Electrical Machinery – Part 2

What are the road-blocks to understanding?

“The Jabberwock was a monster with many heads. As such it resembles, in some way, the manner in which we divide our science into Physics, Chemistry, Biology, etc., and then Physics into Heat, Light, Sound, Magnetism and Electricity. Often one can spot the various heads as being Laws of Physics, and some of them look into mirrors, see their reflections and think that the total number of their kind is bigger than it really is. Thus they attempt to co-exist with their own shadows and reflections. One of the best examples I can give you is the collection of Laws of Electromagnetic Induction.

When I was at school*, I was taught Fleming's left- and right-hand rules, and taught to remember what the fingers and thumbs represented by emphasising the initial letters of the electrical quantities thus:

-thuMb – Motion

-fore-finger – Field

-seCond finger – Current

Then we had to remember which hand to use for motor and which for generator. After that we were taught Lenz's law, the Gripping rule, Corkscrew rule and Ampère's swimming rule. What a business! They were all, apparently, separate, independent heads. But those were the bad old days - I hope. Electromagnetism is a good deal easier than that.”

Eric Laithwaite: Engineer through the looking glass (1980) – a revised and expanded version of his Royal Institution of Great Britain Christmas lectures, 1974/75.

* ‘When I was at school’ would have been shortly before WWII – nothing much has changed!

“There are at least seven mutually exclusive systems of electric and magnetic units in use at the present day, some dating from the time when it was not realised that electricity and magnetism are different manifestations of the same thing. This has made life very confusing to the student of physics or electrical engineering....”

Goodier and Ghey: ELECTROMAGNETISM (1952) – based on the rationalised MKS system of units.

“There are many electronicians, both hobby and professional, who are at war with electromagnetism. Whenever they need to design a coil or a transformer, an abyss of desperation opens in front of these poor people. The worst thing is that usually these poor victims are not really at fault, since the authors of electronic textbooks seem to have struck a plot to explain these things in such a messy way that nobody can really understand them! Or maybe these authors themselves didn't have a clue about the matter?”

“When you enter this page, you have to leave out all obsolete, absurd units of which most textbooks and catalogs are full: Most notably, inches, gauss and oersted.”

Manfred Mornhinweg: Homo ludens electronicus – the inspiration for much that follows.
Electromagnetism comes with plenty of historical baggage, some of which is mentioned by the authors above.

The study of magnetism started with the lodestone and worked up from there. Thus we have the concepts of the isolated magnetic pole and of lines of force. In SI units, all this is swept away and magnetic units are defined in terms of current, even the concept of magnetic poles plays no part in the system.

Field lines may be useful for visualising static magnetic fields but becomes problematic if the fields are changing. For instance, when the strength of a field is increasing, the spacing between the lines needs to decrease and at the same time the number of lines needs to increase. Apart from the fact that this will be visualised as some sort of jerky motion, it raises the issue of having two methods of explaining electromagnetic induction; that illustrated by a conductor cutting field lines, and that illustrated by a field changing within a coil; the implication being that these are two different phenomena. Text books often mangle the cutting explanation to apply to a situation where the field clearly does not intersect the conductor – total confusion. Field lines and the cutting of field lines are not useful concepts; electromagnetic phenomena can be better explained without them.

Another consequence of visualising fields in terms of lines is that it leads to the concept of a magnetic field being a substance and one that is attached to the magnet. This results in all sorts of wonderful diagrams where contorted lines of force are seen to be tugging the machine round; it looks very plausible but does not lead to the sort of explanation that you can put numbers to.

The laws of electromagnetism describe vector fields. Classic experiments involve fields that spew out in all directions. Again, this does not lead to the sort of explanation that you can put numbers to. Actual machines constrain these fields in very definite ways because this is necessary for good performance. This means that we do not have to cope with these complications and scalar quantities can generally be substituted for vector ones.

Direct Current and Alternating Current are marketing terms applied to two competing systems of electricity supply – a DC supply providing an unchanging voltage, and an AC supply providing a sinusoidal voltage waveform. The terms should be reserved for this. Much confusion results from the use of these terms, the expression AC voltage is an obvious example. Note that changing does not equal alternating and, in particular, a changing current can accompany an unchanging voltage.

The term electromotive force is not generally introduced at this level and this has resulted in the term potential difference being very much abused in text books and elsewhere. Voltage will do for both.

Energy was a little understood concept in physics and it was not until the mid 19th century that the Law of Conservation of Energy became accepted. This development came about because of the desire to apply scientific principles to the rapidly growing field of engineering where the well established laws of Newtonian mechanics were proving insufficient. Even now, explanations concentrate on electric current as being the cause of magnetic fields and that this alone accounts for the operation of electromagnetic machines; thus neglecting the fact that the machines are actually transformers of energy. Considering energy from the outset makes everything much clearer.

Much of the published ‘theory’ of electrical machines is in fact a set of mathematical short-cuts to enable engineering calculations to be simplified; this tends to obscure what is actually happening.

Although sinusoidal waveforms are ubiquitous, most electrical machines either do not require them or require other waveforms. Limiting explanations to sine waves, tends to obscure what is actually happening.

But the greatest road-block to understanding is the volume of published explanations that show muddled thinking or that are just plain wrong.