OCR
RECOGNISING ACHIEVEMENT

Thursday 13 June 2013 – Afternoon

A2 GCE PHYSICS B (ADVANCING PHYSICS)

G495/01 Field and Particle Pictures

ADVANCE NOTICE

G412080613

Duration: 2 hours

INSTRUCTIONS TO CANDIDATES

- Take the article away and read through it carefully. Spend some time looking up any technical terms or phrases you do not understand. You are **not** required to research further the particular topic described in the article.
- For the examination on Thursday 13 June 2013 you will be given a fresh copy of this article, together with a question paper. You will not be able to take your original copy into the examination with you.
- The values of standard physical constants will be given in the Advancing Physics Data, Formulae and Relationships booklet. Any additional data required are given in the appropriate question.

INFORMATION FOR CANDIDATES

- Questions in Section C of paper G495/01 Field and Particle Pictures will refer to this Advance Notice material and may give additional data related to it.
- Section C will be worth about 40 marks.
- Sections A and B of paper G495/01 will be worth about 60 marks.
- There will be 2 marks for quality of written communication (QWC) assessed in Sections B and C.
- This document consists of **8** pages. Any blank pages are indicated.

Fiddles of the Future

Although electric violins have a very modern sound, they have been around in one form or another for nearly 100 years. The first type was created by adapting the pickup devices from electric guitars and fitting them to normal violins and although other types now exist, many are still designed in this way. Apart from producing a sound that is in keeping with other electric instruments of the modern era, an electric violin has the benefit of producing notes that can be electronically amplified, especially useful for live performances at big concert venues. The understanding and development of both the acoustic and electric versions of the instrument have relied heavily on the discoveries of many physicists throughout the centuries.

The basic 4-stringed acoustic violin can be traced back to ancient Central Asia but emerged in its current form in Italy in the 16th century. Fig. 1 shows the basic structure and the names of some of the important features.

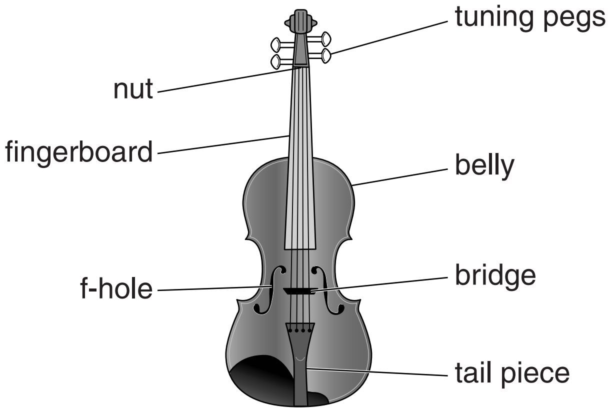

Fig. 1: the basic parts of an acoustic violin

The strings can produce a sound when plucked but the usual way to produce a note is to draw a bow across a string to cause it to vibrate. The note produced depends upon a large number of factors, the most important relating to the nature of the string itself. How the frequency of the note depends upon the length of a string is probably most famously associated with Pythagoras (500 BC). The density and tension of the violin string also affect the pitch of the note it produces since the speed of the wave along the string depends upon these values.

Standing wave theory can be applied to a violin string to account for the range of frequencies that can be produced by a single string. Consider a string that is plucked. The distance between the bridge and the position of the player's finger (or, if an 'open string', to the 'nut' at the end of the fingerboard) defines the length of the vibrating string – see Fig. 2. The pitch of the main note produced is then determined by the fundamental standing wave for that length.

