

Resonance

by Keefe Montebon

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Resonance

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Electrical and Electronic Principles

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Abstract

The aim of the assignment is to provide practical skills to candidates during the course, targeting areas such as practical measurement skills and data analysis. Candidates will be required to perform laboratory exercises that will be based on software simulation and a practical experiment using real equipment. Topics mentioned will be resonance effect, Q factor, bandwidth and inductance over frequency.

1 Introduction

 1 This section should contain the background research related to your report. All third party work used should be cited correctly and listed in the references section.

The Quality Factor of an Inductor

The quality factor, characterized as Q of a circuit can be defined as the equation below.

$$Q = \frac{|Im(Z_{ind})|}{|Re(Z_{ind})|}$$

Caption required

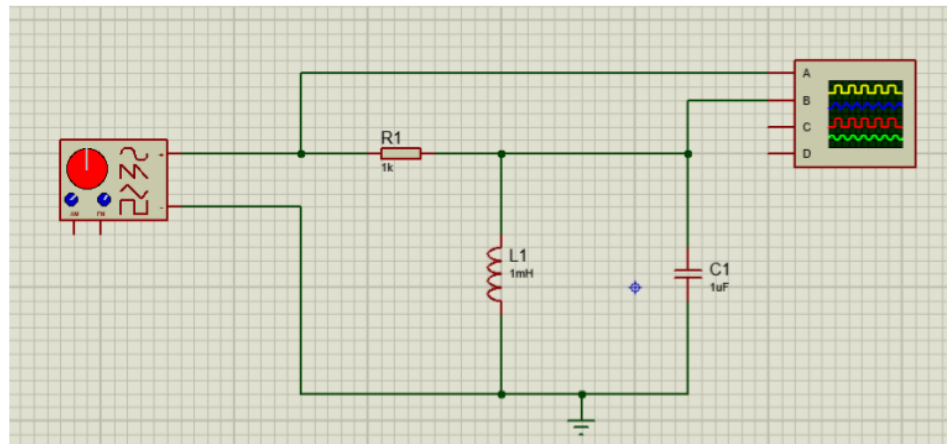
Z_{ind} is the impedance of the inductor. This is not necessarily the most common or basic definition of Q, but it is a good way to characterize the structure. A good way to think about this is that Q is a ratio of the desired quantity (inductive reactance) to the undesired quantity (resistance). In this case, a higher Q device is more ideal.

The Q of an on-chip inductor is affected by many things. At low frequencies, the Q tends to increase with frequency because the losses are relatively constant (mostly due to metal resistance R_s) while the imaginary part of the impedance is increasing linearly with frequency. However, as the frequency increases, currents start to flow in the

through the capacitive reactance, and to a lesser degree, magnetic coupling. This loss of energy in the substrate causes an effective increase in the resistance. In addition, the skin effect starts to raise the resistance of the metal traces at higher frequencies. Therefore, most integrated inductors have Q_s that rise at low frequencies and then have some peak beyond which the losses make the resistance rise faster than the impedance, and the Q starts to fall off again. It is easy to see the need for the proper optimization to ensure that that inductor has peak performance at the frequency of interest. [1]

There were two sets of data. One was for collating data to find the resultant resonant frequency in an inductor. Increasing frequency and noting the change in the resistance. In that set of data, Frequency and VLC have been highlighted. In that table there are two different readings for VLC where one is written in Volts, and the other is written in 2 decimal placed numbers, represented with (mV) and is just an extra set for note taking during the lab experiment. Note: See Appendix A

Another set of data was collated to [pin point](#) the Q factor or also referred to as V_C / V_S or V_L / V_S . This was to find the peak or otherwise referred to as the 'Quality' Factor of the graph that was previously made. Note: See Appendix B



Circuit Diagram 1

Above, is the circuit diagram made in Proteus [2]; this allowed candidates to test the theory of the experiment before moving onto real world applications. In the case of this experiment, that was through the use of Bread boarding. In the circuit above, it has uses a virtual Oscilloscope, a function generator, a resistor, a capacitor and an inductor with the circuit being led to ground.

