing in all 12 keys, produces rather fast beating thirds and sixths. (F3A3 beats about 7bps and thirds beat faster, higher up)
At first I thought, "Well that's just bad. Those out of tune thirds and sixths certainly don't need any more of my consideration." I have since come to appreciate the unique colour of the piano created by these "out-of-tune" intervals. Indeed, many much more learned technicians and musicians have realized this long ago. It behooves us not to work on creating and preserving a smooth transition of colour from one interval to the next.

6.2 Speed of Thirds, Sixths, Tenths, 12ths, 17ths. (Continued)

Here are the areas where it is a good idea to try and create a smooth transition of colour (beat speeds) on the piano. Each section is chosen for the ease of being able to hear the beat speeds of the intervals listed.

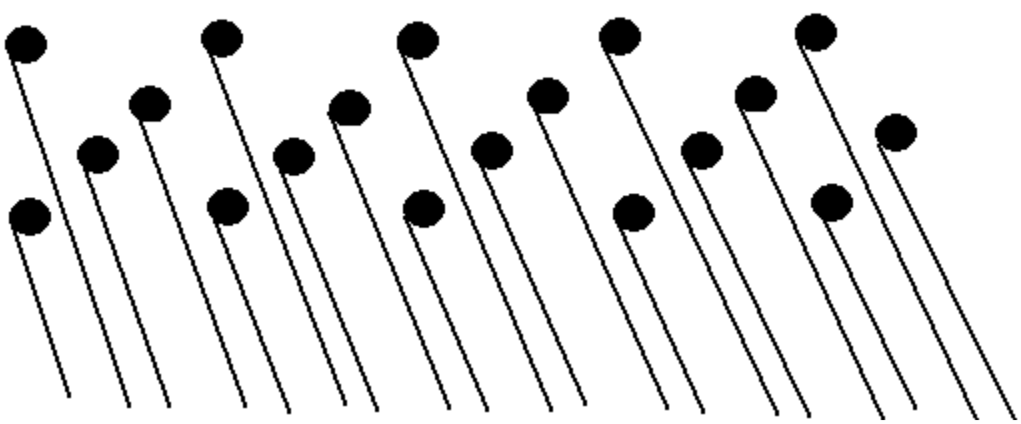


(I like to make the 12ths pure. I.e. no beats at all. Use the check note a Maj6 below the bottom note of a 12th.)

6.3 Bass Tuning Pin Patterns

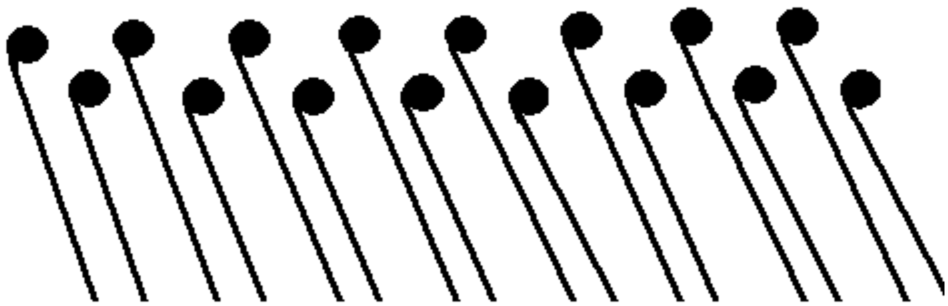
Tuning a middle string in the middle section of the piano; it is easy to figure out which pin to turn. They are oriented vertically, so it is just the middle pin in the vertical group of three.
However, when we get to the pins in the bass bichords, it may not be so intuitive at first.

There are basically two orientations for bass pins, four row and two row.



Four Row Bass Pin Orientation

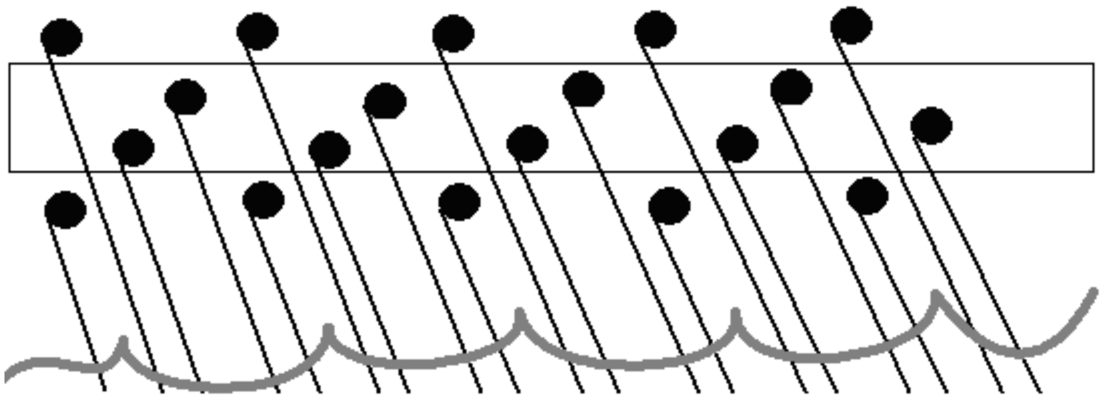
6.3 Bass Tuning Pin Patterns (Continued)



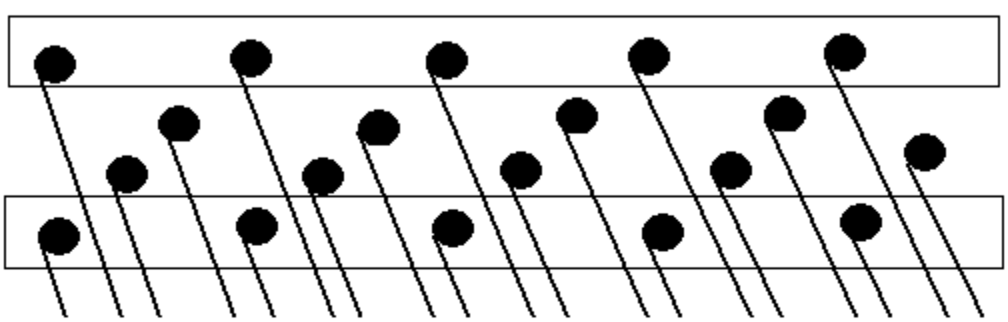
Two Row Bass Pin Orientation

When you insert the mute strip between every second bichord in the bass, as instructed to do in 2.2.1 Muting the Bichords When They End at the Tenor Break (Design #1), you create a pattern of free strings to tune depending on the orientation of the pins. Then when you remove the mute strip a similar pattern is created. Memorize these orientations (shown below) and you will never have to follow the strings up to find the right pin to turn again.

6.3.1 Patterns for the Four Row Orientation



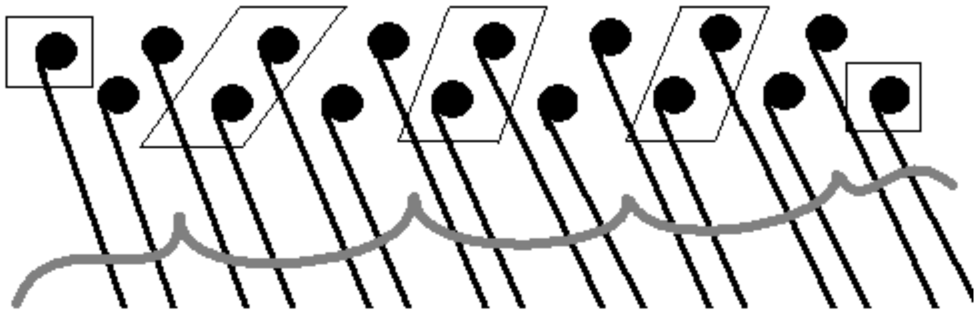
In this four row tuning pin orientation, once the mute strip is inserted between every second note, then the INSIDE pairs become the pins to turn.



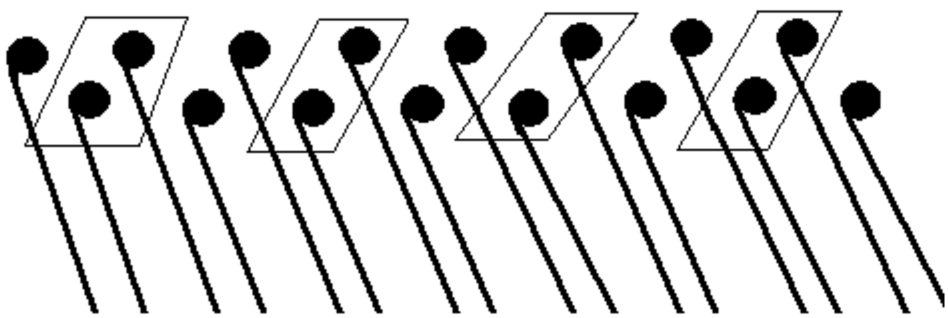
Once the mute strip is removed, then the other pins, the OUTSIDE pairs, are the pins to turn.

Note: When the mute strip is initially inserted, you may end up with the outside pairs being the first to tune. Just look at the strings to figure it out.

6.3.2 Patterns for the Two Row Orientation



When the mute strip is initially inserted into this two row orientation of bass pins, the pattern that is produced is a RIGHT SIDE SLANT SECOND PAIR pattern with some singles on the ends. Rarely you may find left side slant patterns created.



When the mute strip is removed on this two row orientation, the pins left to turn is the other RIGHT SLANT EVERY SECOND PAIR.
Note: Sometimes singles are left at the ends. Closely inspect each situation.

6.4 Tricks for the Bass

Because the bass notes have such little fundamental in their tone, it can be quite hard to tune them. In fact, beginners can sometimes be so off that the string can break, even though the octave seems to sound ok. This is because you can be listening to a 4^{th} or 5^{th} or 11^{th} or 12^{th} and think it sounds like an octave. Here are some techniques that may help you set those low octaves better.

6.4.1 Melodic Tuning

Play an octave major scale down from the high octave note. If the low note is out, your ear will pick it out. You don't need to worry about the octaves sounding clean – they won't unless it is a concert grand anyway – but you can hear the low note out when played in a melody. Get the low notes to sound good melodically and the player will be able to use them musically and you won't be wildly out and risking a break.

6.4.2 Tuning Higher Harmonics Melodically

Place the back of your finger (fingernail) gently against a low string and play. (Try not to touch the string with your skin, the oils can cause rust.) Touch close to the hammer (without touching the hammer on an upright). This should produce a higher harmonic (usually the 5^{th}) which is cleaner and easier to hear than the fundamental. Now play the bottom 7 notes or so, chromatically, each time placing your fingernail gently against the string to produce the same partial. If there is a string that is way off, you will hear it easily because the chromatic scale will sound bad at that note.

CHAPTER VII – Unisons

After tuning the temperament and all the octaves, we now have to tune the unisons.

7.1 How to tune the Unisons

The procedure for tuning the unisons is to remove the mutes so that strings are freed. Once freed, the strings must be tuned to the already tuned string. Only one string per note must be freed and tuned; it is almost impossible to tune two out-of-tune unisons to a third string at the same time. First one, then the other must be tuned.