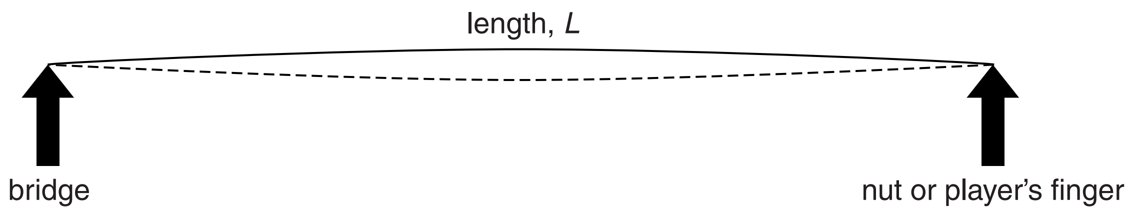

Fig. 2: fundamental standing wave on bowed string

Other factors affecting the tone quality (timbre) include the shape of the violin frame itself, the type of wood from which it is made and, some experts claim, even the varnish with which the violin has been coated.

Sound production

The vibrating strings themselves disturb the air surrounding them only very little, producing hardly any sound. In an acoustic violin, the vibrations of the strings are transferred to the body of the violin via the bridge and sound post (Fig. 3) and a louder sound is produced. The vibrating violin body can also cause the air inside to resonate. This effect is similar to that of producing notes by blowing across the top of a bottle, first studied in detail by Helmholtz in 1885. In the violin, strong resonances at particular frequencies can produce extra, unwanted notes, so-called 'wolf notes'.

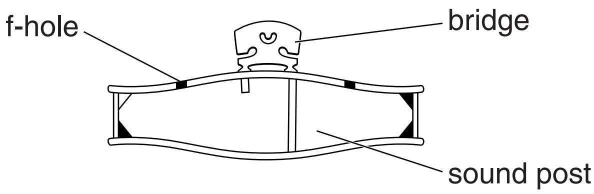

Fig. 3: cross-section of the violin body showing the sound post supporting the bridge

Further resonances are set up in the wooden body of the instrument. As with the strings themselves, standing waves can be set up in the materials of which the violin is made, the wave shapes produced being examples of the two-dimensional standing wave patterns known as Chladni Patterns. The mechanical properties of the material will determine the sorts of patterns produced and these in turn will depend upon many contributing factors. Fig. 4 shows one type of pattern set up in a rectangular wooden plate and a similar pattern produced in the back plate of a violin.

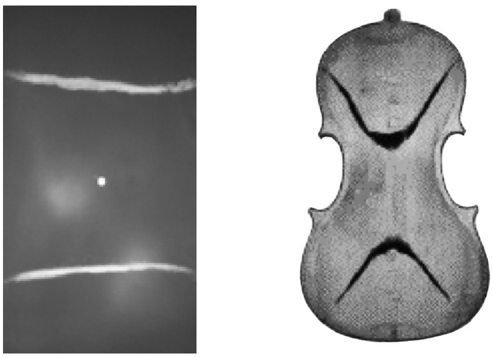

Fig. 4: Chladni pattern for a simple rectangular plate and a violin back plate

The patterns in these pictures have been made visible with sand scattered onto the surface. A more sophisticated modern technique employing lasers and holography can be used to show the nodal lines for the more complicated wave patterns (see Fig. 5).

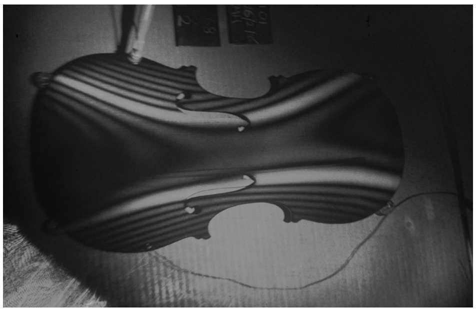

Fig. 5: Chladni standing wave pattern on a vibrating violin plate imaged using holographic techniques

Amplifying the sound

In an electric violin, the vibrations of the strings are detected and converted into electrical signals which can then be electronically amplified and used to produce sound waves in loudspeaker systems. The detection device is called a “pickup” and there are two main types used in electric violins.

1. Magnetic pickup

Magnetic pickups require the violin to have steel strings. The pickup (Fig. 6) consists of a coil of wire wrapped around a permanent magnet, which is placed on the body of the violin underneath each steel string.

