Feedback to Tutors and Candidates on RCF Radio Communications Examinations 2007

The following comments are based on an analysis of candidates responses to questions set in examinations completed in 2007.

Analysis of the Foundation Level tally sheets has shown that there has been a noticeable improvement in the number of correct answers compared with last year. However, candidates' misunderstandings are often rooted in the most basic concepts; potential difference (Voltage), current and resistance

Time spent on the basic topics is very worthwhile as misunderstandings here can cause candidates problems at Intermediate and Advanced Levels.

Teaching electricity is hard, and it is hard to learn. The problem is that it (electricity) is intangible. Certainly much research has been conducted over many years with young people concerning ways of teaching this topic. The results of this research show that frequently they have no intuitive grasp of basic electricity. They simply don't have any 'feel' for what is going on in circuits. Work by Professor Robin Millar of the University of York suggests that for young people entering their secondary education there are four major views of how a simple electric circuit works. Only one of them is actually close to the scientifically accepted view of the basic principles.

In your own radio club you may not find many young people, but what about adults who left their schooldays behind many years ago. Are they better prepared; is their understanding of electricity any greater or simply misunderstandings that have become accepted as being true in the light of 'experience'?

<u>The 'Right' Approach:</u>

Is there any kind of approach that does help the learner to come to some understanding of the fundamentals?

Research does suggest that there is.

Electrical theory makes demands on the learner that may be outside their 'comfort zone'. A full blown rigorous approach to electricity is not exactly going to help a beginner sustain their interest in amateur radio. We make it clear to the learner that our approach is not the whole story, but our account of what is happening in a circuit is simplified to give them a start in the subject. As they progress, these simplified models will be gradually replaced with something that is closer to the truth.

Where should we start?

<u>Energy and Current:</u>

The term 'electricity' is rather a vague one. The language that we use in our teaching has to be carefully chosen. It's better to use words such as 'energy' and 'current'.

At the beginning it is important to point out to the learner that in a circuit there is a 'carrier' that picks up energy from a source and then deposits it somewhere else. A useful example might be the water in a domestic central heating system. It picks up heat energy from a boiler, carries around a circuit and then deposits it in radiators. The current picks up energy from a power supply or battery and then carries it to the various circuit components.

At this point purists will point out that this model of things is rubbish! They are of course correct. Electrons in circuits do not themselves become loaded with energy and then dump it in the nearest component. Energy in a circuit has much more to do with fields and the position of the electron within it.

What we are doing is employing a model that whilst not accurate, it is merely an analogy and not a picture of what is actually going on. As learning progresses we gradually replace these analogies with something more scientifically acceptable. To simply blast away with the 'Truth' would not result in very effective learning. In fact it could be counterproductive for youngsters.

Voltage:

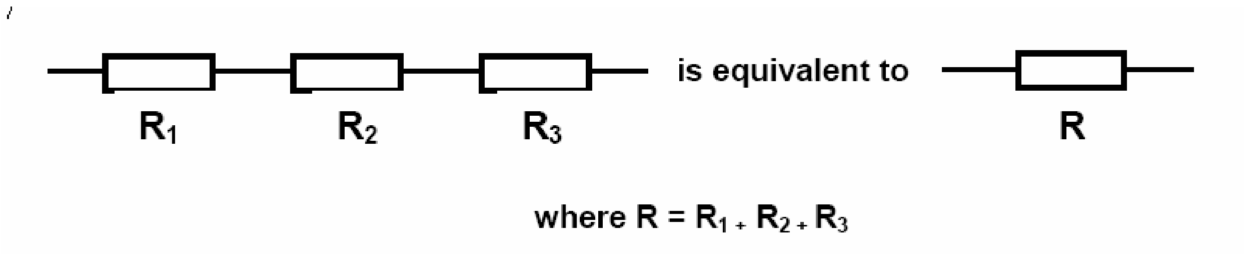
Voltage or potential difference is closely connected with energy, if we begin by considering voltage as the 'push' on the current exerted by the battery. Yes this is wrong! But thinking has to start somewhere. It's not very useful talking to a beginner about field potentials. That comes later when thinking has reached a higher level of sophistication.

