

## **Three new experiments**

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The three experiments mentioned in this paper are at the borderline of electricity and acoustics. The experiments are “Electric load of a conductor using a light-bulb rheostat”, “Electric monochord” and “Demonstrational Farad-Seebeck siren”.

### **Electric load of a conductor**

The essential part of this experiment is a light bulb rheostat. It consists of five car light bulbs of 12 V / 24 W connected in parallel. When connected to a 12 V power source, the current inside each of them should be 2 A. By connecting and disconnecting the bulbs we can change the current in the circuit from zero up to 10 A (at least theoretically). It is necessary to use a strong enough power source with stabilized voltage.

The light bulb rheostat is fixed in a support and connected to the power source by a pair of conductors. One of them is a thick copper wire which has almost zero electrical resistance. The second conductor is varied. All the light bulbs are disconnected at the beginning of each experiment and we observe the conductor as the current increases (= successive connecting of the light bulbs).

When a thick copper wire is used, all bulbs shine at full strength and the wires are not being heated. A thin copper wire gets hot but the light bulbs still shine fully. An interesting effect may be observed when using steel wires. With a thick one, the first light bulb shines fully but after connecting a second bulb, its shine is reduced and reduced again after connecting each succeeding bulb. The wire is being significantly heated. A thin steel wire can maintain one shining bulb but when a second bulb is connected, the light is reduced to zero. The wire is not being heated significantly.

	No. of connected bulbs	1	2	3	4	5
<b>thick Cu wire</b>	voltage on bulbs / V	11.1	11.0	10.9	10.4	10.1
	current in the circuit / A	1.7	3.4	5.0	6.6	8.1
<b>thin Cu wire</b>	voltage on bulbs / V	11.3	11.0	10.6	10.3	10.0
	current in the circuit / A	1.7	3.4	5.0	6.6	8.1
<b>very thin Cu wire</b>	voltage on bulbs / V	11.0	10.3	9.1	7.3	5.8
	current in the circuit / A	1.7	3.3	4.6	5.4	6.1
<b>thick Fe wire</b>	voltage on bulbs / V	9.8	8.4	7.2	5.9	4.8
	current in the circuit / A	1.6	2.9	4.0	4.9	5.5
<b>thin Fe wire</b>	voltage on bulbs / V	8.4	3.6	1.7	0.9	0.4
	current in the circuit / A	1.5	1.9	2.1	2.2	2.1

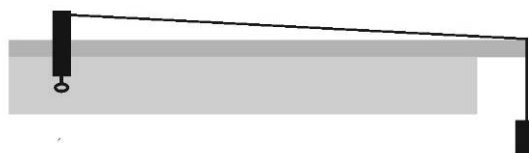
The experiment should demonstrate two significant phenomena: Wires can become dangerously hot with high current flowing through them (this effect can be reduced by the use of thick wires from a sufficiently conductive material) and voltage on the loads can be reduced.

This experiment is a modification of Lucien McLellen's performance at the Physics on Stage festival at Noordwijk 2003.

### **Electric monochord**

A monochord – a string stretched over a resonance chamber (which can be if necessary replaced by an acoustic guitar) – is a common tool for teaching acoustics. To make an electric monochord you need a guitar string (any steel string would work), a small clamp, one weight, a string, a table and some kind of bridge to put below the string. Furthermore you need a small coil with a steel core (e.g. a 12000 turn coil from an old TV), a small neodymium magnet, and an amplifier (e.g. computer speakers). The coil contacts should be connected to a standard 3.5 mm earphone jack.

Fix the clamp about 80 cm from a table edge. One end of the guitar string is left plain; the other one is ended by a metal loop. Fix the plain end of the string to the clamp and use a string to tie a 1 kg weight to the loop on the other side of the string. Let the end of the string with the weight hang freely over the edge of a table as shown in the figure.



If you pluck the string you will find that its sound is very quiet. Put the neodymium magnet into the core of the coil and connect the coil to the amplifier. Now pluck the string again and approach the vibrating string with the coil so that the magnet is about 5 mm away from the string. The speaker should sound with a clear guitar tone.

This setup is identical to a common electric guitar: The magnet at the coil core magnetizes the entire steel string which by moving towards and away from the coil induces inside the coil an electric current proportional to the rate of position change.

You can change the weight pulling on the string and demonstrate the effect of tension on tone pitch; it is also possible to control the string tension by hand. Another possibility is to connect the coil to a computer sound card input and use some suitable software to do frequency analysis of the tone. If you move the coil along the string, you find that the amount of upper harmonic frequencies varies – e.g. a coil near the centre of the string is not able to detect even modes which have nodes there.

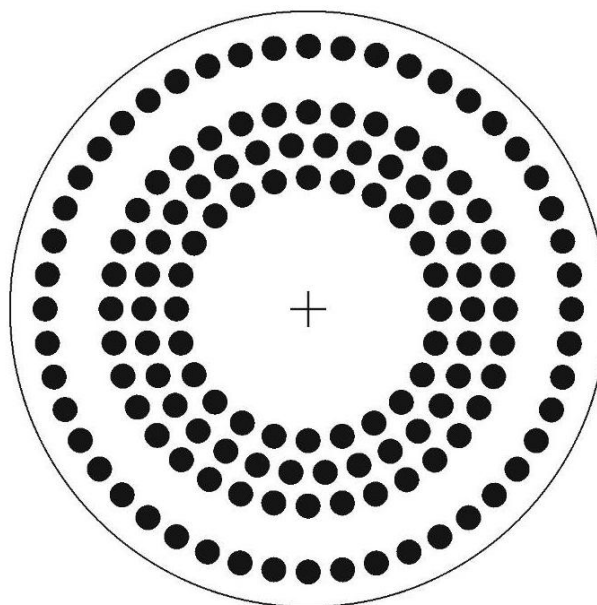
Professional guitars usually have more sets of sensor coils, each suitable for different pitches. The guitarist can change the timbre of the sound by switching between these coil sets. The output of the coils is usually transformed by electronic modulators that change the sound timbre, add echoes or have other effects.



It is possible to support the string by a “bridge” – a piece of L-shaped metal profile that changes the length of the vibrating string. By changing its position you can show the dependence of tone pitch on string length. Use a similar piece to protect the edge of the table from notches made by the string.

### Farad - Seebeck siren

The standard Seebeck siren is a disk with a set of arranged holes (see figure). The disc in the figure has 4 concentric sets of holes – 24, 30, 36 and 48 holes around its circumference. When the disc is spinning and you blow air from a straw towards the holes, you can hear tones composing a major chord (e.g. C-E-G-C). Changing the frequency of disc rotation results in different frequencies of tones, but the tones will still compose a harmonic major chord. This occurs because the numbers of



holes are in the ratio  $1:\frac{5}{4}:\frac{3}{2}:2$ .

These are the ratios of tone frequencies in a major chord (fundamental – third – fifth – octave). This experiment shows that if two tones' frequencies are in specific ratios, we hear them as harmony.

The only disadvantage of this siren is its low volume. It is unsuitable for a common demonstration in a classroom. I tried to remove this disadvantage by changing the

way the tone is created. I drilled holes into a plastic disc in very same way as they are in the Seebeck siren and I glued small ceramic magnets into the holes. The magnets are glued in such a manner that the poles alternate. To keep the speed of rotation stable, I use an electromotor regulated by change of voltage. Such a Farad-Seebeck siren creates tones via a small coil from an old phone (12000 turns, steel core) connected to the microphone input of a computer sound card. When the coil is moved towards the disc, it produces audible sounds. The experiment can be used even in a class that has not yet heard about electromagnetic induction.