Stringed Instrument Tuning:
Just Intonation vs. Equal Temperament

When violin, viola, and cello students first begin learning their instruments, they usually tune using a digital tuner, which follows equal temperament. This system is practical for early learning, providing consistent pitch reference. However, as students progress—playing double stops, chords, or joining advanced orchestras—they are introduced to just intonation, which offers a different, often richer experience. This article explains both tuning systems, their uses, advantages, and limitations.

Understanding Temperament

There are situations where tuning isn't a concern—such as when a well-trained choir sings unaccompanied. Without fixed-pitch instruments, singers naturally adjust to achieve harmonies favoring intervals like perfect fifths and major thirds that reflect the harmonic series.

Similarly, orchestral instruments capable of fine pitch adjustments (like strings and winds) often unconsciously or deliberately tune these pure intervals. A conductor may even request an interval to be "expanded" or "contracted" for expressive or harmonic reasons.

In contrast, fixed-pitch instruments—like pianos, organs, harps, bells, harpsichords, and xylophones—cannot be adjusted during performance. Tuning is critical for these instruments, but a system like just intonation, while beautiful in one key (e.g., C major), can sound unpleasantly out of tune in distant keys (e.g., D♭ major).

To solve this, temperaments were developed—systems that "temper" (slightly adjust) the tuning of intervals to allow music in many keys. Among these, equal temperament and just intonation became the most widely used in Western music.

Equal Temperament

Definition

Equal temperament divides the octave into 12 equal semitones, each the same distance apart. This system is the standard tuning method for most modern Western instruments, especially keyboard and fretted instruments.

Benefits

- Uniformity: Every semitone is equal, enabling easy modulation to any key.
- Practicality: Simplifies transposition and harmony in all keys.
- Consistency: Works well with ensembles involving fixed-pitch instruments like pianos.

Drawbacks

- Some intervals (especially major thirds) are slightly out of tune compared to just intonation.
- Chords may produce beating (a pulsing effect) due to impure intervals. Beats are that waw waw sound that you hear when you play open strings together that are slightly out of tune.
- Harmonic resonance is reduced, which can affect tone color and listener perception.

Use Cases

- Standard for pianos, guitars and digital instruments.
- Preferred in styles requiring frequent modulation or when playing in all keys is necessary.

Just Intonation

Definition

Just intonation is a tuning system based on simple whole-number ratios between note frequencies. It emphasizes purity of sound, producing consonant intervals that align with the natural harmonic series.

Benefits

- Produces rich, resonant harmonies with minimal dissonance.
- Ideal for double stops and chords on string instruments.
- Tones blend naturally due to alignment with the harmonic series.
- Favored in music requiring harmonic purity, such as baroque, Renaissance, and folk traditions.

Drawbacks

- Limited to close keys; modulating to distant keys can create dissonance.
- Requires real-time pitch adjustment, challenging for some players.
- The theory and system can appear complex to beginners.
- Not practical for fixed-pitch instruments, like a piano.

Use Cases

- Commonly used in early music, folk traditions, chamber ensembles, and by advanced string players.
- Often used when purity of intervals in a single key is prioritized over flexibility.

Side-by-Side Comparison

Aspect	**Equal Temperament**	**Just Intonation**
Tuning Basis	Equal division of the octave (12 semitones)	Whole-number frequency ratios
Sound Quality	Slightly compromised intervals	Pure, resonant intervals
Key Flexibility	High—equal sound in all keys	Limited—best in one key
Best For	Keyboard instruments, modern ensembles	Solo strings, vocal groups, early music
Challenges	Some intervals sound impure	Requires pitch adjustment, theory is complex
Historical Use	Became standard in the 18th–19th centuries	Dominated early Western music

Conclusion

Both just intonation and equal temperament serve vital roles in musical tuning. Just intonation offers a rich, natural resonance, especially in homogenous ensembles like string quartets or vocal groups. Equal temperament, though less harmonically pure, provides the versatility needed for modulation and compatibility across instruments.

For advancing string players, learning to hear and adjust intonation is part of musical maturity. Understanding these systems not only improves tuning but deepens appreciation for musical expression across genres and eras.

A story:

A story that might sound familiar to you if you are an advancing player:

First, just to let you know, I'm an adult learner that started on a Fiddle 5 years ago. Been taking 1hr a week lessons since I started.

I learned about "Just" vs "Equal" Temperament about a year in.