7.1.1 Unisons on the Grand Piano

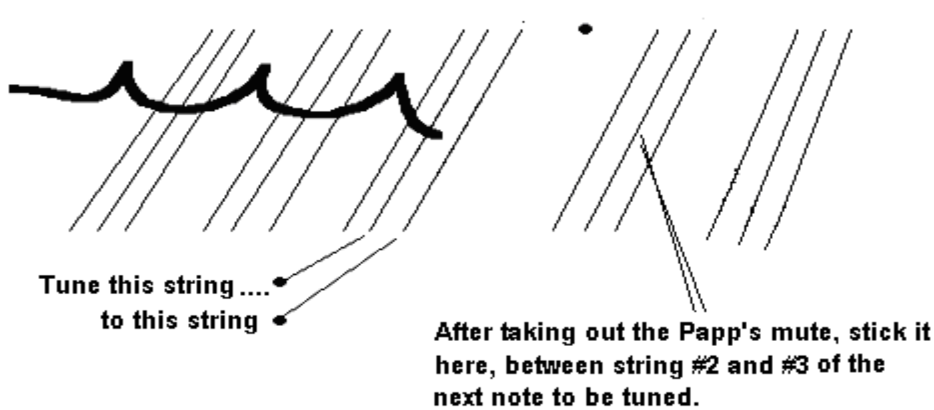
For the grand piano, each note was muted so that only one string was free to vibrate. That was the string that was first tuned for each note. After all the free single strings are tuned, you then simply work your way up or down, as you wish, pulling out the mute strip and rubber wedges. The only thing to really remember here, which is intuitive, is to only free up one string at a time per note, tune the just freed string to the already tuned string, then free up the last string and tune it to the other two.

7.1.2 Upright Piano Treble

For the upright, we cannot get the felt into the treble section because there is no room above the hammers, i.e. between the v-bar and the hammers, for the mute felt. That is why we use the Papp's mute under the hammers to selectively mute off specific strings. The first unison to tune occurs when we remove the Papp's mute. That frees up the center string of the last mid note.

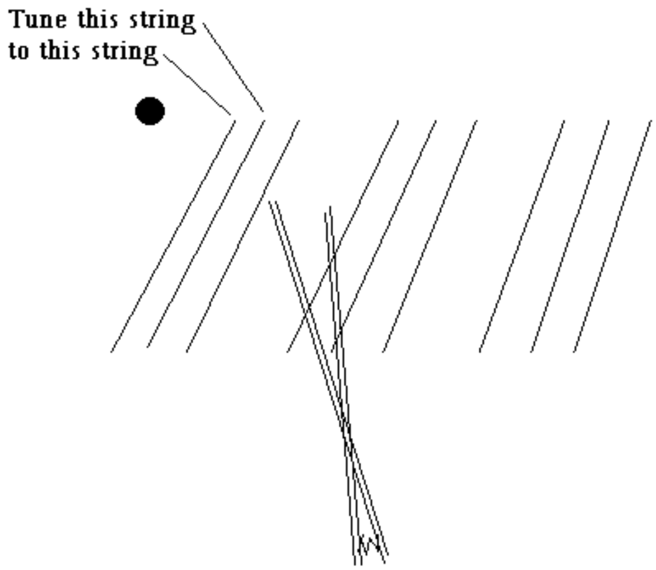
We will start with the note at the Papp's mute.
Take out the Papp's mute and stick it between the second and third string of the first note in the treble.
Now, tune the last note before the treble break, 2nd string segment to 3rd string segment, center to right. (The 3rd string segment was tuned using the intervals below it when you were tuning octaves above the temperament.)

Now, moving up, (leave the center section for now), tune the first treble note like this:
1. Tune the left segment from intervals below, (octave, fourth, fifth, etc,) using compromise and making sure they all sound good.

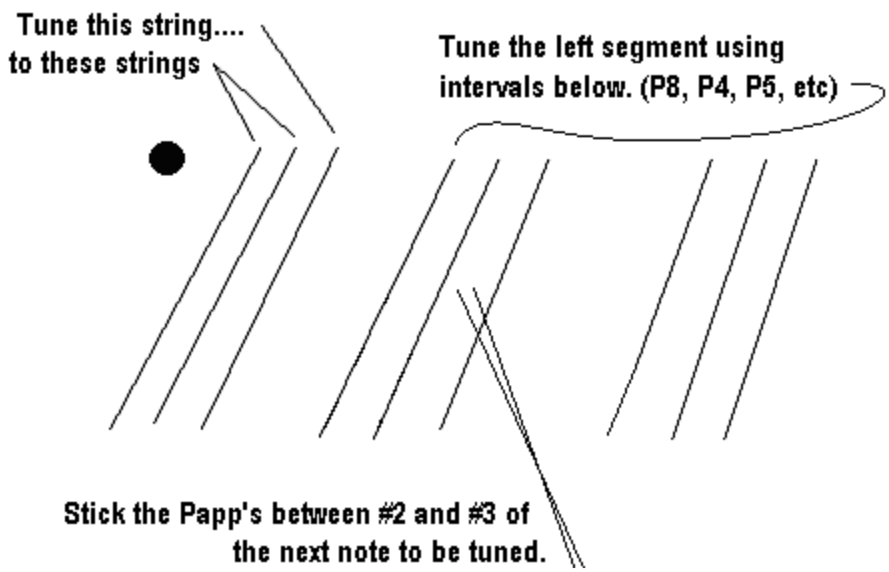


7.1.2 Upright Piano Treble (Continued)

2. Now, take the Papp's mute out of this note and put it between this note and the next note. You have just freed the center segment and it is the next to be tuned. Tune it to #1.



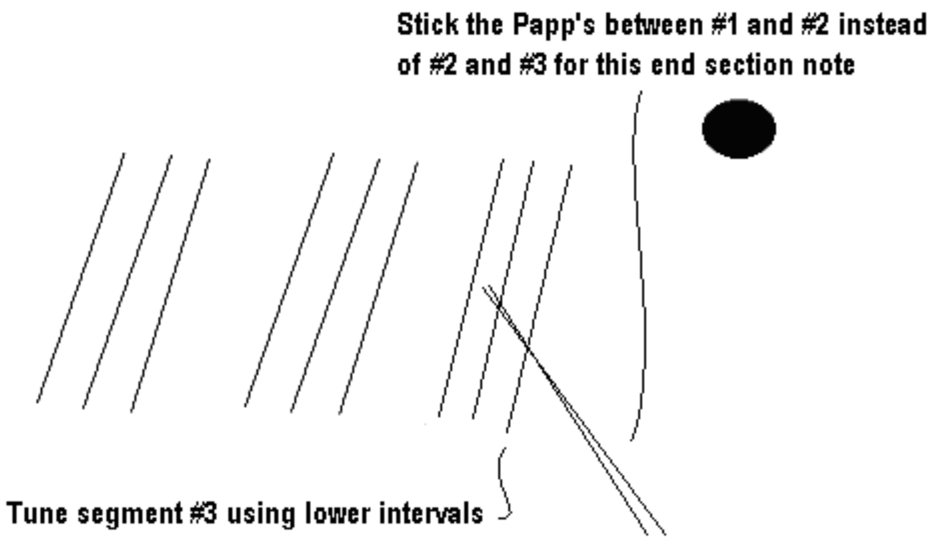
3. Now, move the Papp's mute to between segment #2 and #3 of the next note to be tuned. Then tune the right string (just freed) to the center and left strings (which should sound like one string now.) Finish this step by tuning the left segment of the next string to be tuned using intervals below. (P8, P5, P4, etc)



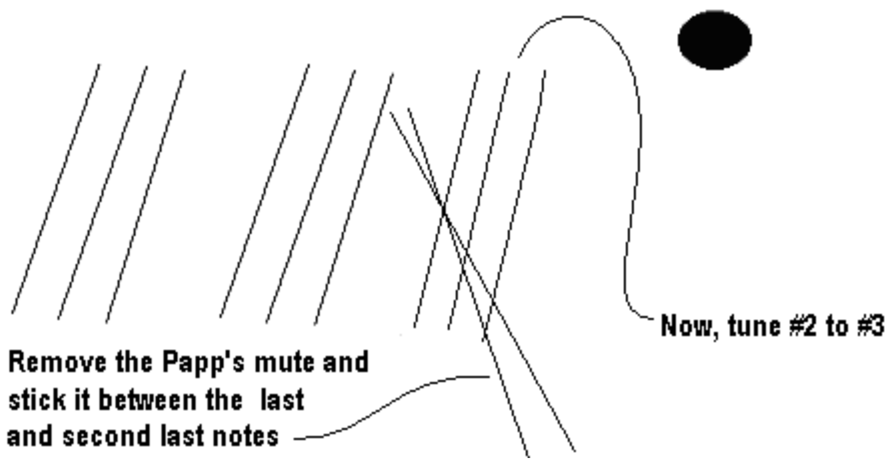
Continue on with this pattern until you get to the top note.

7.1.2 Upright Piano Treble (Continued)

When you get to the top note, stick the Papp's mute between segment #1 and #2 instead. This leaves #3 open to be tuned first. (This technique is the simplest way to tune the unisons of an end note)



Then move the Papp's back between the two notes (last and second last notes) and tune #2 to #3.



After that, take out the Papp's mute and tune #1 to the others. (#2 and #3).

Before you move on to the middle section, check over these treble unisons using the techniques listed in 7.2.3 Comparison Technique for Trichords
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7.1.3 Upright Piano Middle and Bass Sections

After tuning and checking the treble section, it is time to tune the unisons in the bass and middle sections.

7.1.3a Pulling Mutes in the Middle Section

The first thing to do is to take the mute strip partially out of the middle section. Pull it out, one note at a time, until you get to the first trichord. If there is a rubber wedge mute in that trichord, pull it out also.
By following these instructions, you will have succeeded in exposing only one untuned string in every bichord and first trichord in the middle section. (You need to expose and tune only one untuned unison at a time)
Then work your way up, pulling and tuning as needed.

7.1.3b Pulling Mutes in the Bass Section

Once the middle section is tuned and checked (See 7.2.3 Comparison Technique for Trichords), it is time to tune the bass unisons.

If there are any trichords in the bass, you will need to be careful how you pull the mute strip out here. Just remember to only expose one untuned unison at a time per note. It will be like the middle section trichords, just in reverse.

When there are only bichords left to tune, you can whip out the mute strip and expose all the untuned bichord unisons. (There are only 2 strings in a bichord, and at this point, one has been tuned. So, you can rip out the mute strip and you will only be exposing *one* untuned string per note.)

7.2 What to Listen For

The skill of tuning clean unisons may be the most important skill a tuner needs. If there are any unisons out of tune, that is what the customer is going to hear. In general, customers listen more to unisons to gauge whether a tuning is good or not. Use the techniques listed hear to improve your unisons and leave them clean.

7.2.1 What Does a Clean Unison Sound Like?

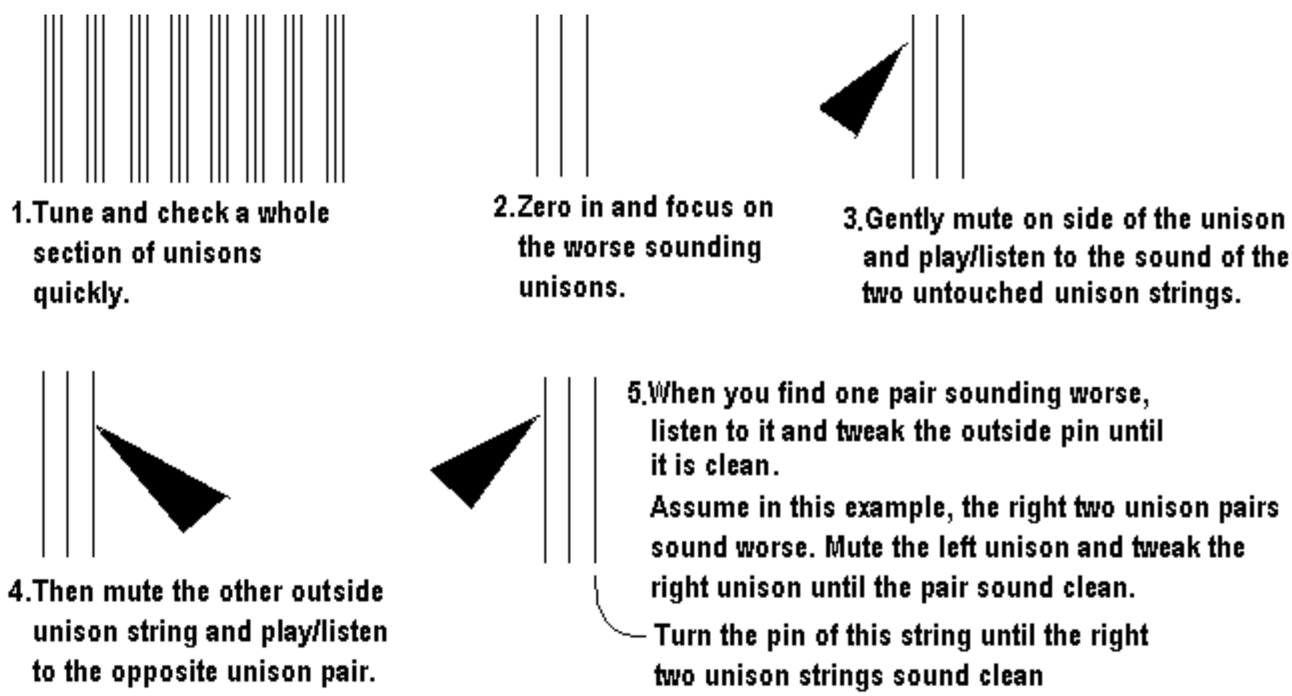
Theoretically, you can read why a unison sounds good in 3.3 Unison Concepts. When the unison is even the slightest bit out of tune, there will be beats of different speeds at each of the harmonic pairs. This results in a “shimmering” tone. A clean unison, while very close to an “only slightly out of tune” unison, sounds completely different; there is no shimmering. In fact, the sound of a clean unison is so unique that we can describe it with strong words. For example: dead, colourless, unmoving, solid, on the floor, etc. Students sometimes tell me that these descriptions are not flattering; that it is unintuitive to use these descriptions since we want a good tone, not a ”dead” one, for example. The descriptions here are really in contrast to the tone of an-out-of tune unison; unisons tuned “dead” or “colourless” really do sound beautiful, especially when played with other clean unisons on a piano with good interval sizes.

