

MP Parallel RLC Circuits

by Michael Peck

FILE	17976_MICHAEL_PECK_MP_PARALLEL_RLC_CIRCUITS_221337_1617262839.DOCX (2.44M)		
TIME SUBMITTED	06-JAN-2020 05:20PM (UTC+0000)	WORD COUNT	1239
SUBMISSION ID	117439302	CHARACTER COUNT	6304

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Abstract

This report investigates the effects on a parallel RLC circuit's voltage while in resonance. Particularly evaluating the differing effect from the results from a circuit built using circuit simulator software, versus the results gained from a circuit built with actual physical components in a circuit and the explanation for differing results due to AC Theory.



Introduction

In AC Theory it is known that when components are configured to construct a parallel RLC circuit there is a power supply frequency at which the circuit begins to resonant, known as the Resonant Frequency, (f_r). At the resonant frequency the voltage across the inductor and capacitor nest is constructively amplified. The reactance's of both the capacitor and resistor become equal, meaning the following is true and f_r becomes calculable as follows:

If at resonance frequency, (f_r), $X_L = X_C$, then when $X_C = \frac{1}{2\pi f_r C}$ and $X_L = 2\pi f_r L$,

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$X_L = X_C$ becomes:

$$\frac{1}{2\pi f_r C} = 2\pi f_r L \quad (1)$$

Multiplying equation (1) by $2\pi f_r C$ gives:

$$1 = 4\pi^2 f_r^2 LC \quad (2)$$

To isolate f_r term, both sides are divided by $4\pi^2 LC$ giving:

$$\frac{1}{4\pi^2 LC} = f_r^2 \quad (3)$$

Transposition then gives rise to f_r ,

as follows:

$$\sqrt{f_r^2} = \sqrt{\frac{1}{4\pi^2 LC}}$$

$$f_r = \frac{\sqrt{1}}{\sqrt{4\pi^2 LC}}$$

$$f_r = \frac{1}{2\pi\sqrt{LC}} \quad (4)$$

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In a parallel resonance circuit stores the circuit energy in the magnetic field of the

"A parallel resonant circuit stores the circuit energy in the magnetic field of the inductor and the electric field of the capacitor. This energy is constantly being transferred back and forth between the inductor and the capacitor which results in zero current and energy being drawn from the supply."

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This is because the corresponding instantaneous values of I_L and I_C will always be equal and opposite and therefore the current drawn from the supply is the vector addition of these two currents and the current flowing in I_R . [1]

The resonant frequency for the component values used, therefore is as follows, when: $L = 1 \times 10^{-3} \text{ H}$ and $C = 1 \times 10^{-6} \text{ F}$

$$f_r = \frac{1}{2\pi\sqrt{(1 \times 10^{-3})(1 \times 10^{-6})}}$$

Therefore $f_r = 5032.92121\text{Hz}$

The resonant frequency is then investigated as follows in both simulated and physical circuits, this establishes the difference between the two types of practical examination tool.

Method

The investigation into Parallel Resonance Circuits was carried out in two forms, the first method was to construct the circuit using simulation software in this case Proteus. The second method was to construct a physical circuit on a breadboard using physical components.

In order to construct the simulated circuit, a power source (in the form of a signal generator) was connected in series with a $1\text{k}\Omega$ resistor, which was then connected in series to a parallel nest consisting of a 1mH inductor in parallel with a $1\mu\text{F}$ capacitor. A ground or earth point was then added to give a reference point for readings to be taken, the circuit then terminates back at the power source.

Once the circuit was built voltage meters were connected to the power source side of the resistor to measure voltage in (V_{IN}) and the voltage across the parallel LC part of the circuit (V_{LC}). To actually ascertain data about the effects of varying power supply frequency on V_{LC} , the supply frequency was increased, from 100Hz to 200Hz , then to 500Hz then in steps of 500 up to 5000Hz . As calculated in the introduction the theory suggests that the resonant frequency, (f_r) is 5032.92Hz to 2 d.p., as such the frequency was then adjusted to try and get as close to the resonant frequency as possible. The closest value to this was 5100Hz , which was then followed by 5500Hz and then increased in 500Hz intervals up to 8000Hz . At 8000Hz the interval was increased by 2000 to show effects at 10kHz and then again at 20kHz .

