Intonation

This activity produces a guitar upon which each string is in tune with itself, and is the final step in setting up the completed instrument. The activity is suitable for students from middle school on up, requiring no more tools than a string crank, screwdriver and an electronic tuner.

Learning Objectives:

1. Students will use an electronic tuner to adjust bridge saddles to shorten or lengthen a guitar string such that the distance from the nut to the 12th fret is musically identical to the distance between the 12th fret to the saddle.

Standards:

Next Gen - HS-PS4-1.
Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

CCSS.Math.Content.HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Materials Required:

1. Guitar with nut and bridge saddle height adjustments complete and strings installed.
2. Clamp-on or cabled electronic guitar tuner
3. #1 Phillips screwdriver
4. Guitar string crank/winder

Basic eye protection

Strings, Standing Waves and Harmonics - https://newt.phys.unsw.edu.au/jw/strings.html
Scale Length Defined - https://en.wikipedia.org/wiki/Scale_length_(string_instruments)

Activity:

Intonation is the process of adjusting a string's bridge saddle fore and aft such that the distance between the nut and the 12th fret is musically equal to the distance between the 12th fret and the saddle. This is required because the different strings of a tuned guitar possess different tensions and masses (and therefore inertia) per unit length. Also, the act of fretting a string towards its middle where the action is highest also yields the greatest change in tension compared to the open string. Typically, the heavier gauge strings must be a little longer than the lighter gauge strings. The intonation operation is conducted with the guitar on its back with a supported neck and the headstock free.

1. Tune the string to concert pitch using an electronic tuner (See figure 1). This example is demonstrated on the low E string at E_2=82.41 Hz. It may be helpful to plug the guitar into an amplifier so it can be heard. Notice the tuner display is centered.

Figure 1

2. Play the second harmonic by lightly stopping (but not fretting) the string at the 12th fret. By definition, the second harmonic is exactly twice the frequency of the open string. In our example the second harmonic will vibrate at 164.82 Hz which is E$_3$, exactly one octave higher than the open string. The tuner display should again be centered (see figure 2).

Figure 2

3. Now fret the string at the 12th fret. Observe the tuner display. It will reveal if the distance between the 12th fret and the saddle is too long (display indicating the tone is flat, figure 3) or too short (display indicating the tone is sharp, figure 4).

Figure 3

Figure 4

4. If the string between the 12th fret and the saddle is too short, it must be lengthened. Remove all the tension from the string (figure 5) and move the saddle aft by turning the adjustment screw clockwise (figure 6). If the string between the 12th fret and the saddle is too long, it must be shortened. Move the saddle forward by turning its adjustment screw counterclockwise.

Figure 5

Figure 6

5. Bring the string back up to tension ($E_2=82.41Hz$) and repeat the process until the pitch at the 12th fret is identical to that of the second harmonic.

6. Repeat the entire process for each string.

Informal Assessment: The instructor monitors the tuner display during the intonation process for accuracy and precision.

Assessment
Intonation

1. Intonation is the process for tuning…

    A. a guitar to other instruments.
    B. an individual guitar string to itself.
    C. a guitar's strings to each other.
    D. a guitar to an open chord.

2. The _____ (or pitch) of a sound is determined by the number of vibrations per second of the object causing the sound, which is measured in Hertz (Hz).

    A. tone
    B. harmonic
    C. frequency
    D. sustain

3. One reason that saddles under heavy low-pitch strings must be placed at different distances from the nut than those for lighter strings is…

    A. the heavy gauge strings have a greater inertia than the lighter strings.
    B. the heavy strings are drawn from different metals than the light strings.
    C. errors in fret placement require the adjustment.
    D. the heavy strings are harder to play than the light strings.

4. You have tuned the open string. When you play it at the twelfth fret, the note is sharp. To properly intonate this string, you should… .

    A. turn the saddle screw for string length clockwise.
    B. turn the saddle screw for string length counter-clockwise.
    C. turn the truss rod adjustment nut clockwise.
    D. turn the tuner knob counter-clockwise.

5. To use the electronic tuner to set the intonation for a string, the frequency at the twelfth fret should be…

    A. four times the open string frequency.
    B. half the open string frequency.
    C. double the open string frequency.
    D. quarter the open string frequency.

6. The relationship between a pitch frequency and one that is exactly one octave higher:

    A. 3:1
    B. 4:1
    C. 1:2
    D. 2:2

7. If the scale length of the instrument is 25.5 inches, then the twelfth fret should be located at…

    A. 12.75 inches.
    B. 6.375 inches.
    C. 19.125 inches.
    D. 12.25 inches.

8. If the scale length of the instrument is 34 inches, the length of each heavier string will be progressively _____ than the scale length of 34 inches.
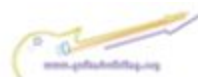
longer -or- shorter

9. If the tuner indicates the 12th fret pitch is sharp, the distance from the 12th fret to the bridge must be _____.

shortened -or- lengthened

10. Before adjusting the bridge saddle distance, the student should…

    A. have a spare string available in case it breaks.
    B. plug the guitar in.
    C. check the 2nd and 3rd harmonic for pitch.
    D. remove all tension from the string.

Assessment Key:

1. B - an individual guitar string to itself.
2. A - tone
3. A - the heavy gauge strings have a greater inertia than the lighter strings.
4. A - turn the saddle screw for string length clockwise.
5. C - double the open string frequency.
6. C - 1:2
7. A - 12.75 inches.
8. longer
9. lengthened
10. D - remove all tension from the string.

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