After trying a Peterson Strobe tuner which didn't seem very useful and some other digging. I concluded the difference was so small and so far beyond my current intonation that I should just stick with a cheap clip on equal temperament tuner.

But the topic keeps rearing it's head.

So what really brought it up this time was during a lesson.

I was playing a Waltz for my teacher and she wasn't very pleased with my intonation. It wasn't my best but I didn't think it was that bad. Then she said I think your fiddle might be out of tune. She proceeded to tune it by ear.

When she handed it back. It was like, wow, this sounds so much better. Then I compared it to my cheapo tuner and she mostly brought the G down a few cents. So it seemed about time I figure this out.

This isn't a small difference. It was about that large a change my teacher made to my fiddle. For single notes, playing solo it's really not too big of a deal. But when you start playing Chords and Double Stops, Harmony etc. these few cent differences are pretty significant.

Playing With Others

Tuning Challenges Between Just Intonation and Equal Temperament

Because instruments in the violin family (violin, viola, cello) do not have fixed pitches, s approach is typically introduced only after students gain some experience. At the beginning level, most students use **digital tuners**, which default to **equal temperament**, simply because tuners are widely available and convenient.

In contrast, **fixed-pitch instruments**—such as **pianos, harpsichords, fretted instruments like guitars, and digital keyboards**—are generally tuned using **equal temperament** so that they can easily play in all keys. While equal temperament is common, not all fixed-pitch instruments are necessarily tuned that.

When musicians playing in just intonation (e.g., string players) perform alongside those using equal temperament (e.g., piano or guitar), **intonation conflicts can occur**. A major example is that string players are often taught to **avoid using open strings (except for A)** in these situations, because open strings are fixed and cannot be adjusted to match equal temperament. Instead, they rely on fingered notes that can be **fine-tuned by ear** to better match the ensemble's tuning.

Ultimately, the key is **active listening**. String players must constantly adjust their intonation in real time to blend with others, whether the ensemble is tuned in just, equal, or a combination of both systems.

Some modern tuners now offer settings for both **just intonation** and **equal temperament**, providing more flexibility and accuracy depending on the musical context.

What Happens with Just Tuning?

The violin—and indeed the entire violin family—sounds its best when the strings are tuned in true perfect fifths, meaning just fifths, not equal-tempered ones. This kind of tuning enhances the resonance across the whole instrument, allowing it to ring more freely and richly. For this reason, violinists (as well as violists and cellists) often prefer to tune using just intonation.

However, just tuning can create challenges, especially when playing in ensembles.

For example:

- In chamber music settings like a string quartet, violinists may choose to tune their E string slightly flat, or avoid using the open E altogether, opting to play E on the A string so it can be adjusted by ear.
- Viola and cello players might tune their C string slightly sharp, or similarly, place a finger near the nut to sharpen the open C pitch slightly.
- Sometimes, if a player uses an open string that can't be adjusted (such as an open A), the others in the group must tune around that note, adapting their finger placement to match.
- They player needs to track the key they are in to raise the 7^{th}, and possibly the 3^{rd}, of the key the piece is in.

You might wonder: *"Why not just tune string instruments using equal temperament like a piano?"* The answer lies in the sound quality. Just tuning produces more pure and resonant harmonies, particularly in unaccompanied string playing or small ensembles. That said, players will often adjust their tuning and intonation based on context—whether they're performing solo, in a quartet, in a full orchestra, or alongside a piano.

This flexibility is one of the great strengths of non-fixed pitch instruments: they can respond to the musical situation, adjusting to blend with the ensemble or match the tuning system of a particular piece.

Some string players even argue that equal temperament makes everything just a little out of tune, and they can hear the difference. However, when playing music written for piano—such as Chopin or Debussy—they often come to appreciate how well equal temperament functions artistically. The slight compromises it makes are what allow that music to be fluid across keys, and still emotionally powerful and beautiful.

In the end, string players rely on careful listening and constant adjustment. Their tuning isn't fixed—it's alive, changing with the ensemble and the music.

The Science Behind Just and Equal Tuning

What is a cent in music?