As the supply frequency was changed, both the V_{IN} and V_{LC} , were measured, using the graphical tools on Proteus, several measurements were taken to establish accurate maximum peak to peak voltage values. All values were record in an MS Excel spreadsheet (See Appendix A) and appropriate graphs plotted to estimate Q-factor. The circuit constructed can be seen below in Figure 1.

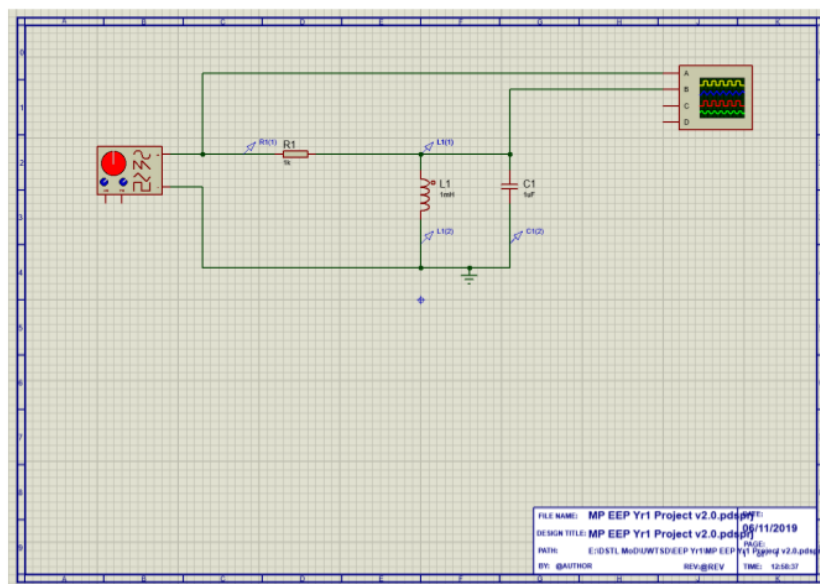


Figure 1. Proteus Parallel RLC Resonance Circuit (As produced by Author)

The second form was to construct a physical circuit using components, this involved using a breadboard as pictured below