Intuitively one feels that a battery with a bigger 'push' will result in a bigger current. The learner is now developing a feeling for what does happen in a circuit.

Resistance:

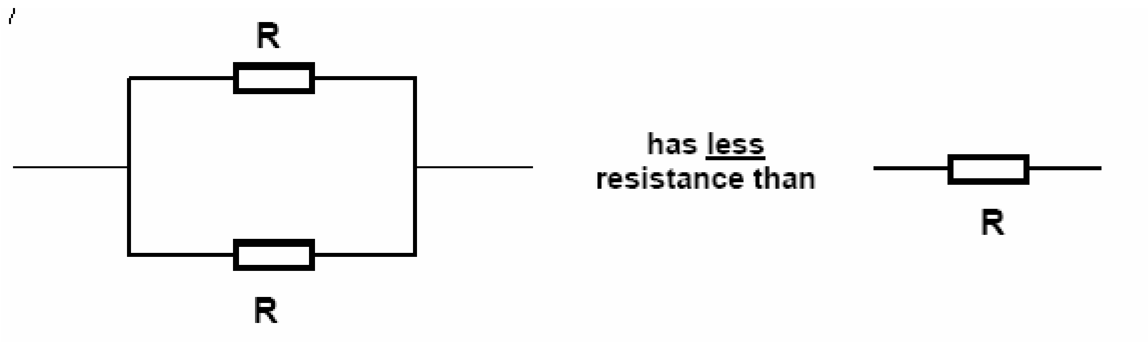
As the name suggests this is a property that materials have which results in energy being dissipated as heat as an electric current flows through it. It is important to stress that resistance is a property that does not disappear when a current switched off. By carefully crafting resistance we can dissipate energy in a controlled way in a circuit. This turns out to be a very useful feature of this physical quantity.

Resistors in series:



Millar's research suggests that most young people have little problem with the idea that resistors in series add up. Intuition suggests that this would be the case. At Foundation level a more rigorous proof of this would perhaps be inappropriate.

Resistors in parallel:



This arrangement of resistors tends to be less intuitive. It is important to stress that having resistors in parallel offers the current an alternative route so the effect of having resistors in parallel is less than having the same resistor on its own.

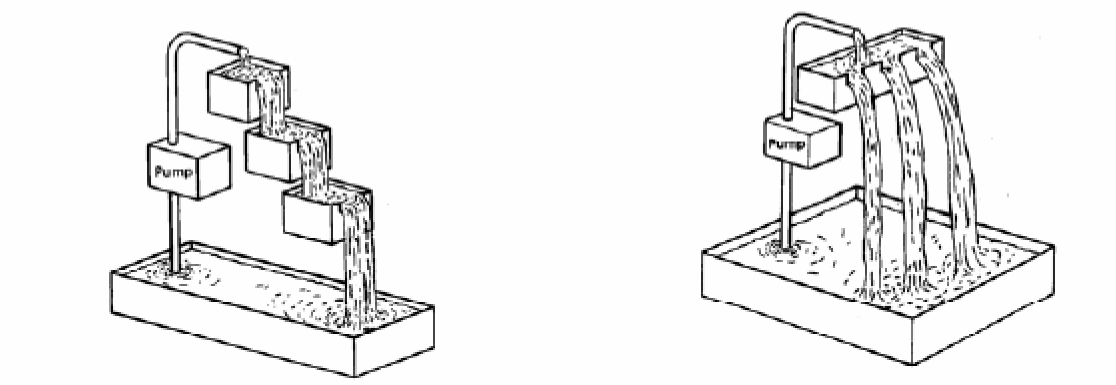
Potential Difference; another look

It is now helpful to develop a more sophisticated understanding of voltage, as the electrical potential difference between two points. PD is linked to energy. In fact the potential difference between two points indicates the number of Joules of energy required to move one unit of charge (1 Coulomb) between the two points. If the electrical potential difference across a resistor is 1 Volt it means that one Joule of energy is required to move 1 Coulomb of charge through the resistor. This energy is supplied by the battery or power supply.