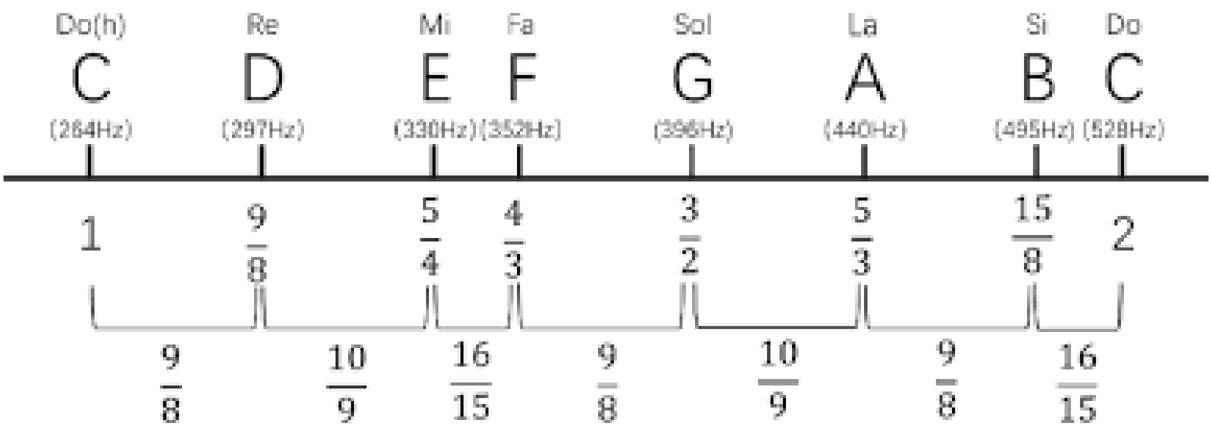
In music, a **cent** is a unit of measurement used to describe the difference in pitch between two notes. It's defined as 1/100th of a semitone in **equal temperament** tuning, where each semitone (the interval between two adjacent keys on a piano) spans **100 cents**. A semitone is also known as a half step. Since an **octave** consists of 12 semitones, it spans a total of **1200 cents** (12 x 100 cents).

However, in **just intonation**, the spacing between half steps is not equal. The intervals in just intonation are based on pure frequency ratios, so some intervals are slightly wider or narrower compared to those in equal temperament.

In the chart below, each row represents a **half step**. This spacing reflects the tuning system used: equal temperament adjusts all intervals to be equally spaced, while just intonation maintains natural harmonic ratios, which results in slight variations in the size of each interval.

Interval	12-tone Cents	Just Intonation Cents
Unison	0	0
Minor second	100	111.73
Major second	200	203.91
Minor third	300	315.64
Major third	400	386.31
Perfect fourth	500	498.04
Tritone	600	582.51
Perfect fifth	700	701.96
Minor sixth	800	813.69
Major sixth	900	884.36
Minor seventh	1000	996.09
Major seventh	1100	1088.27
Octave	1200	1200

This visual illustrates the spacing between the notes of the C major scale. Notice that the distances between E and F (the 3rd and 4th degrees of the scale) and B and C (the 7th and 8th degrees) are noticeably smaller than the other intervals. These are the only half steps in the major scale. In just intonation, these half steps—specifically the intervals between the 3rd and 4th, and the 7th and 8th degrees—are even smaller than in equal temperament. The specific pitch ratios involved in these intervals will be discussed in the next section.



This chart compares the equal distribution of cents in equal temperament (on the right) with the uneven distribution in just intonation (on the left). Take a look at the top C and G—these form a perfect fifth, just like the tuning on your instrument. In just intonation, the fifth is slightly wider than in equal temperament.

The frequency scale used in equal temperament is logarithmic, meaning the intervals are evenly spaced in terms of pitch ratio. In columns 2 and 3, we see two different representations of the same values: one as a fraction (just intonation) and the other as a decimal. These columns show the exact frequency ratios for each interval, revealing the subtle differences between the two tuning systems.

Note	Just intonation	fequency	12-TET	fequency
C	1/1	1	0	1
C#	16/15	1.066	100	1.059
D	9/8	1.125	200	1.122
D#	6/5	1.2	300	1.189
E	5/4	1.25	400	1.259
F	4/3	1.333	500	1.335
F#	7/5	1.4	600	1.424
G	3/2	1.5	700	1.498
G#	8/5	1.6	800	1.587
A	5/3	1.667	900	1.682
A#	16/9	1.777	1000	1.782
B	15/8	1.875	1100	1.888
C	2/1	2	1200	2

A440 refers to a musical note that vibrates at a frequency of 440 Hertz (Hz). This is the standard tuning for the note "A" on the second space of the treble clef staff. When played, this note vibrates 440 times per second.

Sound itself is produced by vibrations—rapid back-and-forth movements of air molecules. These vibrations generate sound waves that travel through a medium, such as air. Our ears detect these waves, allowing us to hear the sound. The frequency of these vibrations (in Hz) determines the pitch of the sound, with higher frequencies producing higher pitches and lower frequencies producing lower pitches.