7.2.2 General Approach to Tuning Unisons

The best way to tune unisons is to run through them quickly, then come back and check them. The benefit of running through them quickly is that you will increase your tuning speed. Also, you will probably have tuned some clean unisons by chance, if anything else. And to get a clean unison from the start is very difficult especially for beginners. Think of the analogy of trying to get 100 darts all in a bullseye. If you were to grab handful after handful and just chuck the darts at the board, you would probably get much more in the bullseye, and faster, than if you took your time with each dart and obsessed about hitting the bullseye. You can always do that later, after you've nailed quite a few. It's the same with unisons.

7.2.3 Comparison Technique for Trichords

Now here's where the beginner can really improve their unisons, and learn what a good unison sounds like. After tuning a section of trichord unisons, go back over the section and check each unison like this: Use your wedge mute and gently mute one of the outside strings. Play and listen. Now gently mute the other outside string. Play and listen. You are now comparing the left two strings to the right two strings. Hopefully, you can hear that one sounds better than the other. I have mentioned in 5.3 Wide Noisy Fourths and Narrow Rolling Fifths and What They Sound Like, the importance of focusing on reducing the bad sounding notes/intervals and not obsessing about "perfect" sized intervals or notes. It is the same approach here. Don't obsess about the perfect sounding unison, just search and improve the bad sounding ones. So, after playing the left and right unison pairs, you should hear that one sounds better and one sounds worse. Mute off the good sounding unison and tweak the bad sounding unison until it is cleaner. Now play all three together. It should sound much better now.
Continue on this way, tweaking the "dirty" unison pairs, and as your ability to discern the "dirty" unisons gets better, so will the quality of the unisons you leave behind.



7.3 Extreme Treble Octaves

Tuning unisons in the extreme treble octaves can be difficult; the tone is generally weak in those areas and the typical techniques don't work as well. Also, because the frequency is so high, the strings are very sensitive to any slight changes in tension. Try the following technique which may improve your results.

Melodic Unisons

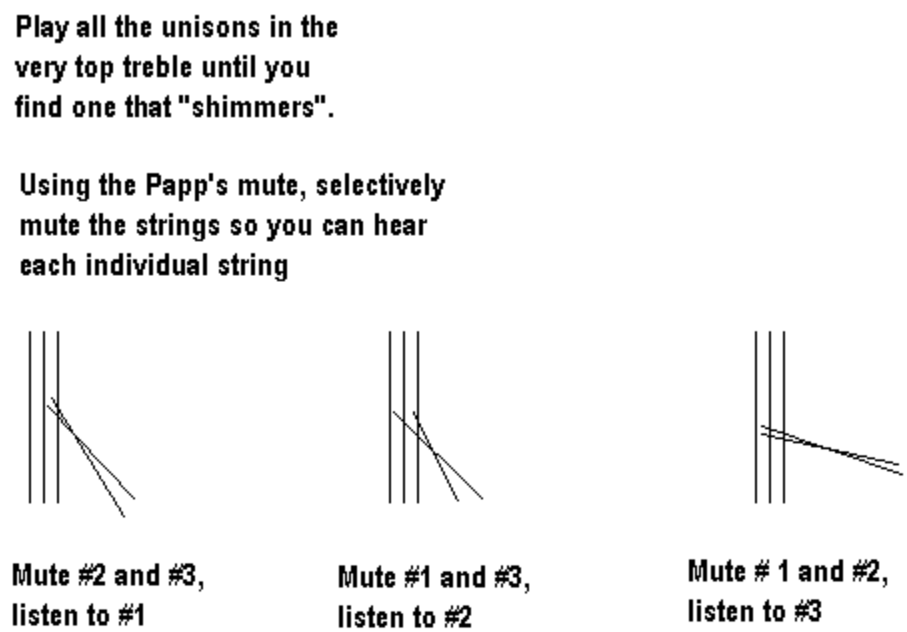
The top treble notes are very sensitive to changes in frequency and it turns out that we can hear those changes when we play each string separately. So, try this when tuning top treble unisons:

1. Stick your Papp’s mute into string #2 and #3. Play the note. You are now listening to string #1.

2. Stick the Papp’s mute so that it is slightly open and pressing outward on the outside unison strings, #1 and #3. Play. You are now listening to string #2.

3. Stick the Papp’s mute between string # 1 and #2. Play. You are now listening to string #3

By checking each unison string separately and listening melodically to each string, you may begin to discern that one string sounds slightly sharper or flatter than the others. Take the mute out now and tweak that string gently in the direction that would make it sound closer to the other strings, while listening to all three unison string being played. You should hear the tone of the unison cleaning up nicely. Remember, don’t look for perfection, just get it sounding *better.*

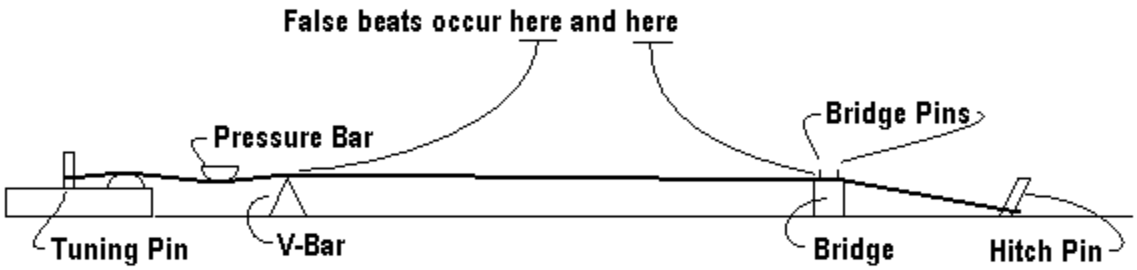


Steps to find a treble unison that can be improved.

7.4 False Beats

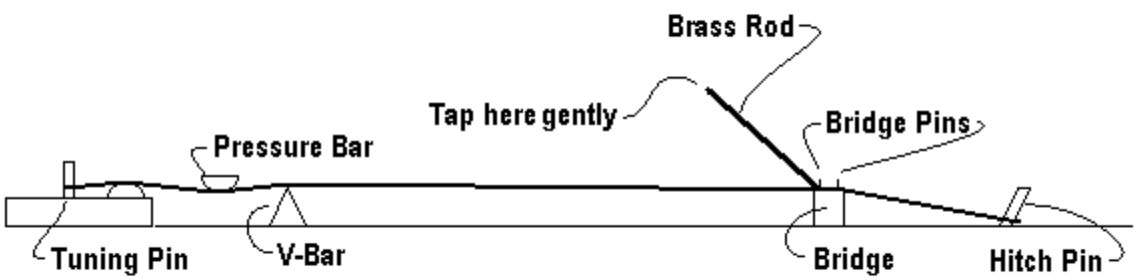
Occasionally, in the treble mostly but elsewhere sometimes, you will hear beating from a single string. This is called a *false beat*. False beats occur when the termination points of a string are not solid, or when the quality of the string is poor, or when there is a structural imperfection in the string, like a kink for example. By far, the most common reason is due to the weak termination points.

There are two termination points for each string; where the string rests on the v-bar (near the tuning pin side) and where the string meets the first bridge pin and the bridge.

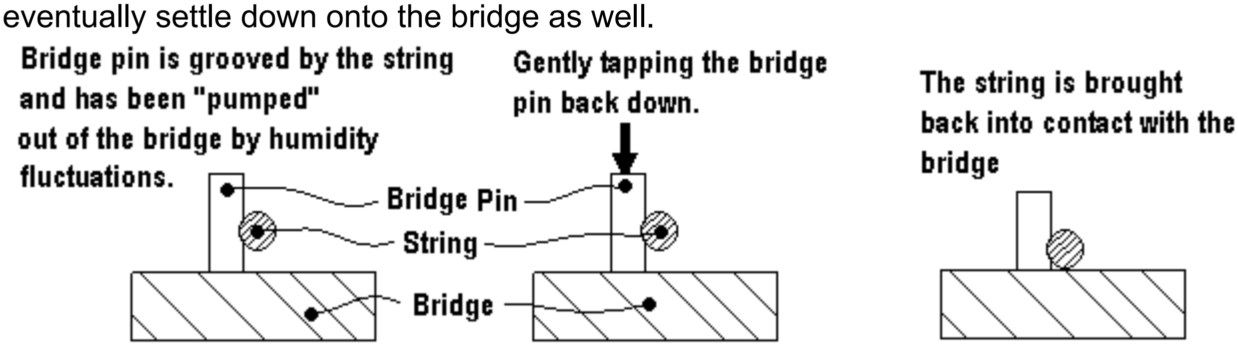


If you hear a false beat on one string, try these procedures to see if you can eliminate it or at least reduce its affect.

Tap the string onto the bridge.
Take something soft like a hammer shank or a brass rod. Do not use a screw driver or you may break the string. Place the rod on the string where it meets the first bridge pin. Gently tap the string. You may even see it move down onto the bridge. Do not tap too hard as you may indent the bridge with the string and that will cause more false beat problems later.

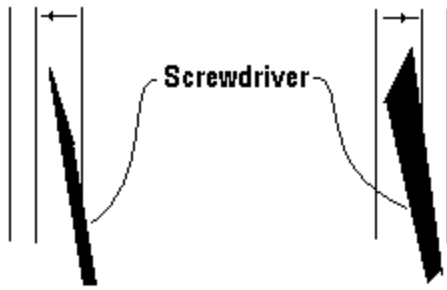


Because of the risk of indenting the bridge, some technicians prefer to tap the first bridge pin into the bridge a bit. They feel that the bridge pin has a groove in the side of it, caused by the string, and that humidity fluctuations cause the pin to be “pumped” out of the bridge. Tapping the bridge pin down gently causes the groove to line up again with the top of the bridge, and the string to follow in the groove and eventually settle down onto the bridge as well.



7.4 False Beats (Continued)

Burnish the V-bar.
Take a screwdriver and move the offending string side to side where it sits on the v-bar. The string may have carved a groove into the v-bar and this burnishing technique will "pave" it out so that the string lies on a flat surface again. You may hear clicking sounds at first as the string goes in and out of the groove. Soon the clicks will subside as the groove is reduced or burnished.