2 Equipment

This section should contain a list of the equipment used in the investigation.

Proteus – software

 EdExcel – software

Oscilloscope

Function Generator

Breadboard

3 Method

To garner test readings, the use of Proteus [2] was essential in the process. Proteus allowed the users to simulate the circuit to prove the theory of our Q factors and the change in amplitude as the frequency was increased, to find the resonant factor. It was to test the peak frequency of the circuit above. See **Circuit Diagram 1 in Introduction**

During the lab, candidates had to use Proteus. [2] Proteus is a computer aided design software capable of creating simulated circuits; such as with this experiment, and also able to write code and had simple program commands.

In the circuit, the use of a digital oscilloscope was used, and a function generator. It was to monitor the change in peak to peak frequency.

The data collected was then inputted to find the correlation in the attenuation over frequency.

Below is a few cells used in EdExcel to locate Q Factor in our table of results. It shows the Band width of the Q factor frequency.

-3dB line			Fres	
x	y		x	y
4000	-1.96587		5000	1.5
6000	-1.96587		5000	-5
FL line			BW	
x	y		Qfactor	6.060606
4575	1.5			
4575	-5			
FH line				
x	y			
5400	1.5			
5400	-5			

Q Factor (Simulated) 1

In the table above, please refer to the Q Factor Graph 2 (Simulated) in the Results section

-3dB line			Fres	
x	y		x	y
3500	-16.1515		5075	-12.5
6500	-16.1515		5075	-20
FL line			BW	1497
x	y		Qfactor	3.390114
4368	-12.5			
4368	-20			
FH line				
x	y			
5865	-12.5			
5865	-20			

Q Factor (Real World) 1

In the table above, please refer to the Q Factor Graph 2 (Real World) in the Results section

$$Q = \frac{f_R}{f_U - f_L}$$

Caption required

The equation above helped in locating Q factor. In the experiment, we input our data, which was aided by the VLC equation. See below.

$$f_{res} = \frac{1}{2\pi\sqrt{LC}}$$

Caption required

The equation above was to help in finding the resonant frequency in an inductor. This is otherwise known as Resonance Effect and occurs when an LC circuit is driven by an

external source by a chosen frequency, f_{res} at which the inductive and capacitive become equal in magnitude, thus outputting our equivalent answer in hertz.