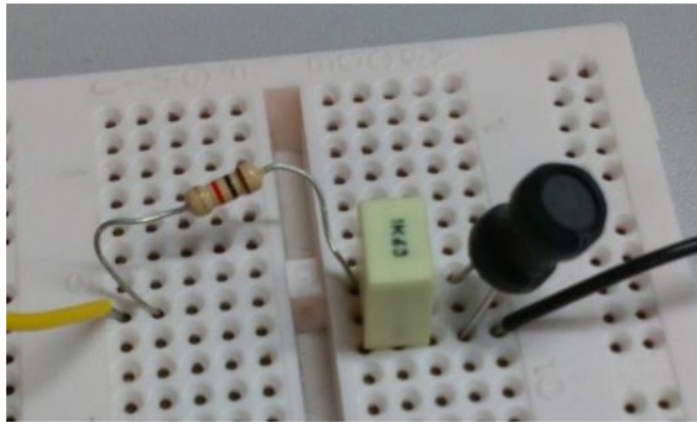


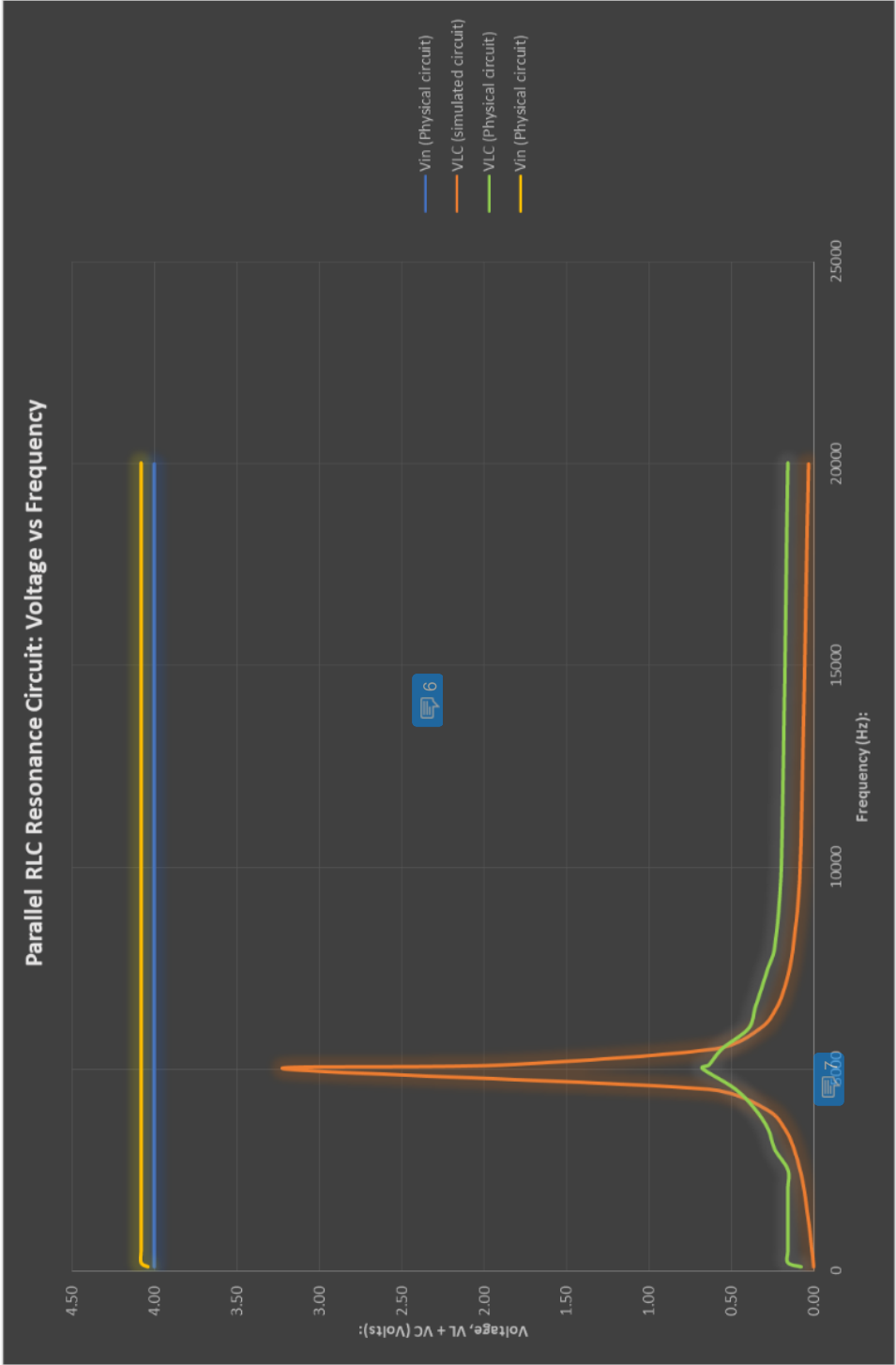
Figure 2. Physical Parallel RLC circuit built on breadboard

in Figure 2. Where the components were simply pushed into the holes to connect them. The horizontal rows of holes are connected either side of the gully in the center and as such act as the wire connections of the circuit. The yellow wire to