7.5 Phasing

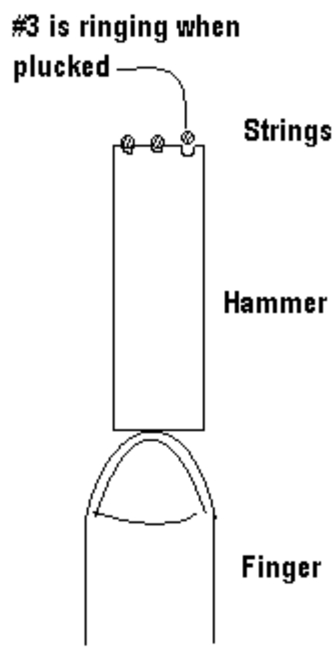
Sometimes, the hammer does not hit the three strings of a trichord at exactly the same time. This starts the strings vibrating at slightly different times, so that the tone has a "whinny" sound to it, even when the unisons are vibrating at the same frequencies. This effect is most audible in the mid section of the piano. The effect can confuse the beginning tuner who may continue, without success, to try and get the unison to sound better. In any event, the tone is poor and must be improved.

When confronted with a bothersome unison in the mid section, test it to see if the hammer is mating well with the string.

Mating Test – Upright Piano

1. Very gently press the hammer against the string.
2. Depress the sustain pedal and press gently against the hammer or hold the hammer gently against the strings by press up on the wippen (preferred).
3. Pluck each string separately and listen for three dull thuds.

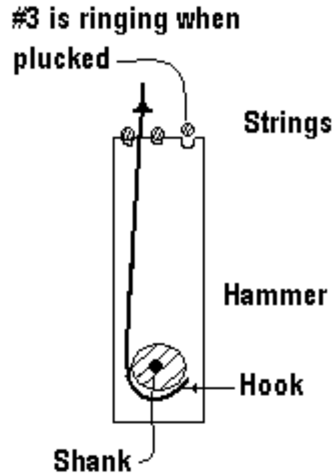
All three strings should make a thud sound. If one or more ring, it means that string is being hit later than the others. In the example, string #3 is being hit later, and rings in the mating test.



7.5 Phasing (Continued)

Mating Test – Grand Piano

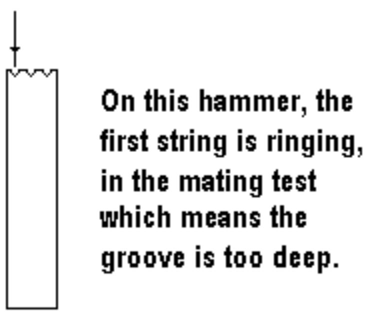
1. Make a hook from a short piece of piano wire.
2. Hook a shank through the strings and pull the hammer up so it blocks against the strings.
3. Press the sustain pedal.
4. Pluck each string separately and listen for three dull thuds.

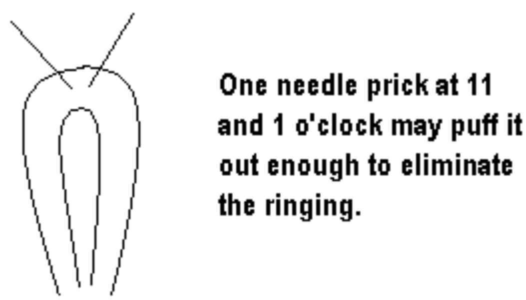


All three strings should make a thud sound. If one or more ring, it means that string is being hit later than the others. In the example, string #3 is being hit later, and rings in the mating test.

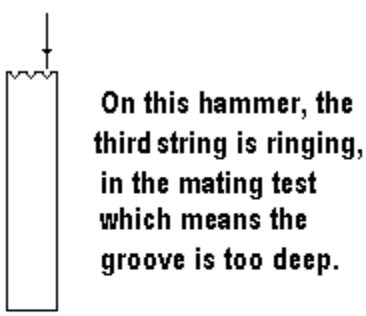
There are three possible solutions to fix this:

1. Use a voicing needle and gently pierce the hammer groove of the ringing string at 11 and 1 o'clock so that it is puffed up again.





2. Use a sanding paddle and sand down the other grooves that are too high.



3. Level the strings. This is not recommended on older pianos as it changes the way the damper meets that string and then the damper may not dampen effectively.
However, if you are working on a grand and the strings are not level, filing or sanding the hammers may improve the tone, but as soon as the shift pedal is used, the tone may be worse. In this case, string leveling and new dampers are the only cure.

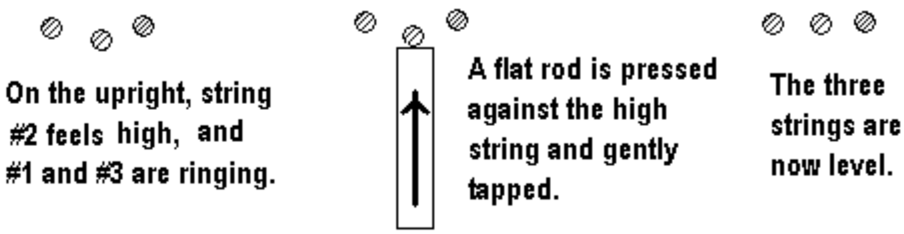
How to Check for String Level

Check to see if the strings are not level by gently feeling the strings with your finger. One or two strings may feel higher or lower. This should coincide with the string that is ringing.
Example: String #1 and #3 are ringing, so #2 should feel higher on the upright. (Lower on the grand)

Leveling Strings to Reduce Phasing

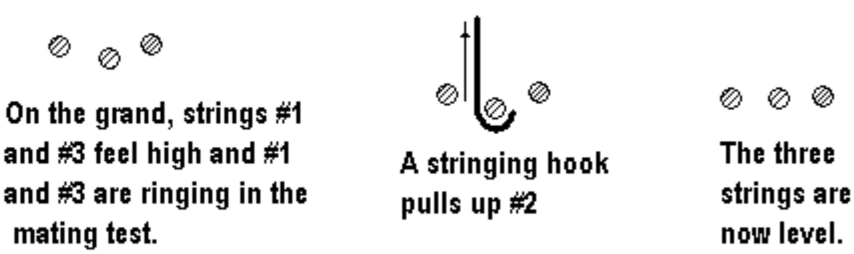
Upright Piano

If one or two strings are higher, and they are blocking against the hammer while the others are ringing in the mating test, then you can gently tap down the higher strings. Use anything that has a flat end. Tap gently and then retest.



Grand Piano

If one or two strings are lower and they are blocking against the hammer while the others are ringing in the mating test, then those strings can be lifted. Use a stringing hook and gently pull up on the string and retest.



7.6 Harmonic Technique for Tuning Unisons

As mentioned in Appendix A – The Harmonic Series and Tone, each string rings with a series of frequencies (higher partials) above a fundamental. When two strings ring together, so do the higher partials. If the fundamental of the two strings is out of tune, there will beat beats at the fundamental, and since the higher partials are multiples of the fundamental, the beats at the higher partials will be faster.

Partial	String One – Frequencies	String Two – Frequencies	Speed of Beats at Higher Partials
8	800	808	8
7	700	707	7
6	600	606	6
5	500	505	5
4	400	404	4
3	300	303	3
2	200	202	2
Fundamental (1)	100	101	1

Listening to the fundamental when tuning a unison is not as accurate because, even if you could tune out the fundamental beat to, say, 0.1Hz, the beat at partial 8 would be 8 times that or 0.8Hz, almost one beat per second!

However, if you could focus on partial 8 and get that to 0.1Hz, then the beat at the partial would be 1/8th of that, or 0.0125Hz, i.e. veeerrrryyy ssllloooowwww.

Here's how you can do that.

1. Press down the key of the unison note you are tuning. This lifts the damper and allows the strings to vibrate sympathetically.
2. Staccato strike the note that corresponds to the 8th partial. (Any appropriate higher partial will do.)

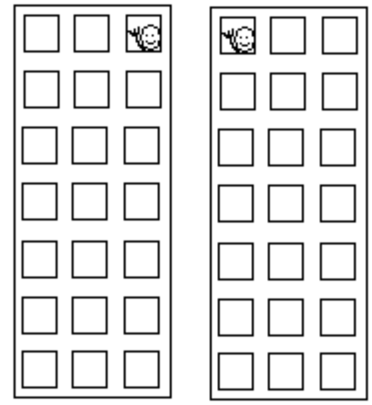
You should hear a faint beating. Tune it out. Now when you play the unison, it should be rock solid!

A few points:

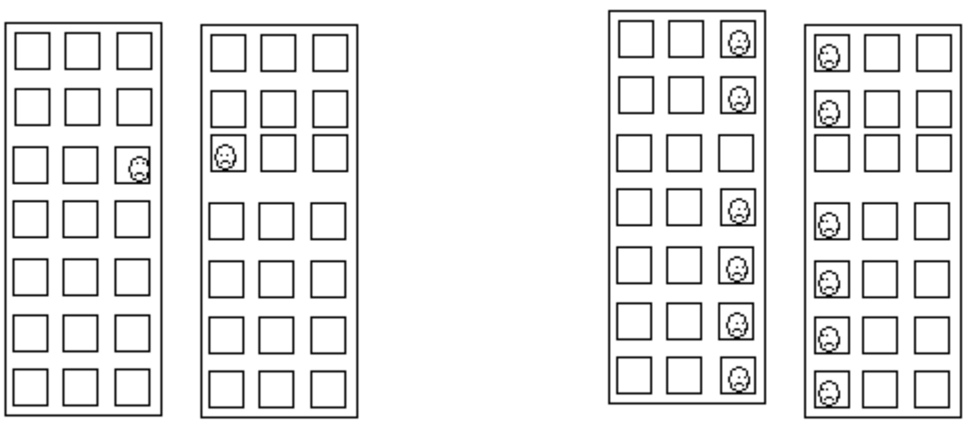
- The note corresponding to the higher partial needs to be fairly close to the frequency of said partial, else the partials will not be excited.
- The note corresponding to the frequency of the higher partial should have a damper associated with it, else it will continue to ring and drown out the beating partials.

7.7 Unmatched Strings

Consider the frequencies of the higher partials as floors of a building. When two strings are tuned as unisons, it's as if two buildings are erected side by side with each floor matching up with the same floor of the other building. This is the situation most of the time; each string of a unison has the frequencies of the higher partials matched to the other unison strings so that, when the unison is tuned, each partial group is identical and there are no beats at those partials.



However, occasionally the string's partials do not line up and no matter how the unison is tuned, it will never sound clean. I.e. the floors of the buildings will never line up, no matter at what height the buildings are erected. This is mostly due to a manufacturing error where the strings are not the same size.



In the first pair of buildings, one of the floors does not line up. For the unison, that means one of the partials is beating while all the others are beatless.

In the second pair of buildings, we have erected the height to line up with that floor, but all the other floors now do not line up. For the unison, we have tuned out the beats at that partial, but all the other partials are beating.

This situation is most noticeable in the bichords. There are only two solutions. (One not really being a solution) You can just try and tune the unison the best you can without one partial sounding too much out of tune. But the only real solution is to change one or both strings. Changing both strings gives you the best chance of getting matching strings. Measuring one and trying to replace it will not always work because the strings may not be *exactly* the same size.

CHAPTER VIII – What Next!?

Now that you've finished the course on Basic Piano Tuning, here are some suggestions for what you can do next to improve your skill.

Join an Association
The Piano Technicians Guild (PTG.ORG) is an excellent place to gain valuable knowledge about piano technology. The cost is about $245USD per year (2010) and includes a professional monthly publication called the Piano Technicians Journal. You will also receive reduced fees for conventions and opportunities to write exams for the Registered Piano Technicians certificate. Also, the Canadian Association of Piano Technicians (CAPT see pianotu.ning.com, yes the . is good). Look for free seminars being given across Canada.

