MATHEMATICS PRIMER

Introduction

This part of the course of study toward the Radio Communications Examination (RCE) is primarily concerned with ensuring that students can cope with the mathematics required.

The RCE is not intended as a test of mathematical ability and thus the teaching approach seeks to avoid getting bogged down in the detail of the mathematics. Instead it relies on students learning a few basic procedures on a standard scientific calculator; widely available for approximately £7.

Teaching of the routines builds on some basic ideas from the Foundation and Intermediate Licence courses to allow the student to tackle ‘real’ problems and build confidence in the approach. These ideas include the use of prefixes, parallel resistor combinations, and tuned circuits.

Prefixes

You should be familiar with the idea of using of prefixes to scale numbers to a convenient size, such a expressing 1000Ω as 1kΩ or 0.001A and 1 mA. However, doing this manually is prone to errors, especially when making calculations.

Using the scientific calculator simplifies the use of prefixes and, with practice, provides a ready means to tackle problems you will encounter in the hobby.

The table below summaries the prefixes you have met previously in the Foundation or Intermediate courses- although I have added an extra column with the title “EXP”

Prefix	**Prefix Name**	**Scaling**		**Example**	**EXP**
p	pico	1/1,000,000,000,000	0.000000000001	1pF	-12
n	nano	1/1,000,000,000	0.000000001	1nF	-9
u	micro	1/1,000,000	0.000001	0.1uF	-6
m	milli	1/1,000	0.001	1mA	-3
k	kilo	1000		1kΩ	3
M	Mega	1,000,000		1MΩ	6
G	Giga	1,000,000,000		1GHz	9

The EXP column indicates how many you must “times by 10” OR “divide by 10” you must apply to the starting number to express it with the corresponding prefix. For example:

To express 18000Ω in kΩ, you must divide by 10 3 times and include the “k” before the Ω so the EXP is 3

To express   0.001 A in mA, you must multiply by 10 3 times so and include the “m” before the A, so the EXP is –3.

Scientific calculators include a special key, labelled ENG (engineering notation), which makes such conversions easy. Let us work through some examples:

To convert 18000Ω to kΩ:

Key(s) to Press	Display	Comment
18000=	18000	Enter starting number
ENG	18x10 03	Use ENG key to convert to EXP notation with the EXP as a multiple of 3

To convert 0.00001A to uA

Key(s) to Press	Display	Comment
0.00001=	0.00001	Enter starting number
ENG	10x10 -06	Use ENG key to convert to EXP notation with the EXP as a multiple of 3, in this case –6 indicating “u”

If the desired EXP does not appear on the right hand side of the display, for example if you wished to display the above answer in mA rather than uA, you can use the ENG again, or the Shift followed by the ENG key, to adjust the EXP to the correct multiple of 3.

To convert 0.00001A to mA

Key(s) to Press	Display	Comment
0.00001=	0.00001	Enter starting number
ENG	10x10 -06	Use ENG key to convert to EXP notation with the EXP

		as a multiple of 3, in this case –6 indicating "u"
Shift ENG	0.01 x10 -03	EXP is now –3, corresponding to "m"

You can use the ENG and Shift ENG keys to adjust the EXP to and fro until the value of EXP, corresponding to the prefix required is displayed.

If you wish to enter a value which is already expressed with a prefix then you use the EXP key enter the number of "times by10" OR "divide by 10" corresponding to the prefix in use.

For example, to express 18kΩ in Ω and in MΩ

Key(s) to Press	Display	Comment
18 EXP 3 =	18000	There is no "x10 " on the display so the answer has no prefix.
Shift ENG	0.018x10 06	Use Shift and ENG keys to adjust the EXP display to the required value for M, which is 6.

To enter numbers with the smaller prefixes (m, u, n, and p) you will need to use (-) key to set the EXP to a – number, such as –3.

For example, to express 10mA as A and uA

Key(s) to Press	Display	Comment
10 EXP (-) 3 =	0.01	There is no "x10 " on the display so the answer has no prefix.
ENG	10x10 -03	ENG keys to adjust the EXP display, EXP is –03 corresponding to m so we need to press it again.
ENG	10000x10 -06	EXP is now –06, corresponding to "u".

At first the above process may seem complicated but, once you have worked through it a few times, it should become second nature.