A good analogy for electrical potential difference is that with gravitational potential difference. The higher we climb the more gravitational potential energy we have. Gravitational potential difference between two points indicates the energy required to move one unit of mass (1 Kilogram) between the two points. As a climber ascends a mountain they have to supply the energy that allows them to move through the gravitational potential difference.

As electric charges move around a circuit they move through an electrical potential difference, which requires energy.

Series and Parallel:



series parallel

In a circuit the electric charges drop to a lower potential. In a series circuit they do this in a series of steps. In a simple parallel circuit they do so in one jump. Only some of the charges pass through any given resistor.

The potential divider circuit is misunderstood by about 1/3 of candidates. Using the water analogy above for a series circuit is helpful in highlighting misunderstanding of this important circuit arrangement.

Qualitative before quantitative

As a tutor it is helpful to keep questioning your students as you progress through the ideas. **Qualitative ideas come first.** Many will dash rather unthinkingly into formulae such as Ohm's Law as this 'explains' all. Until students have a qualitative grasp of basic ideas of current, voltage and resistance they will not be able to apply formulae with reliability or real understanding.

The concept of 'Power'

The word Power finds common usage. This can lead to problems when trying to teach its meaning when we use the word in a scientific sense.

Power is the **rate**, at which energy is transferred within a component. It can be clearly seen that the learner has to understand the meaning of the word "rate" if they are to have an understanding of power.

But what about $P=V\times I$ How do we impart a more intuitive grasp of the concept rather than simply relying upon memory?

Remember that potential difference 'V' is the energy required to move one unit of charge. Current is the rate of flow of charge; the charge passing per second through a component. Thus $V\times I$ gives us the energy being transferred per second i.e. the Power being absorbed by the component.

By all means teach simple mnemonics for example for remembering formulae when under pressure, but they have to be built on a solid understanding of what the formula is telling us. That way correct application is more certain. These basic concepts are well worth spending more time on than perhaps tutors feel they should. Time spent here is important as it underpins work at Intermediate and Advanced levels. Simply 'remembering' the formula does not help the student when they begin to study for themselves.

The Radio Receiver:

Some candidates are confused by the word "detector" when applied to the radio receiver. Unfortunately it is not a happy choice of word to describe its function. However, it appears that we are stuck with it until a more descriptive word such as 'demodulator' enters the greater consciousness. This needs to be pointed out to students.

Intermediate Level

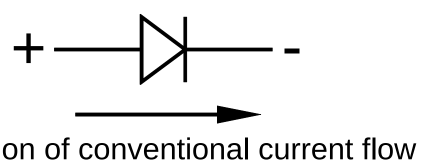
In general the responses to questions were very good. Again though there are areas that continue to cause problems with some candidates.

Ohm's Law and resistors in series and parallel are proving difficult for some. Again this suggests that the basic spadework on potential difference, current and resistance is not being done and in some cases does require more attention from tutors. The use of homework to reinforce these ideas should not be overlooked. Sessions going through homework can prove very enlightening both to the student and the tutor. These can be made light hearted and are a useful ploy for finding out where people are having difficulties. It also gives lessons in radio a more interactive feel so that the students feel they are more in charge of their own learning. Learners like to feel their own efforts are resulting in progress.

The Diode:

Occasionally candidates do forget that in order for a diode to conduct it has to be placed in a circuit with a particular orientation.

A simple way to remember this is that the arrow in the diode symbol shows the direction of conventional current through the diode when it conducts. Conventional current is assumed to flow from the positive to the negative of the power supply in circuit.



Whilst on the subject of the diode…

Rectifier Circuits:

Some candidates are confused by exact function of the transformer and rectifier diodes within simple rectification circuits. The transformer changes the potential difference and the diodes are responsible for the conversion of A.C to D.C.

The varicap diode and frequency modulation were not well understood by significant numbers of candidates.

Polarisation:

This word does appear to cause some candidates to become confused.

In all cases the word does indicate that a sense of direction is important.

For example:

The polarisation of a radio wave indicates the plane in which its electric field oscillates; usually vertically or horizontally. This is linked to the orientation of the antenna.

When applied to an electrolytic capacitor there is a correct way to orientate the capacitor in the circuit.

Polar diagrams used to describe the radiation pattern from an antenna show the directional properties of the flow of radiation from the antenna.