Take More Courses
Mr. Tuner offers an advanced course similar to the basic one except more precise techniques are used and computers are used to test the accuracy of your skill.
Correspondence Courses. Check the internet, there are a few including Randy Potter's course. They tend to be quite expensive and without a live tutor, can be frustrating.
Look for courses offered at other schools in Canada and the US.
Finger Lakes Community College, New York State. www.fingerlakes.edu
Chicago School of Piano Technology. www.pianotechschool.com
Western University in London, Ontario www.pianotech.uwo.ca
Mr. Tuner also offers courses in repair and rebuilding. www.mrtuner.com/courses.htm

Practice
Get an old piano that can be tuned then practice and test yourself with an ETD. You will also be able to practice some of the repair skills that are needed to be a successful piano technician.

Work with Mr. Tuner in your city
We are in the process of creating a business package that will help beginning technicians build their business faster. This includes web site listing, license to use logo, invoices, business crads, promotional materials, shirts, jackets, car signage design, etc. If you are at an acceptable level of ability, you may be eligible to use the services.

Many Happy Tunings!

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Appendix A – The Harmonic Series and Tone

Every musical note contains a series of frequencies called the Harmonic Series which make up the note's tone or Timbre. (*Tam*-ber)
We hear the lowest frequency as the note's actual pitch. This lowest frequency is called the Fundamental or first partial.
The tone is determined by how much of the higher partials are present in the note.
Think Ewwwww and Eeeeeeeee. 'Eww' has less high partials in the tone than 'Eee'.
Your vocal chords have their own harmonic spectrum but the shape of your mouth filters out some of the partials in that spectrum.

The frequencies of the partials in a harmonic series are whole number multiples (1, 2, 3 etc) of the frequency of the fundamental.
Example: A note with a fundamental of 100 Hz has a harmonic series of 100Hz, 200Hz, 300Hz, 400Hz, etc
The actual note names close to those frequencies can be determined by the following chart:

Partial	Interval above fundamental
1	PU (Perfect Unison)
2	P8 (Perfect Octave)
3	Octave plus P5
4	2 Octaves
5	2 Octaves plus a Maj3
6	2 Octaves plus a P5
7	2 Octaves plus a *flat* m7
8	3 Octaves

When naming notes, we use a system where a number is given to each octave.
The bottom three notes belong to octave 0, and they are called, A0,A#0, and B0.
The new octaves start at C, so the next note would be C1. (There is no C0).
The top note is C8.

Example: Harmonic Series of A1

Partial	Note			
1	A1			
2	A2	←Notice the left		
3	E2	←hand bass		
4	A3	←pattern here	←Notice the	←Notice
5	C#3		←Major Chord	←the Dominant
6	E3		←here	←7th chord
7	G3			←here
8	A4			

***For non-musicians, the pattern is:

Start on any note – count up 12, 7, 5, 4, 3, 3, 2.

Start	Up 12	7	5	4	3	3	2
1st Partial	2nd	3rd	4th	5th	6th	7th	8th
1	A2	E2	A3	C#3	E3	G3	A4

Harmonic Series WORKSHEET

Harmonic Series of D1

Partial	Note
1	_____
2	_____
3	_____
4	_____
5	_____
6	_____
7	_____
8	_____

Harmonic Series of E3

Partial	Note
1	_____
2	_____
3	_____
4	_____
5	_____
6	_____
7	_____
8	_____

Harmonic Series of F2

Partial	Note
1	_____
2	_____
3	_____
4	_____
5	_____
6	_____
7	_____
8	_____

Harmonic Series of G#2

Partial	Note
1	_____
2	_____
3	_____
4	_____
5	_____
6	_____
7	_____
8	_____

Harmonic Series of Db3

Partial	Note
1	_____
2	_____
3	_____
4	_____
5	_____
6	_____
7	_____
8	_____

Harmonic Series of Ab4

Partial	Note
1	_____
2	_____
3	_____
4	_____
5	_____
6	_____
7	_____
8	_____

Harmonic Series ANSWER SHEET

Harmonic Series of D1

Partial	Note
1	D1
2	D2
3	A2
4	D3
5	F#3
6	A3
7	C4
8	D4

Harmonic Series of E3

Partial	Note
1	E3
2	E4
3	B4
4	E5
5	G#5
6	B5
7	D6
8	E6

Harmonic Series of F2

Partial	Note
1	F2
2	F3
3	C4
4	F4
5	A4
6	C5
7	Eb5
8	F5

Harmonic Series of G#2

Partial	Note
1	G#2
2	G#3
3	D#4
4	G#4
5	B#5(C5)
6	D#
7	F#5
8	G#5

Harmonic Series of Db3

Partial	Note
1	Db3
2	Db4
3	Ab4
4	Db5
5	F5
6	Ab5
7	Cb6(B6)
8	Db6

Harmonic Series of Ab4

Partial	Note
1	Ab4
2	Ab5
3	Eb6
4	Ab6
5	C7
6	Eb7
7	Gb7
8	Ab7

Appendix B – Tuning A4 with a Check Note

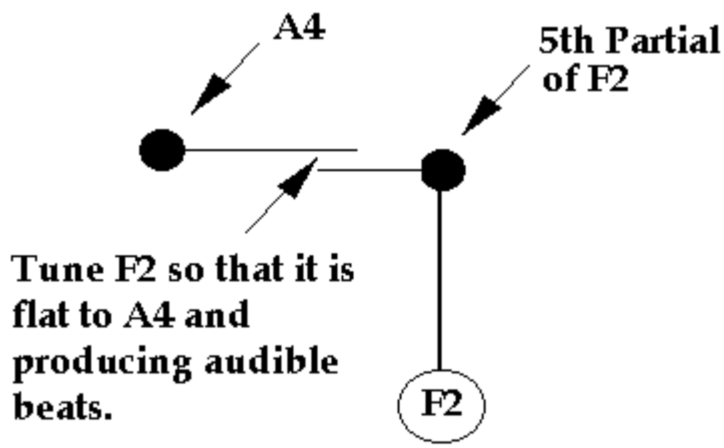
So, let's say you want to know just where A4 is. The check note is two octaves plus a Major 3rd below, which is F2. You don't need to know exactly where A4 is, you only need to know where it is in comparison to the fork. The beats will tell you.

IN ORDER TO USE THE CHECK NOTE TEST CONSISTENTLY, YOU MUST BE SURE THAT THE INTERVAL MADE WITH THE CHECK NOTE IS WIDE (Since it is a compound major 3rd and major 3rds are wide in equal temperament.)

A *compound interval* has one or more octaves added to it. I.e. F2A2 is a major 3rd. F2A4 is a *compound* major 3rd.

So, the first step in tuning A4 to the fork using F2 as a check note, is to tune F2 flat to A4. Listen until F2 is pure with A4, then just lower it until you can hear beats at a reasonable speed. Not too slow, but not so fast that you can't count them or feel their speed.

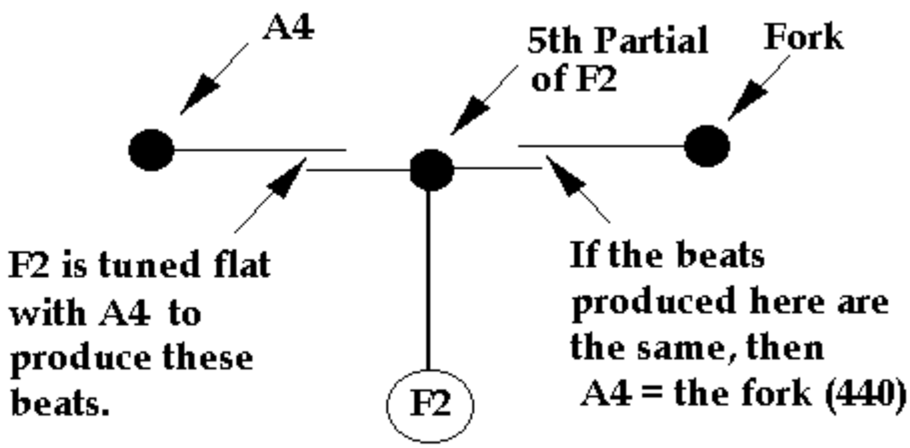
Actually, the first step is really getting A4 as close as possible to the fork just by listening to A4 and the fork together. Strike the fork on your knee. Some people then place it on the piano and play A4 and listen, then change A4 and repeat. Others place the fork in their mouth and listen to A4 *and* the fork as they tune A4.



Now, the beat speed gives you an idea how high A4 is above the 5th partial of F2. The faster the beating, the higher A4 is.

Now, check the speed of the fork with F2.

If the F2/fork beat speed is the same speed as F2A4 beat speed, then the fork is the same distance above F2 as A4 is.



If A4 beats faster than the fork, it is higher than 440.
If A4 beats slower than the fork, it is lower than 440.

THESE RULES *ONLY* WORK IF F2 IS TUNED FLAT TO A4 *AND* A4 IS CLOSE TO 440.

Appendix C – Tips for Hearing the Coincidental Partial Easier

Coincidental Partials

Before we discuss tips for hearing coincidental partials, it is necessary to introduce the concept of coincidental partials and their usefulness.

When a note is played, we hear the note as producing a fundamental frequency, but there are also other frequencies produced above the fundamental frequency. When two notes are heard, they each have a series of frequencies above their fundamental frequency. This series is called the harmonic series and each frequency; a different partial. With many intervals, there is a partial above one note that is very close, if not equal to, a partial over the other note. The musical note that is closest to these partials is called the *Coincidental Partial* (C.P.). When these common partials are not exact, there will be beats. These beats happen at the C.P. Knowing where the C.P. for any interval is imperative if you are going to be able to focus your ear on it to hear it easily and clearly, so you can tell if it is pure or not. (Using a check note will help you determine if the interval is wide or narrow, if not pure. See Appendix H – Check Notes)

Where the Coincidental Partials are for Common Intervals

You can match up the harmonic series of each interval note and figure out where the C.P. occurs, or just memorize the following chart. There are only 5 intervals that we use the most when tuning.

INTERVAL	LOCATION OF C.P.	EXAMPLE
Perfect Fifth, P5	Octave above top note	Interval: C5 G5 C.P: G6
Perfect Fourth	Two octaves above bottom note	Interval: F3 A#3 C.P: F5
Major Third, Maj3	Two octaves above top note	Interval: F3 A3 C.P: A5
Major Sixth, Maj6 (Not really used)	Octave plus a 5th above top note	Interval: F3 D4 C.P: A5
Perfect Octave, P8 (Multiple C.P.s)	2:1 Top note 4:2 Octave above top note 6:3 Octave plus 5th above top note	Interval: A3 A4 2:1 A4 4:2 A5 6:3 E6

If you have a good ear, you won't even need to memorize this chart because you will be able to hear the C.P. and know exactly where it is right away.

COINCIDENTAL PARTIALS WORKSHEET

Cover the right side of this page and see if you can quickly tell what is the first Coincidental Partial (C.P.) of each of the following intervals?

(This exercise should be done in front of a piano)

D3F#3	F#5
C4G4	G5
Ab4C5	C7
F#2B2	F#4
G4C5	G6
Eb3G3	G5
Bb2F3	F4
A4E5	E6
Db4Ab4	Ab5
C#3F#3	C#5
Gb2Bb2	Bb4
Bb3D4	D6
F4A4	A6
D2F#2	F#4
A3C#4	C#6
F4C5	C6
G4D5	D6
E2G#2	G#4
B4E5	B6
Bb2F3	F4

Tips To Use To Hear Coincidental Partials (C.P.) Better.

1) FOCUS YOUR EAR. Play the C.P. first. Then play the interval. This can have the effect of tuning' your ear to the correct partial to listen for. Just like tuning your radio to a specific station.

2) GHOSTING THE C.P. Gently press down the keys of the interval. This lifts the dampers off the strings and will allow the strings to be excited. Whack the note corresponding to the C.P. Sometimes you can hear the C.P. beating quietly. The C.P. from each series has been excited by the whacking of the C.P. note and they are now both ringing. When it works, it is great. The problem is: the C.P.'s frequencies need to be pretty close to that of the ghost note in order for the ghost note to be able to excite each C.P.