		Just Intonation		Equal Temper.	
Note/Interval		RATIO	A=440 FREQUENCY	RATIO	A=440 FREQUENCY
Tonic	C	1	*264*	1	*261.63*
Minor 2nd	c#	16/15	*281.60*	$2^{1/12}$	*277.18*
Major 2nd	D	10/9	*293.33*	$2^{1/6}$	*293.66*
Minor 3rd	e#	6/5	*316.80*	$2^{1/4}$	*311.13*
Major 3rd	E	5/4	*330*	$2^{1/3}$	*329.63*
Perfect 4th	F	4/3	*352*	$2^{5/12}$	*349.23*
Augmented 4th	f#	45/32	*371.25*	$\sqrt{2}$	*369.99*
Diminished 5th	Gb	64/45	*375.47*		
Perfect 5th	G	3/2	*396*	$2^{7/12}$	*391.99*
Minor 6th	g#	8/5	*422.40*	$2^{2/3}$	*415.30*
Major 6th	A	5/3	***440***	$2^{3/4}$	***440***
Minor 7th	a#	9/5	*475.20*	$2^{5/6}$	*466.16*
Major 7th	B	15/8	*495*	$2^{11/12}$	*494*
Octave	C'	2	*528*	2	*523.25*

Let’s compare the frequencies of two commonly used intervals to highlight the difference between **just intonation** and **equal temperament** tuning. Just intonation intervals are ever-so-slightly wider than their equal-tempered counterparts.

Octave Comparison (C to C):

- **Just Intonation:**
  The interval between C and C (one octave) is calculated as:
  528 Hz−264 Hz=264
  This represents a natural ratio of 2:1, which is slightly wider in pitch than in equal temperament.
- **Equal Temperament:**
  In equal temperament, the octave interval is slightly compressed:
  523.25 Hz−261.63 Hz=261.62 Hz
  Here, the pitch difference is slightly smaller due to the equal distribution of intervals across the scale.

Perfect Fifth Comparison (A440 to D):

- **Just Intonation:**
  For a perfect fifth (like your instrument is tuned, starting from A440), the interval is:
  440 Hz−293.33 Hz=146.67 Hz
  The ratio of 3:2 in just intonation creates a slightly wider fifth compared to equal temperament.
- **Equal Temperament:**
  In equal temperament, the perfect fifth is a bit narrower:
  440 Hz−293.66 Hz=146.34 Hz
  The difference is minimal but noticeable to the trained ear, with equal temperament slightly flattening the interval.

The **harmonic series** (also **overtone series**) is the sequence of harmonics, musical tones, or pure tones whose frequency is an integer multiple of a ***fundamental frequency***.

What Is the Harmonic Series?

When a note is played—whether sung, bowed on a violin, or plucked on a guitar—it doesn't just produce a single frequency (the **fundamental**). It also produces a series of **overtones**, which are higher frequencies that occur at integer multiples of the fundamental frequency.

For example, if the fundamental pitch is **G (196 Hz)** (open G string on a violin or guitar), the harmonic series would include:

- **1st harmonic (fundamental)**: G (196 Hz)
- **2nd harmonic**: G (392 Hz) – *1 octave up*
- **3rd harmonic**: D (588 Hz) – *Perfect 5th above the 2nd harmonic*
- **4th harmonic**: G (784 Hz) – *2 octaves above fundamental*
- **5th harmonic**: B (980 Hz) – *Major 3rd above the 4th harmonic*
- **6th harmonic**: D (1176 Hz) – *Perfect 5th above the 4th harmonic*
- **7th harmonic**: Slightly lower than F (not quite a minor 7th)
- **8th harmonic**: G (1568 Hz) – *3 octaves above fundamental*

However, after the 6th harmonic, the intervals start getting **smaller** and **less consonant**. The 7th, 11th, 13th harmonics, etc., do not correspond exactly to notes in the equal-tempered scale and give a unique flavor to acoustic timbre.

Practical Application: Open Strings and Vibrato

Your example is excellent:

- When you place a 3rd finger on the **D string**, you're playing a **G**.
- If that G matches the pitch of the **open G string**, the two resonate sympathetically.
- Adding **vibrato** to the stopped G on the D string makes the **open G string ring with vibrato**, even though you're not touching it—thanks to sympathetic resonance and the overtone series.