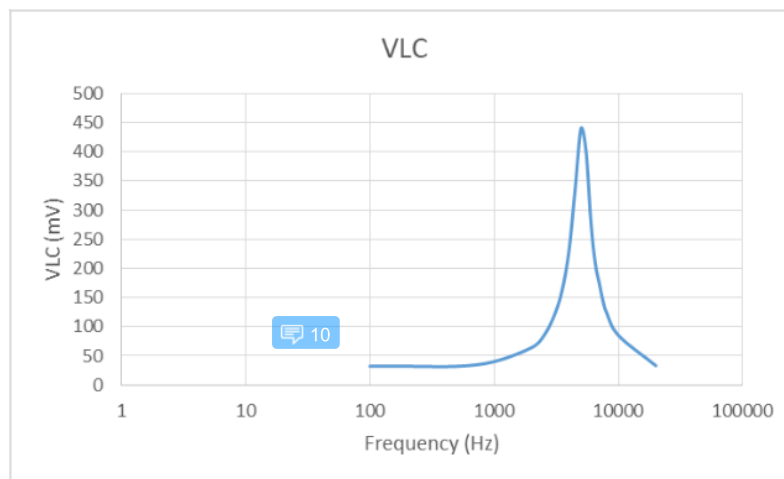
$$\times 10^{-3}$$

$$10^{-3} = \text{ANS}; \text{ANS} \times 2$$

Squares counted $\times$ Ch2 (Voltage) 9

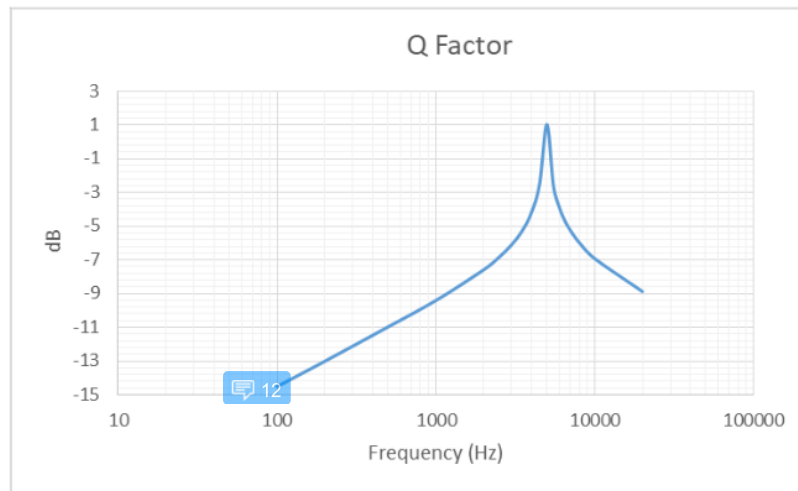
These were noted equations used personally as a small guide during the converting process when plugging in the data and changing said values from Volts to (mV).