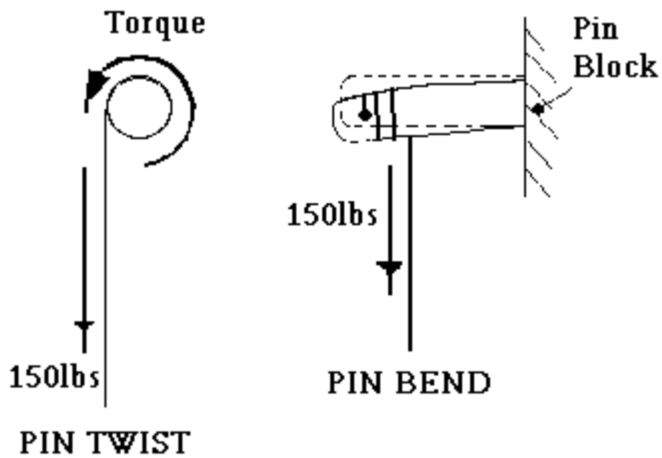
3) FILTER THE FREQUENCIES. Turn your head slightly and slowly from side to side. This can filter or enhance certain frequencies and make the C.P. easier to hear.

Appendix D – Tuning Stability

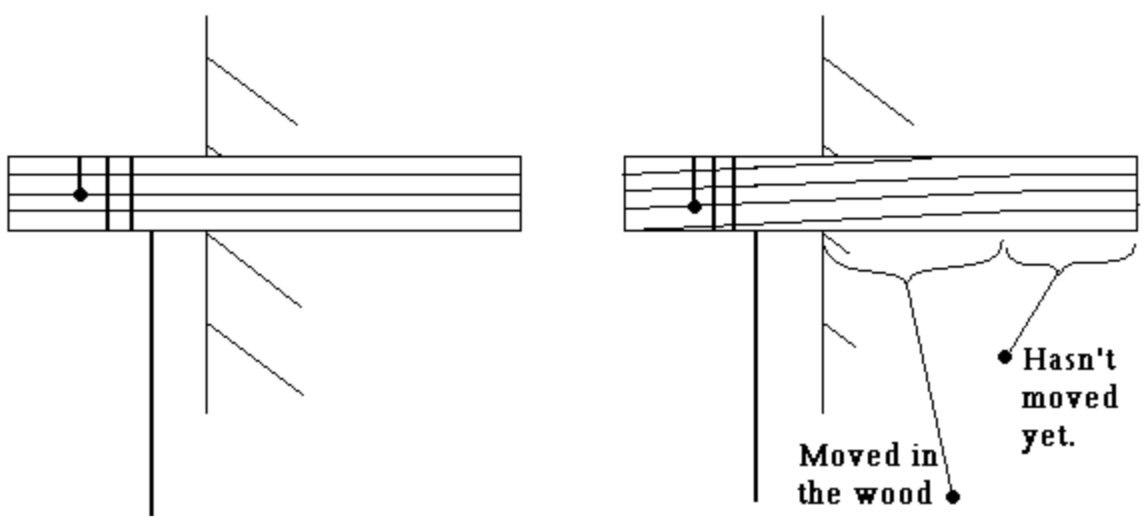
Understanding the forces on the tuning pin and string are the keys to developing a good stability.

FORCES ON THE PIN

At rest, the pin is under approximately 150 pounds of tension from the string. The string is wound around the pin and the pin is sticking out of the pin block. The tension from the string is causing the pin to bend and twist.

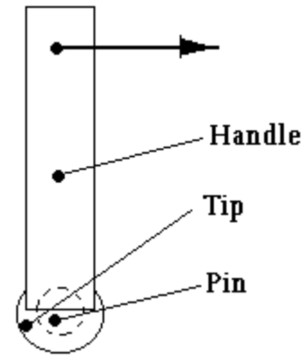


Furthermore, when the pin is turned, it doesn't turn evenly in the hole. The part in the top of the hole turns first. The bottom of the pin, known as the 'foot', turns last.

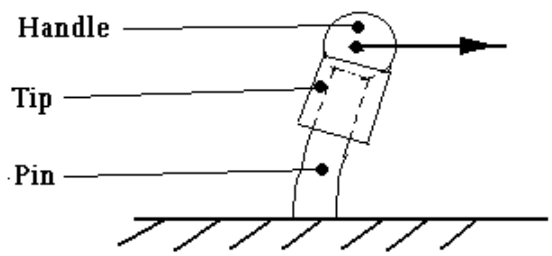


WHAT HAPPENS WHEN YOU TURN THE PIN WITH YOUR HAMMER?

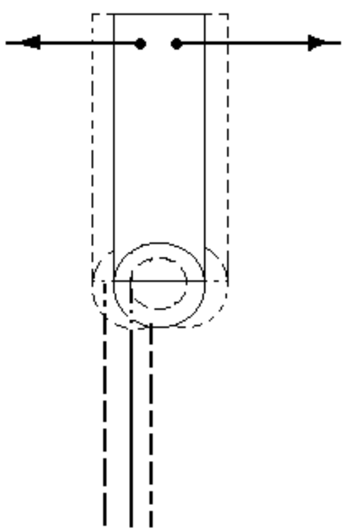
To understand this, you must realize that you are applying force with your hand to the handle of your hammer, not the pin directly. Your hand is above and beside the pin.



TOP VIEW - Hammer at 12 o'clock position.



FRONT VIEW - Hammer force causes bend in pin.



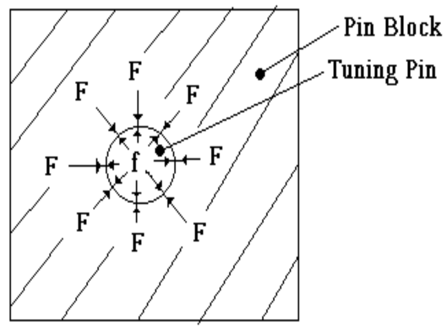
12 o'clock hammer induces side to side bend which does not affect pitch.

Without too much visualization, you should be able to see that when the hammer is at 12 o'clock, and force is applied to the left or the right, the pin moves side to side but the string length is unaffected, which means pitch is unaffected. So to reduce the affect of bend on the pitch, keep your hammer closer to 12 o'clock.

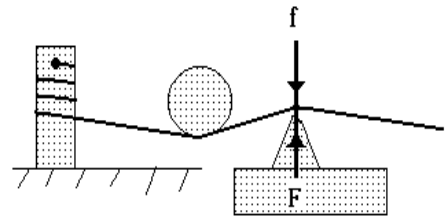
Appendix E - Hammer Technique

One of the keys to being able to tune well is knowing how to make that last very fine adjustment to put the string in tune. The reason this is difficult is because of the frictional forces at play in the piano.

Friction is the force that keeps one thing from sliding on another. The amount of this force depends on how hard the two things are pressing together. A very important property of friction is that once something starts sliding, the frictional force that wants to keep them from sliding, reduces, and the objects are easier to slide.



f = force of tuning pin against pin block.
F = force of pin block against tuning pin.



f = force of string on V-bar.
F = force of V-bar on string.

There are basically two areas where frictional forces make it difficult to fine tune a piano. Frictional forces between the tuning pin and the pin block, and those between the string and the V-bar.

The problem with friction is that, if it is high, once you begin to move the pin in the pin block, or move the string across the V-bar, the friction drops and the pin/string moves farther than wanted. While the best hammer technique involves a slow consistent motion of the hammer, excessive friction can cause jumping of the pin. The following hammer techniques may help:

KARATE CHOP – One technique involves using a short jab at the tuning hammer, much like karate chop. Once the pin/string starts to move, the force is gone and the pin/string only moves a very small amount. This is used mostly to raise the pitch.

WIGGLE – This technique involves wiggling the hammer back and forth, again applying force in one direction for a very short amount of time. This is usually used to lower pitch. Make the wiggling force slightly higher on the downward movement. (To the left on an upright)

PRESS and WHACK – Another way to get the string to move a very small amount is to gently turn the hammer in the direction you want the pitch to go. Then whack the key while keeping the force on the hammer. The movement of the string will temporarily lower the friction enough to allow the string to move slightly across the V-bar in the direction you wish it to go. This is usually used to lower pitch.

CHOP and SETTLE – You can tune most pianos with this technique. “Chop” the string up so it is very slightly sharp, then gently “wiggle” or simply lean the hammer to lower the pitch. (The hammer is usually at about 10 or 11 o’clock.) This serves to settle the pin and string and create good stability.

STABILITY (Not a technique) – Getting the pitch where it sounds good is one challenge. Another is keeping it there. If the pitch will not stay where you put it, we say the tuning is not stable. Good tuners have good stable tunings. You should know how to test for stability. Simply whack the note a few times at a loud volume and check the pitch. If it moved, the pin/string was not “set” and therefore not stable.

Appendix F – Equal Temperament

Remember from our discussion in Chapter 1.3 Pure, Wide, and Narrow Intervals, that we can produce a pure fifth above any note by multiplying the frequency of the bottom note by 1.5 (and this pure fifth will not be beating). Also I suggest that from an aesthetic point of view, pure intervals, in most cases, are the most pleasing to hear, ideally, and therefore preferred, especially in groups of instruments with flexible pitch control like choirs, wind orchestras, etc.

Also, understand that we can produce an ideal octave by multiplying a bottom note's frequency by 2.

By using these two factors (pure fifth = 1.5 and octave = 2) we can demonstrate an interesting problem with the physics of music. I am going to show that it is impossible to go from one note to another by producing pure intervals in two different ways. i.e. the intervals don't fit or work out!
(The small discrepancy in final frequency when going from one note to another by pure intervals in two different ways, is called a musical *comma*. There are different commas depending on what two ways you use. See the end of this appendix for different examples)

Starting at A440 and multiplying by 2, we can get a frequency of A0 to start with.

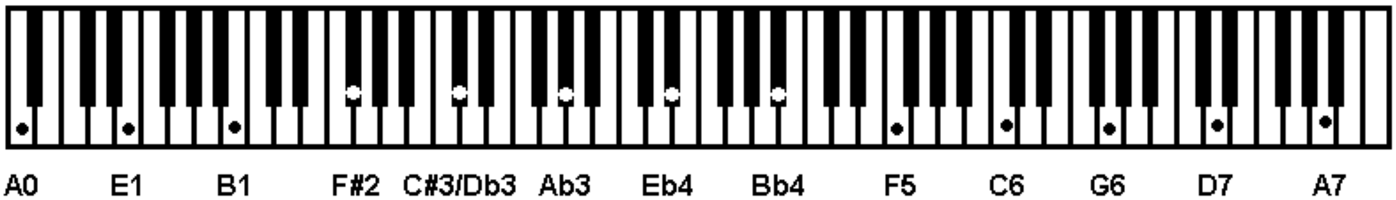
A4 = 440Hz
A3 = 220
A2 = 110
A1 = 55
A0 = 27.5

Now starting at A0 approximately 27.5Hz, and using a factor of 2, we can calculate the ideal octave frequencies of all the A's.

A0 = 27.5Hz
A1 = 55
A2 = 110
A3 = 220
A4 = 440
A5 = 880
A6 = 1760
A7 = 3520 (Note this frequency created by pure octaves from A0)

(Now, to understand this next procedure, you need to understand the Cycle of Fifths. If you are not familiar with this, please see Appendix G - Cycle of Fifths.)

We can also get from A0 to A7 by creating pure fifths using the factor 1.5. This will produce musically pleasing pure fifths. Here we go, starting at A0 (27.5Hz), frequencies to one decimal place.



