ELEMENTARY LUTHIERY

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Contents

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1 BASIC SET-UP

1.1 Inspection

1.1.1 Neck

1. Eyeball the neck to see if it is warped.
2. Play every note on the neck, looking for buzz sounds.
3. If there are buzz sounds, use a fret rocker to identify their origin.

1.1.2 Pots, Switches and Contacts

1. Listen to each pick-up individually, looking for microphonic noises. If it is the case, check the soldering.
2. Make sure the jack socket is not faulty. If it is the case, check the soldering. If there is a constant hum, check the ground.
3. Check every pots (full range) and switches. Look for cracking sounds. If yes, clean them with a contact cleaner (anything except WD40, because it is greasy).

1.2 Fingerboard Planimetry

1.2.1 Straightening the Neck

Tying the trussrod will reduce the bow of the neck, that is it will make it less concave. A convexe (backbow) neck is unplayable. The idea is that, for optimal string vibration, the neck must be slightly concave around the 9th fret and straighten up beyond the 12th fret.

1. Put a capo at the first fret.
2. Press the last fret.
3. Adjust the trussrod to have a gap between the top of the 9th fret and the string (relief), given in Table 1.

Table 1: Indicative neck relief for guitars and basses, depending on the fingerboard radius.

Fingerboard radius	**Guitar relief at the 9th fret**	**Bass relief at the 11th fret**
7.25 in / 18.4 cm	0.012 in / 0.3 mm	0.014 in / 0.35 mm
9.5 to 12 in / 24.1 to 30.5 cm	0.010 in / 0.25 mm	0.012 in / 0.3 mm
15 to 17 in / 38.1 to 43.2 cm	0.08 in / 0.2 mm	0.010 in / 0.25 mm

1.2.2 Fret Filing

To be done only if, after adjusting the truss rod and setting the action, buzz sounds persist, or if the frets are particularly worn out.

1. Adjust the trussrod.
2. Mask the fingerboard with painter's tape.
3. Also protect the pick-ups, otherwise they will attract the metallic dust produced by sanding the frets.
4. Gently sand the frets with movements parallel to the neck, using a sanding block with the proper radius and 240 grit sand paper.
5. Proceed slowly, by checking if the buzz sounds remain after a few passes, and iterate.
6. Crown the frets (*i.e* make them rounder) with a specific crowning file.
7. When it is done, polish the frets energetically, otherwise string bending will feel very scratchy.

1.3 Intonation

Adjusting the intonation is necessary to have the most in-tune instrument possible.

1. Tune the string to its pitch.
2. With a precise electronic tuner, check the pitch of the 12th fret.
   - If it is lower than the pitch of the harmonic at the 12th fret, move the saddle towards the neck;
   - If it is higher than the pitch of the harmonic at the 12th fret, move the saddle away from the neck.
3. Repeat the operation for each string.

1.4 Action

The action is the gap between the top of the 12th fret and the bottom of the string. It is determinant in the playability of the instrument. It is set, once the trussrod has been adjusted, by raising or lowering the saddles. Recommended actions are given in Table 2. This table gives a range of values. The lowest values are achievable only on a recent, good quality instrument.

Table 2: Indicative action for guitars and basses, depending on the fingerboard radius.

	Radius 7.25 in	**Radius 9.5 to 12 in**	**Radius 15 to 17 in**
Guitar, low E	2 mm < 2.2 mm < 2.5 mm	1.6 mm < 2.2 mm < 2.5 mm	1.6 mm < 2.2 mm < 2.5 mm
Guitar, high E	1.6 mm < 1.75 mm < 2 mm	1.6 mm < 1.75 mm < 2 mm	1.6 mm < 1.75 mm < 2 mm
Bass, low E	2.8 mm	2.4 mm	2.4 mm
Bass, high G	2.4 mm	2 mm	2 mm

1.5 Cleaning

1.5.1 Body and Fingerboard

1. Clean the whole guitar with Super Nikco, except if there is a rosewood fingerboard:
   - Apply the product;

- Remove the excess.

2. Clean a rosewood fingerboard with clarified linseed oil (lemon oil is useless).
3. Use several micro-fiber clothes: at least one for cleaning and one for buffing.

1.5.2 Frets

1. Mask the fingerboard, either with painter's tape or with a fret guard.
2. Polish the frets with either:
  - Steel wool 0000; or
  - Sand paper (600 grit).

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2 STRING TENSION

- With equal temperament, the frequency ratio between two notes a half-step apart is $\nu_2/\nu_1 = 2^{1/12}$. It means that an octave apart (12 half-steps), the frequency ratio is exactly a factor of 2.
- In standard tuning, the frequencies of the guitar strings are given in Table 3.

Table 3: string frequencies in standard tuning.

E (high)	B	G	D	A	E
330 Hz	247 Hz	196 Hz	147 Hz	110 Hz	82 Hz

2.1 Relation between Tension, Frequency and Length

There is an approximate relation, for ideal strings, between the string tension, F, the pitch frequency, ν, the length of the vibrating string, L, and its diameter, d:

$$F = \pi\rho d^2 L^2 \nu^2, \tag{1}$$

where ρ is the density of the string material ($\rho \simeq 7850$ kg/m^3 for steel). These tensions are usually expressed in kg at the sea level, $F[kg] = F[N]/g$, with $g = 9.81$ m/s^2.