Practice with the following:

Starting Value	Convert to	Correct Answer
100mA	A	0.1A
390kΩ	MΩ	0.390MΩ
4.7MΩ	kΩ	4700kΩ
15mV	V	0.015V
1.296GHZ	MHz	1296MHZ
144625kHz	MHz	144.625MHz
1000V	kV	1kV (or 1.0kV)
100pF	nF	0.1nF
1nF	pF	1000pF
1000nF	uF	1uF

Calculating Parallel Combinations of Resistors

One of the formulae that you need to be able to work with calculates the total value, R_T of a combination of number of resistors in parallel. The formula for two resistors, R_1 and R_2 in parallel is:

$$1/R_T = 1/R_1 + 1/R_2$$

If there are three, or more, resistors in parallel the formula has the corresponding extra terms added. Thus:

For 3 resistors: $1/R_T = 1/R_1 + 1/R_2 + 1/R_3$

For 5 resistors: $1/R_T = 1/R_1 + 1/R_2 + 1/R_3 + 1/R_4 + 1/R_5$

Once again, using the calculator and a simple procedure greatly simplifies the solution of this problem.

For example, calculate the total value of a 18kΩ resistor in parallel with a 10kΩ resistor, expressing the answer in kΩ

Key(s) to Press	Display	Comment
1 ÷ 18 EXP 3 + 1 ÷ 10 EXP 3 =	0.000155555	Enter 1/R terms and press = to get $1/R_T$

		BUT we need R_T so we must need to divide this answer into 1. This is rapidly done with the x^{-1} key which means "divide 1 by the answer"
x^{-1} =	6428.57	I've ignore the digits after the .57
ENG	6.628…… x10 03	Again, I've ignored some digits after the .628

Practice the technique with the following examples:

R_1	R_2	R_3	Answer R_T =
15kΩ	10kΩ	18kΩ	4.5kΩ
10kΩ	6.8kΩ	5.6kΩ	2.349kΩ
180kΩ	10kΩ	12kΩ	5.294kΩ
100kΩ	47kΩ	Not used	3.197kΩ
120kΩ	120kΩ	120kΩ	40kΩ

Common mistakes to watch for:

Forgetting to enter the 1 ÷

Forgetting to use the x^{-1}

Working With More Complex Formulae

Probably the most complex formula you will need to work with as part of your RCE, is the one used to calculate the resonant frequency, f, of a tuned circuit with and inductor, L, and a capacitor, C.

The formula is:

$$f = 1 / 2\Pi \sqrt{LC}$$

In this formula, if L and C are in Henries and Farads then f will be in Hertz. However, L and C are normally expressed with a prefix, typically uH and pF, so you need to ensure you enter the values correctly into the calculator.

This formula requires the use of two special keys, the Π key (Shift EXP), the √ key (in the 2^{nd} row of black keys), and the (and) keys (middle 4^{th} row of black keys).

Π is a mathematical constant, equal to about 3.142, which is used a lot in science, engineering, and mathematics. *Don't worry about it just use it when needed!*

√ is a function that tells you which number, multiplied by itself, gives you the number after the symbol. So, √4 is 2, √25 is 5, √100 is 10, √10000 is 100.

(and) are called brackets and are used to tell the calculator "work this bit of the formula out first and then use the result in the next part".

To evaluate this formula we will first evaluate the 'bottom line' (or denominator), 2 Π √ LC, and then use the x^{-1} key to complete the calculation.

We will also use the (and) keys to group parts of the calculation.

So, to find out what frequency (in MHz) a tuned circuit with an L of 1uH and a C of 100pF resonants at we use the following key sequence:

Key(s) to Press	Display	Comment
2 x Π x √ (1EXP-6 x100EXP-12)	0.000000062	To get Π press Shift then EXP Be sure to use the (-) key to get the – in the EXP.
x^{-1} =	15915494.31	Use the x^{-1} key, which divides the bottom line into 1, to complete the calculation. This answer is in Hz. To convert to MHz use the ENG key.
ENG	15.915……..x10 06	The answer in MHz (EXP =6). Again, I've ignored some digits.

Practice this key sequence with the following examples:

L	C	f
1nH	100pF	
10uH	150pF	
1uH	200pF	
2.5uH	100pF	
2.5nH	250pF	