A0 = 27.5Hz
E1 = 41.2
B1 = 61.9
F#2 = 92.8
C#3/Db3 = 139.2
Ab3 = 208.8
Eb4 = 313.2
Bb4 = 469.9
F5 = 704.8
C6 = 1057
G6 = 1586
D7 = 2379
A7 = 3568!!!

PURE FIFTHS ABOVE A0(27.5Hz) PRODUCE A7 = **3568Hz**, WHICH IS MUCH HIGHER THAN THE A7 = **3520Hz** PRODUCED BY PURE OCTAVES ABOVE A0.

PURE OCTAVES FROM A0 → A7 = **3520Hz**
PURE FIFTHS FROM A0 → A7 = **3568Hz**

(If this is the first time you have been exposed to this, you might want to take a break and re-evaluate the meaning of life.)

Musically speaking, the pure octaves are more important to preserve, so the only option to fit the fifths into the octaves smoothly, is to shrink (narrow) all the fifths by an equal amount. I.e. temper all the fifths)

This how the Equal Tempered Tuning System is created. The benefit of this system is that we can play in all twelve keys and each key will not sound more or less out-of-tune than any other key.

Some Interesting Facts about Equal Temperament and Other Historical Tuning Systems

Keyboard music of the early Baroque period was played on instruments that were not tuned to equal temperament. As a result, composers heard their music differently; choosing a key in which to compose was a big deal. A piano concerto in C major was a drastically different colour than one in A major for example.

These early tuning systems favoured the white keys. In fact, some keys with black keys were unplayable because they would have been so out of tune. Some early keyboards even had two black keys for each sharp. The keyboardist would know which black to play depending on the tonality (key) of the piece of music they were playing.

Before equal temperament allowed us to play in all 12 keys and have the same colour, there was a tuning system called Well Temperament in which all 12 keys sounded ok but not the same. Bach wrote his famous book The Well-Tempered Clavier to explore and demonstrate the ability of the piano to play in all 12 major and minor keys.

Today virtually all pianos are tuned to Equal Temperament except maybe a few harpsichords in universities. By the way, harpsichordists usually tune their own instruments anyway because they go out of tune so easily.

Understanding Interval Sizes in Equal Temperament

Because the fifths are narrow in equal temperament, this sets up a whole series of un-pure intervals.
It is these un-pure intervals that give the modern piano its colour. To really perfect the art of piano tuning, you need to understand, study, and listen to the colour of these intervals and be able to reproduce them in order to produce a fine tuning acceptable for the concert stage or recording studio. Many accomplished pianists today are aware of this colour and expect even and smooth colour from a professional tuning.
You will often have to refer to the correct size of the intervals in order to troubleshoot and improve your initial tunings. Memorize the following table:

An important note about the bps numbers above: These are approximate. The correct speeds will be determined for each piano as a good tuner tweaks the intervals so they all sound good.

Aural Examples of Musical Commas You Can Produce on the Piano

Cycle of Fifths (Pythagorean Comma)
Start on A3 and tune *pure* Fifths and Fourths up and down as shown until you get to A4.
Then play A3A4 and listen to the “wolf” tone.

A3 – E4 – B3 – F#4 – C#4 – G#4 – D#4 – A#3 – F4 – C4 – G4 – D4 – A4

Stacked Major Thirds (A little harder to hear the pure 3rds)
Start on any note and tune three *pure* major thirds, one on top of the other. The upper third will share its bottom note with the lower third. Example: C to E, and E to G#. (These are called Contiguous Thirds)
Then listen to the octave produced by the pure major thirds. (“Wolf”)

Example: F3 – A3 – C#4 – F4

BASIC TEMPERAMENT WITH PURE INTERVALS WITHIN F3F4
Tune the following intervals and then listen to the last interval.

A3-E4-B3-F#3-C#4-G#3-D#4-A#3-F4-C4-G3-D4

which brings us back to A3.

Listen to D4A3. (“Wolf”)

Interval	Size in ET	Quality
P5	Narrow	- Very slow beat - Often referred to as *rolling.* - Approximately 1 beat every second
P4	Wide (Inverted P5)	- Faster beat - Referred to as *noisy* - Approximately 1 beat per second (bps)
M3	Very Wide	- Starting at F3A3, it beats at 7bps - M3’s beat faster going up, and slower going down
M6	Very Wide	- Starting at F3D4, these beat approx 8bps - Also speed up as you move up the keyboard
m3	Very Narrow	- Starting at F3Ab3, approximately 9bps

Appendix G - Cycle of Fifths

Intervals

It is beyond this text and course to teach and explain the theory of musical intervals. Having said that, if you are not familiar with the cycle of fifths, you will need some temporary theory to deal with this until you work on this yourself, to memorize and know intimately all the keys and their intervals.

Common intervals in the key of C (no sharps/flats) and the number of semitones (keys) that they are above C, NOT including C. If you are not fluent in music interval theory, you can always count the keys to figure out each interval, no matter which note you are starting on.

Notes	Interval Name	# of Keys above C
C C	Perfect Unison, PU	0
C Db	Minor Second, min2, m2	1
C D	Major Second, Maj2, M2	2
C Eb	Minor 3rd, min3, m3	3
C E	Major 3rd, Maj3, M3	4
C F	Perfect Fourth, P4	5
C Gb	Diminished Fifth, dim5	6
C G	Perfect Fifth, P5	7
C Ab	Minor Sixth, min6, m6	8
C A	Major Sixth, Maj6, M6	9
C Bb	Minor Seventh, min7, m7	10
C B	Major Seventh, Maj7, M7	11
C C	Perfect Octave, P8	12

Cycle of Fifths

The Cycle of Fifths is an extremely useful tool for musicians for composing, practicing, improvising, etc and is a requirement to memorize in order to know music theory better.

The property of the Cycle of Fifths that makes it so useful is that, starting on any note, you can build 12 perfect fifths above the starting note and you will be back where you started, having produced all 12 notes in western music.

Example:

A – E – B – F# - C#/Db - Ab - Eb – Bb – F – C – G – D – A

Cycle of Fourths

Similarly, the Cycle of Fourths has the same characteristics, and is just the Cycle of Fifths in reverse.

A – D – G – C – F – Bb – Eb - Ab – Db/C# - F# - B – E – A

Some Important Concepts to Understand as the Cycle of Fifths Relates to Piano Tuning.

The Cycle of Fifths/Fourths can be used to memorize an order of notes to tune within the temperament octave F3F4.

Please understand that the Cycle of Fifths produces note names that are perfect fifths *above* each successive note in the order, but in order to keep the notes within F3F4, the actual note may have to be brought down the octave. This of course produces a musical perfect fourth if you were to look at it as a musician sees intervals. Please don't get confused. It is still the Cycle of Fifths. A perfect fifth above a note produces the same note name as a perfect fourth below the same note.

Appendix H – Check Notes

A check note is a note that produces beats with *each* of the interval notes separately. By comparing the speed of each interval note with the check note, we get an idea of the size of the interval we are checking. This comparison will tell us if the interval we are checking is narrow, pure, or wide.

(For this technique, we have two interval notes, N1 and N2, and we want to know if the interval N1N2 is wide, narrow, or pure. We also have a check note, CN, that we will use to help us. We use the check note by alternately playing CN-N1 and CN-N2 and comparing the beats speeds of these two check intervals.)

As we have discussed in Appendix C – Tips for Hearing the Coincidental Partial Easier and Chapter 1.3 Pure, Wide, and Narrow Intervals, when two notes are played simultaneously (an interval), there are multiple frequencies produced above each fundamental frequency (harmonic series). When the frequencies above each interval note line up, these two frequencies are called the Coincidental Partials (C.P.) When the C.P.'s are not the same, beats are produced. When they are exactly the same, no beats are produced and the interval is said to be pure.

Now, if the interval is not pure, the C.P.'s are not the same, and a beat is produced at the C.P. So, whenever we hear a beat at the C.P. of an interval, we know that the interval is not pure. What we don't know is whether the interval is wide or narrow! And this is usually what we really need to know, especially when trying to tune slightly narrow fifths or slightly wide fourths.

This is where check notes are extremely useful. A check note is a third note, usually lower than each interval note, that produces the same C.P. with each interval note as the C.P. of the interval itself. But alternately playing the check intervals (Play the check note with Interval Note #1 and then the check note with interval #2) we can hear a difference in beat speeds. By comparing the two speeds we are able to determine whether the interval is wide or narrow.

WHERE IS THE CHECK NOTE?

The check note for any interval is two octaves plus a Maj3 below the C.P.

The most common intervals that we use a check note for are P4, P5, and P8.

To determine the check notes for each interval, you can visualize the C.P. and then go down a P8+M3, or just memorize this chart:

Perfect Fifth	From bottom note: Up a minor 3rd, then down a P8 (or down 9 semitones)
Perfect Fourth	From bottom note: Down a Major 3rd (or down 4 semitones)
P8, 4:2 size	From bottom note: Down a Major 3rd.

It may be useful for musicians to notice that for the P4 and the P5, the check note is the note that makes a minor chord with the m3 in the bass.

Examples:

INTERVAL	CHECK NOTE	CHORD PRODUCED	CHECK INTERVALS
C4-G4	Eb3	Eb3-C4-G4	Eb3C4 and Eb3G4
G4-C5	Eb4	Eb4-G4-C5	Eb4G4 and Eb4C5

HOW TO USE THE CHECK NOTE
Once you determine what the C.P. is and what the check note is, you have to make sure the check note is producing wide intervals with each interval note.

HOW TO MAKE SURE THE CHECK NOTE IS PRODUCING WIDE INTERVALS WITH THE INTERVAL NOTES.
1. Play the check note and one of the interval notes together.
2. Adjust the check note up and down very slightly while listening to the beats produced by the check note and the interval note. If the interval is wide, you should have the following agreements:
Raise check note → beats slow down
Lower check note → beats speed up

If it is the opposite, then the interval is narrow – lower the check note.

NOTE: if the check note is very out of tune, you may have to tune the check note so it makes a pure interval (no beats) with an interval note, and then lower it.
Tune the check note so it makes easily heard beats, about 7bps, as fast as you can tap.
It may be useful to tune the check note from its higher octave if that note has been tuned already.

HOW TO TELL IF AN INTERVAL IS WIDE OR NARROW
Now when you play the two check intervals, you should be able to tell if one is faster than the other, or if they are the same. The faster beating check interval has its interval note sharp from pure.

Faster bottom check interval? → bottom interval note is sharp from pure → interval is *narrow*
Faster top check interval? → top interval note is sharp from pure → interval is *wide*
Both check intervals beating the same speed? → Interval is *pure*

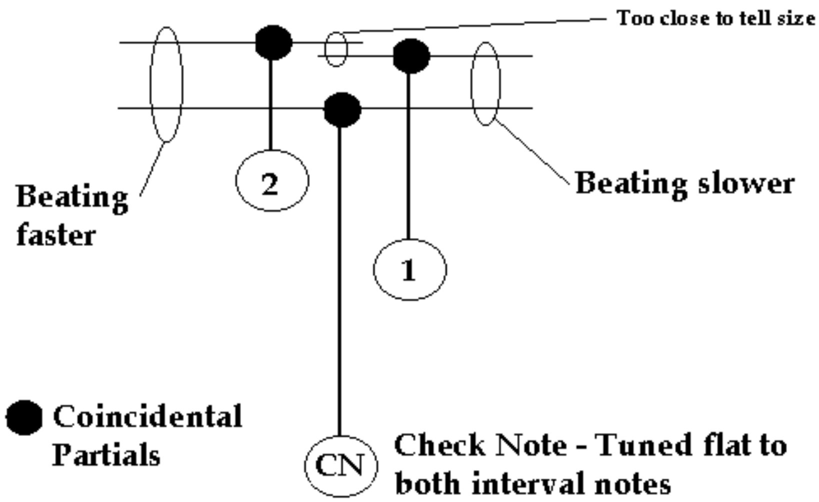
NOTES:

If both check intervals are beating too fast to tell which is faster, then the check note is too low. Raise it a bit. Listen to a check interval while you are raising the check note; you do not want to go past pure.