Eq. 1 applies to open strings as well as fretted strings. The vibrating length of an open string is called the *scale length*. It depends on the model of the guitar. Some manufacturers have different preferences. The two most common guitar scale lengths are:
Gibson: L = 24.75 in = 628.7 mm;
Fender: L = 25.5 in = 647.7 mm.

2.2 String Bending

- Eq. 1 shows that string bending, which consists in increasing string tension by pushing it up or down, leads to $F \propto d^2\nu^2$. It means that to bend a string by N half-steps, the string tension increases by a factor $\delta F/F = 2^{N/6} - 1$, which is 12% for a half-step, 26% for a whole step and 41% for a minor third.
- It also shows that, to achieve bending to a given pitch on two different string gauges, the increase of tension is $\delta F/F = (d_2/d_1)^2 - 1$, which is 56% going form $d_1 = 0.008$ in to $d_2 = 0.010$ in, and 125% going from $d_1 = 0.008$ in to $d_2 = 0.012$ in. In other words, bending a string requires to apply more than twice the strength with a gauge 0.012, compared to 0.008.

2.3 Effect of String Gauge

Eq. 1 shows that increasing the string gauge increases the tension by a factor $\delta F/F = (d_2/d_1)^2 - 1$. Table 4 gives the tensions for a few typical electric guitar sets. It shows that a 0.012 string set applies twice more tension on the neck than a 0.008 set. It also means that playing 0.012 gauges requires twice more strength than 0.008 gauges.

2.4 Effect of Detuning

It is interesting to know what is the effect of detuning on the string tension. In particular, it is useful to know the rough standard-tuning equivalent string gauge in an alternate tuning. For a given scale length, if we want to keep the string tension F, by decreasing its frequency, we must increase the string gauge by a factor $d_2/d_1 = \nu_1/\nu_2$. This is shown in Table 5. We can conclude from these numbers that:

- playing a set of 0.012 in E$\flat$ standard will be slightly harder than playing a set of 0.011 in standard tuning;

Table 4: ideal string tension as a function of gauge, for typical string sets, for a Fender scale length ($L = 647.7$ mm), with steel strings.

String	Frequency	0.008 in string set	0.010 in string set	0.012 in string set
E (high)	330 Hz	F=4.74 kg (d=0.008 in)	F=7.41 kg (d=0.010 in)	F=10.7 kg (d=0.012 in)
B	247 Hz	F=4.15 kg (d=0.010 in)	F=7.02 kg (d=0.013 in)	F=10.6 kg (d=0.016 in)
G	196 Hz	F=5.88 kg (d=0.015 in)	F=7.55 kg (d=0.017 in)	F=13.8 kg (d=0.023 in)
D	147 Hz	F=6.48 kg (d=0.021 in)	F=9.94 kg (d=0.026 in)	F=14.1 kg (d=0.031 in)
A	110 Hz	F=7.41 kg (d=0.030 in)	F=10.7 kg (d=0.036 in)	F=13.8 kg (d=0.041 in)
E	82 Hz	F=6.61 kg (d=0.038 in)	F=9.68 kg (d=0.046 in)	F=11.9 kg (d=0.051 in)
Total		F=35.3 kg	F=52.3 kg	F=74.9 kg

- playing a set of 0.012 in D standard will be slightly easier than playing a set of 0.011 in standard tuning, but noticeably harder than 0.010.

Table 5: Rough equivalent string gauge when detuning. This table shows what string gauge in standard tuning would have a similar tension to a 0.012 in string set, when detuning each string by a half-step (E♭ standard) or a whole step (D standard).

String	Diameter	E♭ standard	D standard
E (high)	d=0.012 in	$d_{eq} \simeq 0.0113$ in	$d_{eq} \simeq 0.0107$ in
B	d=0.016 in	$d_{eq} \simeq 0.0151$ in	$d_{eq} \simeq 0.0143$ in
G	d=0.023 in	$d_{eq} \simeq 0.0217$ in	$d_{eq} \simeq 0.0205$ in
D	d=0.031 in	$d_{eq} \simeq 0.0293$ in	$d_{eq} \simeq 0.0276$ in
A	d=0.041 in	$d_{eq} \simeq 0.0387$ in	$d_{eq} \simeq 0.0365$ in
E	d=0.051 in	$d_{eq} \simeq 0.0481$ in	$d_{eq} \simeq 0.0454$ in

2.5 Effect of Scale Length

We can also estimate the equivalent string gauge when changing the scale length. For instance, if we have a Telecaster (L=647.7 mm) with a set of 0.010, what would be the string gauge we would have to put on an ES 335 (L=628.7 mm) to keep the same tension. In this case, the string gauge ratio is simply inversely proportional to the scale length ratio 647.7/628.7=1.03. This is shown in Table 6. It is quite small. Playing with the same set of string on a Fender will require roughly 6% more strength than on a Gibson.

Table 6: Rough equivalent string gauge when going from a Fender scale length to a Gibson scale length.

String	Fender string gauge	Equivalent Gibson string gauge
E (high)	d=0.010 in	$d_{eq} \simeq 0.0103$ in
B	d=0.013 in	$d_{eq} \simeq 0.0134$ in
G	d=0.017 in	$d_{eq} \simeq 0.0175$ in
D	d=0.026 in	$d_{eq} \simeq 0.0268$ in
A	d=0.036 in	$d_{eq} \simeq 0.0371$ in
E	d=0.046 in	$d_{eq} \simeq 0.0474$ in