4 Results

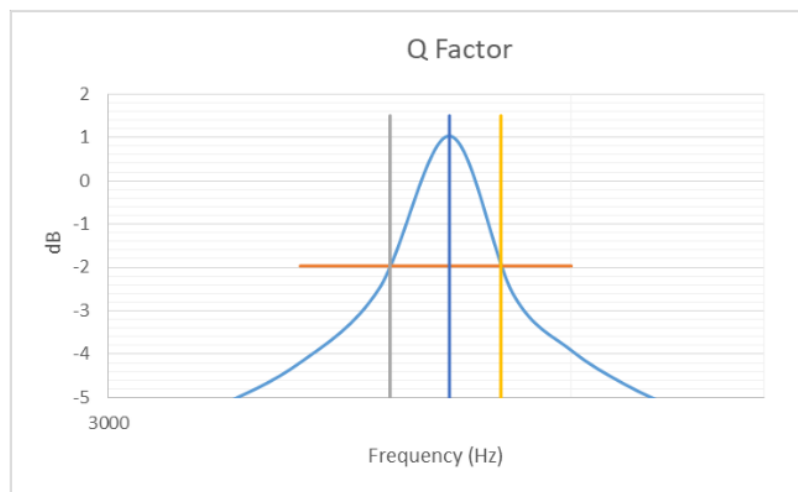


VLC Graph (Simulated) 1

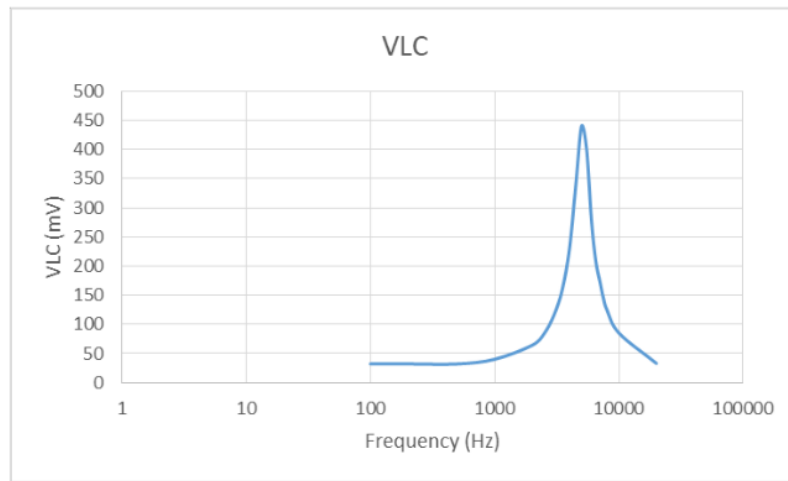
11



Q Factor Graph (Simulated) 1

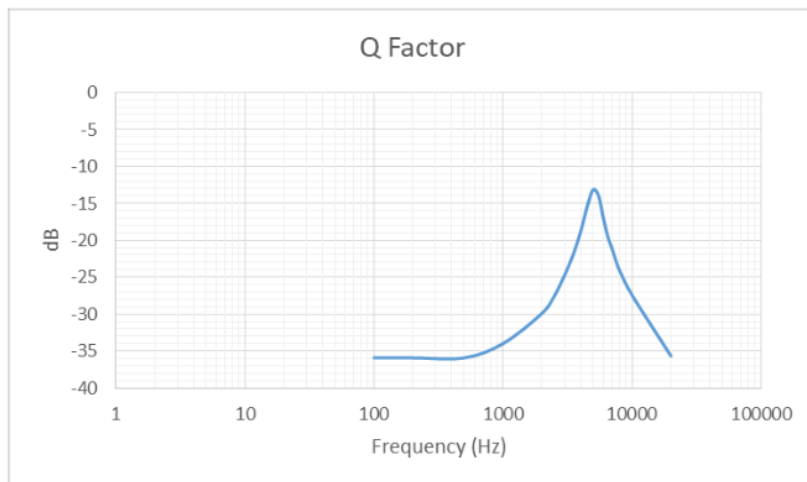


Q Factor Graph (Simulated) 2

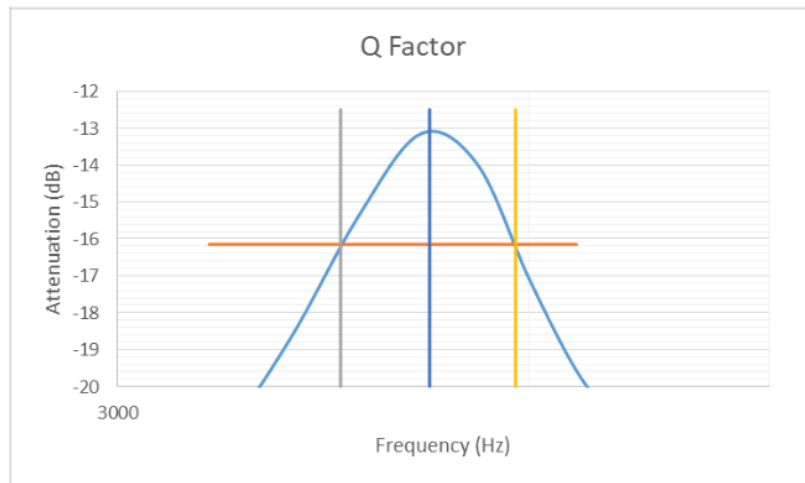


VLC Graph (Real World) 1

15



Q Factor Graph (Real World) 1



Q Factor Graph (Real World) 2

To see the table of results please refer to the appendix, through sections A, B, C. Please

note: Appendix C shows the results table of the second set of results. The

5 Discussion

During the testing, you can see a clearer set of results in the simulated test results, and a consistent graph from both the VLC graphs and the Q factor graphs. In the simulated set of results, the bandwidth is narrower, suggesting a cleaner set of frequencies. However, this can be offset due to the second set of readings, when compared with the Bread board versions of the circuit.

As stated above; the first sets of results were taken from a simulated circuit. In the second set of results, one could argue the bandwidth is larger in comparison to the first set of results and the frequency which the Q factor was lower than the first set.

A number of factors could have occurred to have a few minor deviations when testing. One factor could be through component resistance. Components such as wires, resistors and the inducer that was used in the experiment could have outputted its separate set of frequencies which could be the reason for the discrepancy between the first and second set of results.

Another factor is the simulation itself. The software deals with a number of complicated mathematics and can dismiss the fact of a few a minor deviations to the overall circuit, which could also be a reason for the change in results.

Other factors could also include the reading of the oscilloscope in both digital and real world application. During the experiment, the skill in being able to read and use the oscilloscope could be the cause for the difference in both results. In real world use, there may not be an exact reading that can give the voltage or in some cases the (mV) to the correct decimal. Most candidates had to inspect the results by eye. In some places it was an educated guess as to where the frequency was being pointed. Although mentioned, it's doubted that in cases such as making an appropriate estimation of the frequency is a major cause for concern, and should be noted that if it was major problem during the experiment, the difference would be small and mostly inconsequential to the overall lab.