Raising the check note can also exaggerate the difference in beat speeds between the check intervals. Consider two check intervals that are beating at 10 and 11bps. That is very hard to tell which is faster. But if you raise the check note, it will slow down the speed of both check intervals to something like 3 and 4bps. This is a lot easier to tell which is faster.

DIAGRAM EXAMPLE:

Maybe this diagram example will help you visualize the relationship of the check note with the interval notes..



In this example, we are trying to determine if the interval N1N2 is wide, narrow, or pure.
N1N2 is beating, but they are too close together for us to hear if it is wide or narrow.
We determine the CN using the chart or memory or analysis, and then make sure it is producing wide intervals with each interval note.
Now we play CN-N1 and CN-N2 alternately, back and forth, until we can tell if one is faster.
In this case, CN-N2 is faster, so N2 is the sharper note.
Top note sharp? → Interval is wide.

IMPORTANT NOTE FOR BEGINNERS!
Sometimes, beginners have a hard time telling the difference in beat speeds. They may even have trouble hear any beat at all. If this is the case, try these ideas:

1. Try to listen for colour or emotion in the tone of the interval. Now, when you are listening to each check interval, instead of trying to hear which check interval is faster, try to hear if one is brighter…or more angry.
2. Sometimes beginners hear a fast beating interval and say it is pure, i.e. no beats. This is common because the beats are so fast that you cannot really tap or discern each beat. However, when students are asked "Does this interval sound pretty or beautiful to you?" they say no, because, of course, the interval is *not* pure! So when you think an interval is pure, ask yourself if it sounds pretty or beautiful. If not, it is probably a fast beating interval.

Appendix J – Basic Temperament by Fourths and Fifths

Notes:

1. The musical note names are derived from the cycle of fifths. However, because the notes are kept within the temperament octave F3F4, sometimes the notes make musical intervals of fourths.
2. The diamond notes have already been tuned in the previous step; tune the regular shaped notes.

Appendix K – Interval Size Worksheets

Use these worksheets to test your hearing of narrow, wide, and pure intervals within the F3F4 temperament octave.
Go through each of the fourths and fifths within an untuned temperament octave and then have your instructor confirm your answers. Your instructor may want to detune a few intervals for you before you do the exercise. If you are not taking the course, you will need a mentor, or know how to use an Electronic Tuning Device to confirm your answers.

Put a check mark in the column that describes the size of each interval.

INTERVAL	Narrow	Pure	Wide	Correct:
Fourths:				
F3 Bb3				
F#3 B3				
G3 C4				
Ab3 Db4				
A3 D4				
Bb3 Eb4				
B3 E4				
C4 F4				
Fifths:				
F3 C4				
F#3 C#4				
G3 D4				
Ab3 Eb4				
A3 E4				
Bb3 F4				

Appendix K – Interval Size Worksheets, Copies.

INTERVAL	Narrow	Pure	Wide	Correct:
Fourths:				
F3 Bb3				
F#3 B3				
G3 C4				
Ab3 Db4				
A3 D4				
Bb3 Eb4				
B3 E4				
C4 F4				
Fifths:				
F3 C4				
F#3 C#4				
G3 D4				
Ab3 Eb4				
A3 E4				
Bb3 F4				

INTERVAL	Narrow	Pure	Wide	Correct:
Fourths:				
F3 Bb3				
F#3 B3				
G3 C4				
Ab3 Db4				
A3 D4				
Bb3 Eb4				
B3 E4				
C4 F4				
Fifths:				
F3 C4				
F#3 C#4				
G3 D4				
Ab3 Eb4				
A3 E4				
Bb3 F4				

Appendix L – Basic Tuning Procedure

1) Mute the piano
b) Upright - Strip mute from highest trichord before treble, down to first bichord.
- Put a wedge mute on the first trichord if needed. (Note: if there is an odd number of bichords to the right of the tenor break, you will not need a wedge mute here.)
- Put the Papp's mute on the last trichord before the treble break.
c) Grand Piano - Strip mute from the highest C down to the first bichord
- Jump from the far side of the dampers to the near side when there is room for the strip on the near side.
- Put wedge mutes in the notes on the ends of each section so that only one string segment is free to vibrate.
2) Tune A4 to the fork Tune A3 to A4
3) Tune the temperament octave, usually F3 to F4
4) Tune F#4 up to high C (C8) using octaves and other checks. (Uprights – in the treble section, you will need to start using the Papp's mute and start tuning unisons as you go.)
5) Tune from E3 to the first note, A0, using octaves and other checks. (Tune the unison on the first bichord as you pass it, if the last unichord was muted.) (Notice the pattern in the tuning pins. This helps speed tuning.)
6) Starting at the first note to the right of the tenor break, pull out the strip mute (and wedge if used) up to the first trichord.
7) Tune the unisons that have been revealed and continue up. Grand Piano – pull out the wedges as needed and use them to help isolate unisons. Upright Piano – the treble section has already been tuned with the Papp's mute.
8) Pull out the strip mute in the bichord bass section and tune the unisons revealed. Notice the pattern of tuning pins needed. This helps speed tuning time.
9) Now the first pass is done. Check all the unisons again. (It is a good idea to play all the notes loudly before this unison check to test stability.) Start in the treble. Use melodic checks in the highest treble. Check two notes of a unison at a time. Move a wedge from note to note and use a pattern of outside unisons/inside unisons to reduce the number of times you have to move the mute.
10) Now check octaves and fifths from C3 to C8 using a chord approach. All keys, bottom note from C3 to C4.

Bar 1 – Listen for in tune unisons
Bar 2 – Listen for in tune intervals
Bar 3 and 4 – Listen for in tune octaves that have in tune unisons that are also in tune with the left hand

11) Play a test piece. Criteria: Slow - to allow out of tune notes to be heard. Melody that uses a lot of different notes, or change the key of the song as you play. Change the octave of the melody and accompaniment to test all areas of the piano. Use wide chords and intervals.

Appendix M – Mock Exam

In each section of this exam, you will be given a mark of 1, 2, or 3.

1 = RPT level
2 = Acceptable for this course
3 = Needs work

SECTION	SCORE	NOTES
A4	1 2 3	
A3A4	1 2 3	
The Skeleton	1 2 3	
The White Anchor	1 2 3	
F3F4 temperament	1 2 3	
Upper octaves to the break	1 2 3	
Upper octaves and unisons past the break	1 2 3	
Lower octaves	1 2 3	
Unisons	1 2 3	

Appendix N – Different Skeleton Procedures

The method mentioned in Section 5.7.2 has been developed over many years by the author. Before arriving at that simpler, faster, and more precise method, the author used the following methods. They are presented here for information purposes only and are not recommended unless they give you good results and you are having trouble with the tonal method in section 5.7.2.

Tuning the Skeleton Using 4:5 Ratio Contiguous Major Thirds.

1) Set F3A3 approximately 7bps
2) Tune F3F4
3) Now tune C#4 so that A3C#4 beats in a 4:5 ratio with F3A3.
How do you do that? Well, first play F3A3. Listen to the beats. Feel the groups of four thinking “Ma-ni-to-ba”. Now tap the first beat of each four and feel that. Now fit five beats into the same time, thinking “U-ni-ver-si-ty”. A3C#4 should be beating at that speed.
4) Now here is where the real refining takes place. Play C#4F4. That should beat in a 4:5 ratio with A3C#4. If it doesn’t, then your F3 can be improved.

If C#4F4 is too fast, then F3 is sharp. (C#4F4 too fast → F4 sharp → F3 sharp. Remember, major 3rds are *wide* in ET)
Lower F3 the smallest amount possible, retune F3F4, reset C#4, and try C#4F4 again.

If C#4F4 is too *slow*, then F3 is *flat*. (C#4F4 too *slow* → F4 *flat* → F3 *flat*.)
Raise F3 the smallest amount possible, retune F3F4, reset C#4, and try C#4F4 again.

Keep adjusting until F3A3, A3C#4, and C#4F4 all fit in a 4:5 ratio. Now F3, A3, C#4 and F4 are all accurate. (Well, as accurate as is your ability to tune a good F3F4 octave and hear 4:5 ratio major thirds)

Tuning the Skeleton Using Identical Beating Major Thirds

1) Tune F3A3 approximately 7bps.
2) Tune A3C#4 so that it beats the *same* as F3A3
3) Tune the lower C#3F3 so it *also* beats the same.
4) Here’s the test. Play C#3C#4. If that octave sounds good, then F3 is good.

Here’s the thought process if C#3C#4 does not sound good:

C#3C#4 wide? → all three intervals wide, including F3A3 → F3 is flat.
Raise F3 a smidge, retune C#3 and C#4 to make C#3F3 = A3C#4, and recheck C#3C#4.

C#3C#4 *narrow*? → all three intervals narrow, including F3A3 → F3 is *sharp*.
Lower F3 a smidge, retune C#3 and C#4 to make C#3F3 = A3C#4, and recheck C#3C#4.

Keep adjusting F3 and retuning C#3 and C#4 until C#3C#4 is a good octave. Then F3 is good, but C#3 and C#4 will have to be retuned later.

Appendix O – Tuning Hammer Stability Worksheet

Using an interval that is easy to tell if it drifts, tune one of the notes using each of the approaches below, whack it threes times, fff, and see if the note drifts, i.e. the interval beats change.

Some good intervals to use are the M10 and the M17. Also, you can use an Electronic Tuning Device or a software program that measures frequency, to determine if the frequency of the note changed after you whacked it.

When you are turning the pin, you are creating instability in the string tensions across the bearing points, and moving the pin away from its stable point of rest. One of these hammer approaches may cause you to leave the string tensions equal and the pin back in its stable rest position.

You will try different hammer positions, 3:00, 9:00, 12:00, 6:00.

You will also approach the target pitch from above or below.

Example, on an upright, approaching the target pitch from below, and putting the hammer at 3:00, means that you will be pulling down on the hammer at 3:00.

Try to move the hammer slowly and evenly until you are at the target frequency.

For this worksheet, the target frequency is anything other than the original. I.e. just move change the frequency.

When you find a hammer angle/approach combination that results in no change of frequency after the whacks, then that is the hammer angle/approach that you should use on that piano.

Note: Other sections of the piano have different bearing points, and different non-speaking lengths, so the hammer angle/approach combination may need to be different.

	APPROACHING FROM ABOVE				APPROACHING FROM BELOW			
PIANO	12:00	3:00	6:00	9:00	12:00	3:00	6:00	9:00
1								
2								
3								
4								
5								

b = went flat
# = went sharp
- = didn't change

Appendix P

Mark Cerisano's Temperament Notation

Diamond note = Already tuned	">" = barely faster
Regular note = Note to tune	"<" = barely slower
Square note high = Coincidental Partial	">>" = definitely faster
Square note low = Check Note	"<<" = definitely slower

March 2013

Cut Along This Line

A3: 1 2 3 4

Appendix Z – Octave Templates

OCTAVE TEMPLATE SHEETS – USE THESE TO HELP YOU VISUALIZE THE DIFFERENT OCTAVE SIZES AND THE OUT-OF-TUNESS OF THE PARTIALS.

1) Place A3 (this sheet) on top of A2 (the other sheet)
2) Line up A2 Partial 2 over A3 Partial 1. This is the size of a 2:1 octave. Notice how out of tune the 8:4 partials are.
3) Line up A2 Partial 8 over A3 partial 4. This is an 8:4 octave. Notice how out of tune the 2:1 partials are.
4) The optimum size for most octaves, except the low bass, is that which compromises the out of tune partials. Place A2 Partial 4 over and slightly to the left of A3 partial 2, so that A2 Partial 6 is slightly to the right of A3 partial 3. All the partials pairs are now only slightly out of tune.

So, we say the optimum size for this octave is slightly larger than a 4:2 octave and slightly smaller than a 6:3 octave.

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A2:

1 2 3 4 5 6 7 8