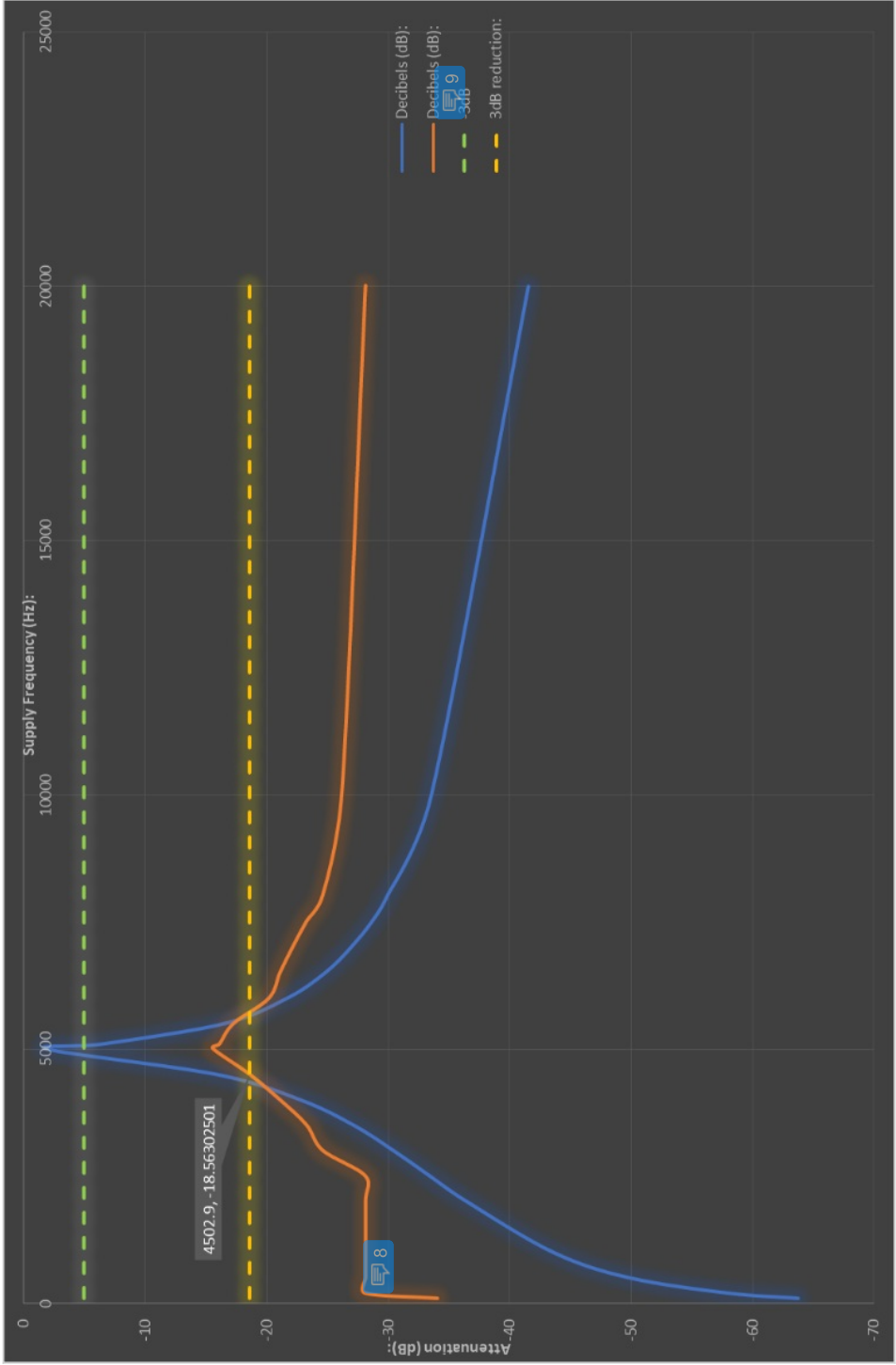
the left of the picture is the V_{IN} side of the circuit which was connected to the physical signal generator on the worktop. The black wire to the right connects back to ground and completes the circuit. Measurements were again taken with the frequencies being set to as close to those used for the simulated circuit as possible. V_{IN} was measured with a voltage meter across the left-hand side of the resistor and black wire. The voltage across the parallel LC part of the circuit (V_{LC}) was measured from the right-hand side of the resistor to the black wire. Again these results were recorded in the MS Excel spreadsheet in Appendix A.