Other minor problems could constitute towards human error. Human error when plugging the correct values for the equations presented above, but like the previous statement above, the final test results were collated together with other sets of results and the correlation seems to be the correct conclusions to the experiment.

6 Conclusions

The RLC circuit showed a gradual increase in the lower ranges of the frequency tested, however as the frequency was set higher the line indicated that it was a steep and exponential increase in attenuation. And as the circuit reached higher frequencies, the drop in attenuation was steep and was immediately noticeable.

Though the results were clear in showing the curve and correlation of both tests, the minor difference between simulated and real world application is quite interesting to note. Though the simulated circuit was correct in its correlation to the graph made, the observation made is that the climb of the frequency for the simulated circuit was quite clear and showed a consistent gradient.

However, the second set of readings showed a decrease in the consistency of the gradient; though for arguments sake, is quite small. The observation made here is interesting because before the experiment it was not noted that the difference in the manufacturing of said components, could be a factor in the change of its frequency and subsequently, on the gradient of the second set of results.

In conclusion, the difference between both sets of results outlined the disparity between real world testing and simulated testing, and although small, could be the difference to using proper shielding solutions, the difference in component quality, and the cost efficiency when working with the added knowledge of manufacturing inefficiencies.



7 References

- [1] C. P. John W. M. Rogers, "The Use and Design of Passive Circuit Elements in IC Technologies," in *Radio Frequency integrated Circuit Design* , Artech House, 2010, p. 144.

[2] “PCB Design and Circuit Simulator Software for modern EDA development,”

[Online]. Available: <https://www.labcenter.com/>.

Ref Qual

8 Appendices

Frequency	Vin	VLC		dB	VLC (mV)
100	4	0.00125		-14.51544993	1.25
200	4	0.0025		-13.01029996	2.5
500	4	0.00638		-10.97589661	6.38
1000	4	0.01313		-9.40867637	13.13
2000	4	0.03038		-7.587061152	3.04E+01
2500	4	0.04275		-6.845319405	4.28E+01
3000	4	0.06019		-6.102378283	6.02E+01
3500	4	0.08831		-5.269950576	8.83E+01
4000	4	0.14513		-4.191214024	1.45E+02
4500	4	0.3175		-2.491281352	3.18E+02
5000	4	1.61		1.03412938	1.61E+03
5500	4	0.3		-2.614393726	3.00E+02
6000	4	0.165		-3.912580279	1.65E+02
6500	4	0.115		-4.696510798	1.15E+02
7000	4	0.09		-5.228787453	9.00E+01
7500	4	0.07438		-5.64271913	7.44E+01
8000	4	0.06375		-5.977599054	6.38E+01
10000	4	0.04125		-6.922880236	4.13E+01
20000	4	0.01675		-8.879925943	1.68E+01

Appendix A

Frequency	Vin	VLC		dB	VLC (mV)
100	4		0.00125	-14.51544993	1.25
200	4		0.0025	-13.01029996	2.5
500	4		0.00638	-10.97589661	6.38
1000	4		0.01313	-9.40867637	13.13
2000	4		0.03038	-7.587061152	3.04E+01
2500	4		0.04275	-6.845319405	4.28E+01
3000	4		0.06019	-6.102378283	6.02E+01
3500	4		0.08831	-5.269950576	8.83E+01
4000	4		0.14513	-4.191214024	1.45E+02
4500	4		0.3175	-2.491281352	3.18E+02
5000	4		1.61	1.03412938	1.61E+03
5500	4		0.3	-2.614393726	3.00E+02
6000	4		0.165	-3.912580279	1.65E+02
6500	4		0.115	-4.696510798	1.15E+02
7000	4		0.09	-5.228787453	9.00E+01
7500	4		0.07438	-5.64271913	7.44E+01
8000	4		0.06375	-5.977599054	6.38E+01
10000	4		0.04125	-6.922880236	4.13E+01
20000	4		0.01675	-8.879925943	1.68E+01