More generally there was confusion over the various modes of propagation at HF and VHF/UHF.

Radio Receivers:

The superheterodyne and tuned radio frequency receiver are both within the scope of the Intermediate examination. It is perhaps unintentional on the part of tutors, but there does appear to be a tendency to teach these two approaches to receiving radio signals in isolation from each other. Knowing how they relate is important; the reasons why the Superhet Principle is considered to give a superior result to the TRF approach should be known.

Electromagnetic Compatibility (EMC):

Some candidates were confused by the difference between "direct pick-up" and interference entering through connecting leads. The great majority of candidates were familiar with high and low-pass filters. However, the fact that televisions receive UHF signals and to prevent entry of amateur radio transmissions at HF and VHF requires a high-pass filter seems not to have been appreciated by many students.

Advanced Level

In the Advanced Examination the seeds of confusion have taken root in many areas of the syllabus.

The reason for this is that candidates have perhaps the same kinds of study methods as they used at Foundation and Intermediate levels. At the lower levels of examination, memory and recall are very much part of learning process. It is possible to 'get by' with a rather slender appreciation of the technicalities of the subject. The Advanced Examination is a different kind of assessment. At this final level, understanding technicalities is absolutely essential. The examination is designed to assess the comprehension and application of technical principles. Thus the learning process has to be rather different at this level. Since a real understanding of principles is the key to success, it is imperative that earlier learning at Foundation and Intermediate has already inculcated in the candidate the desire to understand concepts. Simply 'knowing' is not enough. Understanding and applying at Advanced level now become essential if there is to be a reasonable chance of success.

The candidate may quite reasonably ask why there is such a change in emphasis as they attempt the advanced course. The reason for the change is that once the candidate has successfully achieved a pass at this level the only type of training or study they are likely to do in the future is on their own using what knowledge and skill they have acquired as they have progressed through the different examination levels. The possession of a pass at the Advanced Level does entitle the holder, after being licensed, to use up to 400 Watts of RF. This is a power level that can cause serious problems if not handled with understanding and correct application.

Ofcom does expect the examination to discriminate between candidates who are likely to use high power with competence and those who would be less competent. It is the duty of the RCF to provide an examination that does allow such important discrimination.

Tutors are also reminded that the syllabus does use the word "Understand…" in many of the technical topics covered in the syllabus.

Candidate's responses in more detail:

The syllabus sub sections are included for reference:

Licensing Conditions:

In general these were very well answered although 2f.1 gave difficulty. This concerns cross band working and may well benefit from a little more emphasis.

2g.1 Candidates did tend to overlook the restriction limiting beacon power to 25Watts.

Technical Basics:

3c.1 The equations for Power were not well understood. This links with the earlier comments about candidates understanding of Power made in reference to the Intermediate Examination.

3d.1 The Potential Divider: One third of candidates still have difficulty with calculations relating to this common device. Again it calls into question candidate's basic understanding of potential difference, current and resistance. This comment relates to ones already made in a previous examiners report and in this report at Foundation Level. It is difficult to over emphasise the importance of basic concepts and getting a firm understanding of what they mean.

3e.3 Many candidates were unaware that ceramic dielectrics were often used as they are less 'lossy' at RF. There was a trend apparent that candidates did not appreciate that energy was required to polarise and re polarise a dielectric when in use.

3e.4 and 3f.3: The concept of 'Time Constant' gave difficulty to many candidates.

3f.4 Inductors in parallel. Candidates had a poor appreciation in general of the outcomes of putting inductors in series and parallel combinations.

3g.1 Comparison of DC with peak-to-peak and RMS values. An area of the syllabus that would benefit from a little more study by most candidates. The significance of $\sqrt{2}$ was not appreciated by many candidates.

3h.2 Vector addition of R and C in series not well understood by many candidates. The majority of candidates probably have little appreciation why vectors have to be used when considering components with inductive, and capacitive elements. The phase relationship between voltage and current does introduce complications, which many candidates appear to be unfamiliar with.

3i.3 Circuit Q as Freq/bandwidth not well understood by many candidates.

3j.2 Impedance transformation assumed to be the same as the turns ratio.