Results

Below can be seen the results of the 2 previous methods. Both in a $V_c + V_L$ against frequency graph



And as a Attenuation against frequency to determine the Q factor: (Note the Orange line = Physical circuit and Blue line the simulated circuit)



Discussion

As previously mentioned when the Parallel RLC circuit power supply oscillates at the resonant frequency, resonance occurs, effectively meaning that the voltage across the inductor capacitor network constructively interacts.

This interaction causes a large spike in voltage, equivalent to that of the supply. This would mean that the attenuation versus frequency, as plotted to estimate the Q-factor should peak at 0dB.

A line can then be plotted at -3dB and the intersect with the data line give the band width i.e. lower and upper frequencies. When resonant frequency is divided by band width it gives Q factor which reflects the goodness of any type or collection of components in a circuit. In this case acting as an indicator of current magnification. [2]

Therefore based on the theory at 5032.92121 Hz a peak in voltage equivalent to the supply voltage of 4 V peak to peak would be expected and therefore a attenuation versus frequency peak at 0dB. This did not happen for either the simulated or physical circuits.

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For the physical circuit the Q-factor came out at about 4.12 and the simulator at about 42.3

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These results are not massively accurate as the attenuation should be set to 0dB and as it wasn't did not give a true representation of the actual data and therefore didn't reflect the true Q factor.

Conclusion

 12 The experiment lacked accuracy in many places and highlights the differences in results due to simulators not factoring in resistances in inductors supplies and many areas. This coupled with the inability to accurately set the supply frequencies' made it difficult to obtain accurate results.

If done again, it would be wise to build a simulator circuit with series resistances to better emulate the physical components.

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References

- [1] E. Tutorials, "Parallel RLC Resonance Circuits," [Online]. Available: <http://www.electronics-tutorials.ws/accircuits/parallel-resonance.html>. [Accessed 20 11 2019].
- [2] J. Bird, Electrical Circuit Theory and Technology, London and New York: Routledge Taylor & Francis Group , 2013.

Ref Qual 

Appendix

SIMULATED CIRCUIT		fres		5032Hz		PHYSICAL CIRCUIT		Decibels (dB):	3dB reduction:
Frequency(Hz):	Vin (simulated circuit)	VLC (simulated circuit)	Decibels (dB):	3dB reduction:	=	Vin (Physical circuit)	VLC (Physical circuit)		
100	4.00	0.00260	-63.74173287	-4.93820026		100.005	0.080000	-34.06582756	-18.56302501
200	4.00	0.00500	-58.06179974	-4.93820026		200.01	0.160000	-28.13080361	-18.56302501
500	4.00	0.01280	-49.89700043	-4.93820026		500.60	0.160000	-28.13080361	-18.56302501
1000	4.00	0.02640	-43.60912129	-4.93820026		1000.2	0.160000	-28.13080361	-18.56302501
2000	4.00	0.06000	-36.47817482	-4.93820026		2007.3	0.160000	-28.13080361	-18.56302501
2500	4.00	0.08500	-33.45282131	-4.93820026		2502.3	0.160000	-28.13080361	-18.56302501
3000	4.00	0.12000	-30.45757491	-4.93820026		3007.7	0.240000	-24.60897843	-18.56302501
3500	4.00	0.17500	-27.18043885	-4.93820026		3509.2	0.280000	-23.27004263	-18.56302501
4000	4.00	0.29000	-22.79323987	-4.93820026		4002.7	0.360000	-21.08715325	-18.56302501
4500	4.00	0.64000	-15.91760035	-4.93820026		4502.9	0.480000	-18.58837851	-18.56302501
5000	4.00	3.20000	-1.93820026	-4.93820026		5010.2	0.680000	-15.56302501	-18.56302501
5100	4.00	1.90000	-6.466127808	-4.93820026		5101.6	0.640000	-16.08960378	-18.56302501
5500	4.00	0.60000	-16.47817482	-4.93820026		5503.5	0.560000	-17.24944272	-18.56302501
6000	4.00	0.33000	-21.67092103	-4.93820026		6003.4	0.400000	-20.17200344	-18.56302501
6500	4.00	0.23000	-24.80664311	-4.93820026		6509.2	0.360000	-21.08715325	-18.56302501
7000	4.00	0.18000	-26.93574972	-4.93820026		7002.1	0.320000	-22.1102037	-18.56302501
7500	4.00	0.14800	-28.63596552	-4.93820026		7513.2	0.280000	-23.27004263	-18.56302501
8000	4.00	0.12800	-29.89700043	-4.93820026		8033.2	0.240000	-24.60897843	-18.56302501
10000	4.00	0.08400	-33.55561411	-4.93820026		10072.8	0.200000	-26.19260335	-18.56302501
20000	4.00	0.03350	-41.54030369	-4.93820026		20014.7	0.160000	-28.13080361	-18.56302501