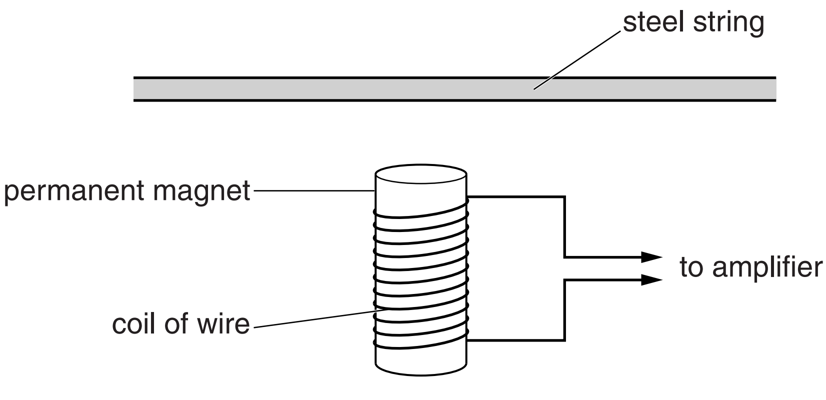

Fig. 6: magnetic (induction) pickup for one steel string

The permanent magnet produces a flux linkage in the coil which depends mainly upon the permeance of the material within the coil, ie the permanent magnet. However, the steel string near the coil contributes to the permeance too, slightly changing the strength of the magnet. If the steel string vibrates and moves relative to the pickup, the total permeance of the magnetic circuit changes. This produces an emf across the coil. This emf produces a current, the frequency components of which will be the same as those of the string. Hence the vibration of the string is detected electrically and can be amplified and broadcast through a sound system.

2. Piezoelectric pickup

The piezoelectric effect was first demonstrated in the late 19th century by the brothers Pierre and Jacques Curie. They showed that voltages can be generated across some materials when they are squeezed. Today this effect has many applications including producing sparks in gas lighters. This effect is especially useful for sensing subtle changes in force and is used in a wide range of sensors from strain gauges to accelerometers used in mobile phones – and, of course, violin pickups.

In this type of pickup, the piezoelectric sensor is placed onto the body of the violin usually on or near the bridge. The sensor then detects the vibrations produced in the instrument body when the strings are bowed or plucked (Fig. 7).

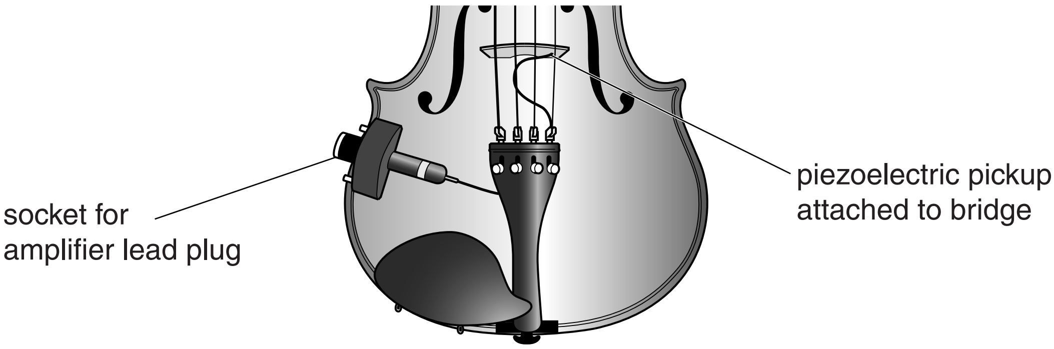

Fig. 7: piezoelectric pickup attached to an acoustic violin

Although the vibrations of the strings and of the instrument body will have the same dominant frequencies, the amplified sound of the notes produced in each case will be very different as the vibrations are being produced in different media in each case. The quality of the sound heard, described as the timbre of the sound, depends on the presence of higher frequencies above the dominant frequency. This is why, for example, a flute sounds different from a violin when they play the same note; the dominant frequency is the same but the mix of higher frequencies is specific to the instrument.

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