3n.1 The depletion layer of a reverse biased diode not understood by candidates.

3n.3 The nature of the dielectric in a varicap diode not known by many candidates.

3o.1 10:1 voltage ratio wrongly taken as 10 dB.

3p.2 Current rating and PIV of rectifier diodes was not well answered by many candidates.

Transmitters and Receivers

4b.1 The precise function of the transistor in an oscillator - of replacing energy losses in the tuned circuit - was not well answered.

4f.1 The definitions of narrow- and wide-band FM not well answered.

4g.4 That one effect of speech processing is to increase average power output for the same peak level was not well understood.

4h.4 Half the candidates did not know that stray coupling in a PA stage is likely to cause self-oscillation at an unknown frequency.

Feeders & Antennas

5a.1 The only question used from this sub-section concerned a 1/4 wave matching stub and most candidates failed to allow for the velocity factor in coaxial feeder.

5a.2 The formula Zf = root of Zin x Zout was not well applied.

5c.1 In calculating the length of a dipole the 95% end correction was often missed.

5c.4 Many confused the side length of a Quad antenna with the perimeter length. Tutors must make certain that candidates do understand the meaning of 'perimeter'.

5d.2 Most did not realise that increased loss in the feeder actually reduces the SWR seen at the transmitter.

Propagation

6a.1 Circular polarisation was not well understood by candidates.

6a.2 There was some confusion as to whether the inverse square rule applied to field strength or to power flux density, but different questions on this point gave varying results.

6b.3 There were unrealistic expectations about the range achievable by a single ionosphere "hop".

6b.5 The likely times of high and low MUF were not well known.

EMC

7a.4 In fitting ferrite rings to combat interference entering a neighbour's hi-fi, a majority thought they should be at the speaker end of the speaker leads. This suggests that candidates have learned about ferrite rings but not understood how they perform their function.

7a.5 Many candidates thought to cure ‘passive intermodulation products’ by filtering at the transmitter and did not realise that they are actually generated at the "rusty bolt" non-linearity.

7a.6 Many thought ‘ghosting’ was least likely by sea, rather than ionospheric reflections.

7b.3 The effect of a ferrite ring on different currents flowing in a twin feeder was not well understood.

7b.4 Only a minority understood that an open ended, rather than short-circuited, 1/4 wave stub acts to remove the frequency it is designed for, not pass it.

7b.5 Several people did not realise that a band pass filter in a TV downlead reduces interference from frequencies above, as well as below, its passband.

7c.1 Only half of the candidates managed a calculation of field strength correctly.

Safety

9d.1 60% did not know the exposure limit field strength for EM radiation.

Conclusions:

The analysis of the tally sheets at all three levels do point to a number of matters that tutors and candidates need to pay heed to if they are to be successful in their roles:

Tutors:

- Be sure to plan your lessons carefully. Take care in the language you use when explaining fundamental concepts
- Don't 'gloss over' fundamental principles at Foundation and Intermediate levels.
- Be prepared to use analogies when explaining basic principles. Point out that they are, however, only analogies.
- Set homework; this allows you to diagnose areas of your teaching where perhaps you have not succeeded as well as you would like to.
- Encourage candidates to learn definitions and test them regularly. This will not appeal to candidates, but it is well worth their effort. Knowing a definition for Dynamic Resistance or 'Q' does make a real and positive difference in the Advanced Examination.
- Encourage class discussion. Students can learn from the experience of each other just as well as from you the tutor. Constantly ask questions of your students and listen carefully to what they say in response. You may detect hidden problem areas that even they are not aware of.
- Take time to cover principles adequately. This may lengthen courses at Foundation and Intermediate level, but gains time at Advanced Level.

Candidates:

- Be sure that you take adequate notes during lessons.
- Ask questions if you are not certain of something. Don't be afraid of looking silly; any tutor should listen carefully to your question and treat it with care.
- If you get homework, do it carefully. It is designed to improve your learning and make your eventual success more certain.
- Learn any definitions you are given carefully. This really helps when answering more complex questions designed to test your understanding of principles. Knowing the difference, for example, between Field Strength and Power Flux Density by definition, does make answering questions about these topics more straightforward.