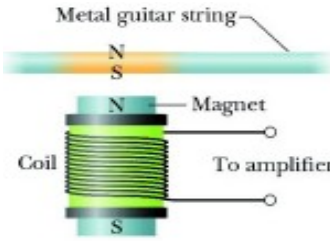
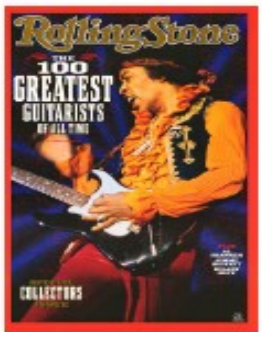
State Examination Commission – Physics Higher Level, 2006

Question 11

Read the following passage and answer the accompanying questions.
The growth of rock music in the 1960s was accompanied by a switch from acoustic guitars to electric guitars. The operation of each of these guitars is radically different.
The frequency of oscillation of the strings in both guitars can be adjusted by changing their tension. In the acoustic guitar the sound depends on the resonance produced in the hollow body of the instrument by the vibrations of the string. The electric guitar is a solid instrument and resonance does not occur.
Small bar magnets are placed under the steel strings of an electric guitar, as shown. Each magnet is placed inside a coil and it magnetises the steel guitar string immediately above it. When the string vibrates the magnetic flux cutting the coil changes, an emf is induced causing a varying current to flow in the coil. The signal is amplified and sent to a set of speakers.
Jimi Hendrix refined the electric guitar as an electronic instrument. He showed that further control over the music could be achieved by having coils of different turns.
(Adapted from Europhysics News (2001) Vol. 32 No. 4)





(a) How does resonance occur in an acoustic guitar? (7)
(b) What is the relationship between frequency and tension for a stretched string? (7)
(c) A stretched string of length 80 cm has a fundamental frequency of vibration of 400 Hz. What is the speed of the sound wave in the stretched string? (7)
(d) Why must the strings in the electric guitar be made of steel? (7)
(e) Define magnetic flux. (7)
(f) Why does the current produced in a coil of the electric guitar vary? (7)
(g) What is the effect on the sound produced when the number of turns in a coil is increased? (7)
(h) A coil has 5000 turns. What is the emf induced in the coil when the magnetic flux cutting the coil changes by 8×10^{-4} Wb in 0.1 s? (7)

(a) How does resonance occur in an acoustic guitar? (7)

In an acoustic guitar the sound is produced by the vibration of the strings. These can only displace a small amount of air, so the volume of the sound needs to be increased in order to be heard. In an acoustic guitar, this is accomplished by using a soundboard and a resonant cavity, the sound box. The air in this cavity is set vibrating by the soundboard (which receives energy transferred from the strings) and resonates with the string, increasing the volume of the sound.

(b) What is the relationship between frequency and tension for a stretched string? (7)

frequency is proportional to the square root of the tension, $f \propto \sqrt{T}$.

(c) A stretched string of length 80 cm has a fundamental frequency of vibration of 400 Hz. What is the speed of the sound wave in the stretched string? (7)

$\lambda/2 = 0.80\ m \Rightarrow \lambda = 1.6\ m$
$v = f\lambda = 400 \times 1.6 = 640\ \text{m s}^{-1}$

(d) Why must the strings in the electric guitar be made of steel? (7)

Steel is capable of being magnetizsed

(e) Define magnetic flux. (7)

Magnetic flux through an area A is the product of the magnetic flux density and the area, $\Phi = B\,A$

(f) Why does the current produced in a coil of the electric guitar vary? (7)

Because the magnet moving inside the coil causes a changing magnetic flux through the coil which induces a varying emf in the coil causeing a varying current to flow.

(g) What is the effect on the sound produced when the number of turns in a coil is increased? (7)

More turns in the coil would cause a larger emf to be induced, and hence a larger current to flow. This would be amplified proportionally and would lead to sound of greater amplitude.

(h) A coil has 5000 turns. What is the emf induced in the coil when the magnetic flux cutting the coil changes by 8×10^{-4} Wb in 0.1 s? (7)

$$\mathcal{E} = -N\, d\varphi/dt$$

$$= 5000(8 \times 10^{-4} / 0.1)$$

$$= 40 \text{ V}$$