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

57 / 100

PAGE 1

PAGE 2



Comment 1

Your abstract should also contain some results.

PAGE 3



Comment 2

You should introduce the variables and describe what they are, including any units.

where X_L is the inductive reactance in ohms, f_r is the resonant frequency in Hz, and L is the inductance in Henrys.



Comment 3

Incomplete sentence.



Comment 4

Direct quotes should be indented and italicised to allow the reader to identify easily which parts of the text are from the reference source.

PAGE 4

PAGE 5

PAGE 6



Comment 5

Your method reads like an instruction manual. You only need to state what you have done, you do not need the minute detail you have included.

All you need to do is say WHAT you did, you don't need to say HOW.

This is all you really needed:

"The circuit was connected as shown in Figure 1. The input and capacitor voltages were measured at a range of frequencies, and plotted. The -3dB bandwidth was estimated from the graphs and Q-factor calculated using Equation 1. The process was repeated for both the practical and simulated circuits."

You should try to be as concise as possible.

PAGE 7



Comment 6

Your colour scheme is distracting. Graphs are supposed to be plain, clear and simple. You should use a white background with thin lines for each of the series plotted. The series lines should be as thin as possible to allow accurate readings to be made from the graph.



Comment 7

This was supposed to have a logarithmic x-axis

PAGE 8



Comment 8

I suspect you may have one or two data handling errors.



Comment 9

Your legend should state the data source, not the units.

PAGE 9



Comment 10

Why did it not happen?



Comment 11

Yes they are. I suspect your preconception of what they should be like is not massively accurate.

The output does not go to 0dB for real physical reasons:

1. The circuit is essentially a frequency selective potential divider. For the output to equal the input (0dB) the bottom resistance must be infinite. The impedance of the LC network never goes to infinity

- this is mainly due to the resistive element associated with the inductor.

2. The test equipment used has impedances associated with it: output impedance of the signal generator and combined input impedance of the oscilloscope and probe will also have an effect - but to a lesser extent.

3. Even in the perfect simulated circuit, the output does not go to 0dB, so why should the practical circuit?

PAGE 10



Comment 12

You could simulate the effect of this by adding a resistor in series with the inductor. That would give more evidence to support your argument.



Comment 13

Why didn't you do this?

PAGE 11

QM

Ref Qual

You should try to use more high quality reference sources, such as textbooks from reputable academic publishers and articles from peer reviewed journals.

Additional Comment

More references needed

PAGE 12

GRADING FORM: SMU GENERIC_SMOSEY

MICHAEL PECK

56.70

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty

-  Inclusion of a limited range of research-informed literature, including sources retrieved independently. Referencing conventions mostly consistently applied.

2.6

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.

-  Knowledge is extensive. Exhibits understanding of the breadth and depth of established views.

18.9

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.

-  Evidence of some logical, analytical thinking and synthesis. Can analyse new and/or abstract data and situations without guidance. Valid conclusions and recommendations, where relevant

15.6

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.

-  A good and appropriate application of standard methods, materials, tools and/or techniques. Good appreciation of the context of the application, with

16.2

some use of examples, where relevant.

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.



Can communicate well, confidently and consistently in a suitable format. Work is coherent and fluent and is well structured and organised.

3.4