



CAN YOU Believe it?

WITH ASSOCIATE PROFESSOR DEREK LEINWEBER

Screaming magnets

From an 1831 laboratory emerged a 1960s revolution.

CAN renowned physicist Michael Faraday, as he played around with magnets and coils of wire in his 1831 laboratory, have anticipated the wild screams of Jimi Hendrix's distorted guitar revolutionising the music scene of the '60s?

It's easy to forget the science at the heart of the things we take for granted. With the Adelaide Guitar Festival paying tribute to the magic of Hendrix, it is timely to explore the physics behind Jimi's guitar, the Fender Stratocaster.

Leo Fender is credited as the inventor of the electric guitar in the 1940s. But the discovery of the necessary physics goes back to the time of Faraday. When a magnetic field is moved past a conducting wire, a voltage is produced that will cause a current to flow in a circuit. Add an amplifier to turn this tiny voltage into something that will drive a loud speaker and you've got a screaming audience.

Well, there is a little thing called talent somewhere in between.

But the scientific key here is movement. A stationary magnet creates no voltage and therefore no sound. The magnet has to move relative to the conducting wire.

So how does an electric guitar work? Perhaps not quite the way you might guess.

On a six-string guitar, the pickup is composed of six magnets, one placed under each string. Each magnet is oriented so that a line through the north-south poles of the magnet intersects with the metal string above it.

You may think the guitar string plays the role of the conducting wire. This is not the case. Upon touching the string, you would become part of the electrical circuit.

Instead, a thin copper wire is wound around each magnet. The sole purpose of the magnets in the pickup is to magnetise the guitar string above it.

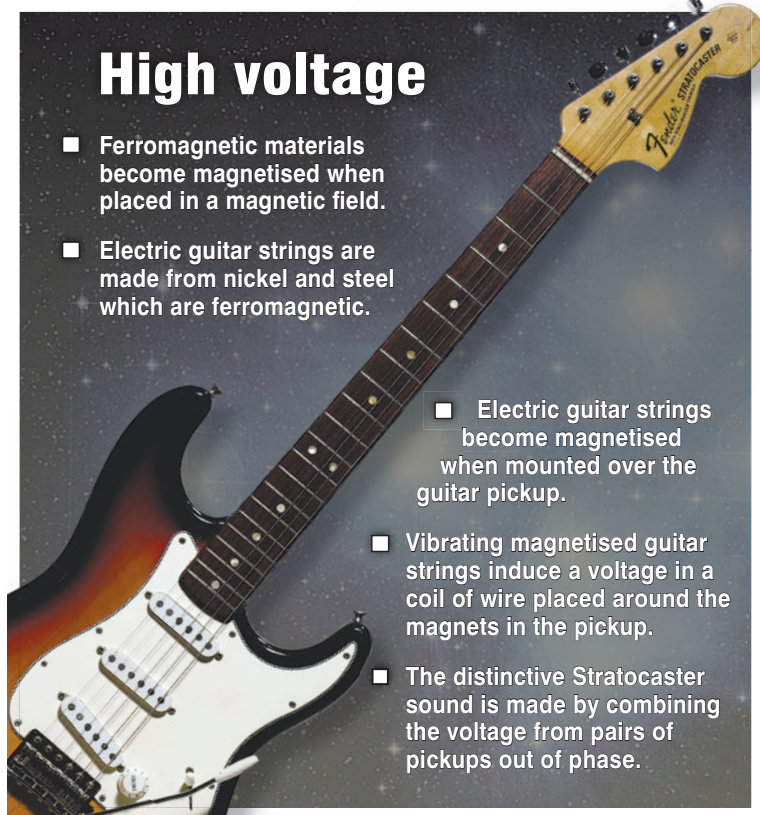
Pluck the magnetised string and you have a moving magnetic field. And that coil of copper wire wrapped around each magnet in the pickup is in a perfect place for the moving magnetic field to create fluctuating voltage.

The frequency of the voltage fluctuation matches the frequency of the string's vibration.

But that's only the beginning.

When you pluck a guitar string, several forms of vibration occur. These vibrational "modes" are called the fundamental, second harmonic, third harmonic and so on.

Essentially, the vibration of the fundamental mode looks like a skipping rope; fixed at both ends and looping around in the middle. The



High voltage

- Ferromagnetic materials become magnetised when placed in a magnetic field.
- Electric guitar strings are made from nickel and steel which are ferromagnetic.
- Electric guitar strings become magnetised when mounted over the guitar pickup.
- Vibrating magnetised guitar strings induce a voltage in a coil of wire placed around the magnets in the pickup.
- The distinctive Stratocaster sound is made by combining the voltage from pairs of pickups out of phase.

second harmonic has an additional fixed point in the middle called a node. The third harmonic has two nodes and so on. While the pitch of a note is governed by the fundamental mode, the tone colour or timbre is determined by the relative strength of the other modes.

Now here's what makes the Stratocaster special. The combination of the modes determining the string's tone can be changed at the flip of a switch.

Three pickups are strategically placed near the bridge of the guitar which fixes one end of the vibrating string. In this position, all three pickups will accurately pick up the fundamental vibrational mode, defining the pitch of the note.

But the magic is in combining the output of pairs of pickups. Some vibration modes are enhanced and become louder, others are suppressed. It all comes down to changing the tone or timbre of the guitar.

The most amazing sounds are created by combining the pickups out of phase, changing again which harmonic modes are emphasised or suppressed. It's the out-of-phase combination that creates the classic Stratocaster sound. Be sure to listen for it at the festival.

Derek Leinweber is an Associate Professor of Physics at the University of Adelaide. He's also an accomplished electric guitarist who has not been invited to play at the Adelaide Guitar Festival.