Appendix B

Frequency	Vin	VLC		dB	VLC (mV)
100	2		0.032	-35.91760035	32
200	2		0.032	-35.91760035	32
500	2		0.032	-35.91760035	32
1000	2		0.04	-33.97940009	40
2000	2		0.064	-29.89700043	64
2500	2		0.084	-27.53501419	84
3000	2		0.116	-24.73144013	116
3500	2		0.16	-21.93820026	160
4000	2		0.23	-18.78604319	230
4500	2		0.34	-15.39102157	340
5000	2		0.44	-13.15154638	440
5500	2		0.4	-13.97940009	400
6000	2		0.28	-17.07743929	280
6500	2		0.21	-19.57621402	210
7000	2		0.175	-21.15983894	175
7500	2		0.145	-22.79323987	145
8000	2		0.125	-24.08239965	125
10000	2		0.085	-27.4322214	85
20000	2		0.033	-35.65032112	33

Appendix C

Resonance

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

59/100

PAGE 1

PAGE 2



Comment 1

This text was supposed to be deleted from the template.

QM

Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....

PAGE 3



Comment 2

You seem to be a bit vague here. You need to define exactly what measurements you made, where they are from and why you took them.



Comment 3

do you mean "....to determine the Q factor..."

PAGE 4



Comment 4

Microsoft Excel. EdExcel is an education and examining body.

PAGE 5



Comment 5

Which was used to monitor the changes? Your phrasing makes the sentence ambiguous.



Comment 6

"help to determine the Q factor"?



Comment 7

When copying data from Excel, it always looks more professional when a table is created in Word and the data added to that table, rather than adding a screen shot of the data in excel.

PAGE 6



Comment 8

See comment on previous excel data.

QM

Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....

QM

Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....

PAGE 7



Comment 9

What do these mean?



Comment 10

Your x axis limits should be set to allow you to make the most of the available space. i.e. they should be 100 Hz and 20 kHz



Comment 11

You should include figure numbers on your captions to allow you to refer to them in your text.

e.g. "As shown in figure 1"

Figure 2: Graph of capacitor voltage plotted against frequency for the simulated circuit.

PAGE 8



Comment 12

See comment on previous graph



Comment 13

figure number?

Figure 3: Graph of circuit attenuation plotted against frequency for the simulated circuit.



Comment 14

figure number?

PAGE 9



Comment 15

See previous comments on graphs and captions

PAGE 10



Comment 16

Incomplete sentence.



Comment 17

What do you mean by "cleaner set of frequencies"?



Cap. Error

Capitalization

PAGE 11

Commonly Confused

Commonly Confused Words:

Words that have similar sounds but different meanings often cause trouble for student writers. Please watch for such confusions in your writing.

Some of the more common of these common confusions include:

Accept (to receive) and except (to leave out)

Affect (to influence) and effect (result or to accomplish)

Allusion (an indirect reference) and illusion (a false perception)

Its (possessive form of "it") and it's (contraction of "it is")

Their (possessive form of "they"), there (indication of location, and they're (contraction of "they are")

Then (next or at that time) and than (used in comparisons)

To (toward), too (also or excessively), and two (number)

Your (possessive form of "you") and you're (contraction of "you are")



Comment 18

inductor



Comment 19

outputted a ... set of frequencies? frequency of what?

I'm not sure what you are trying to say in this sentence.



Comment 20

the



Comment 21

"minor deviations", such as?

PAGE 12



Comment 22

Conclusions are weak. Your conclusions lack specificity. You have only alluded to the source of the difference between the two circuits when you should have clearly stated the cause and supported your statement with evidence from your results.

PAGE 13

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.

PAGE 14

KEEFE
MONTEBON

58.55

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



References to a limited range of mostly relevant sources. Some omissions and minor errors. Referencing conventions evident though not always applied consistently.

2.4

KNOWLEDGE & UNDERSTANDING

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



Knowledge is accurate with a good understanding of the field of study.

15.6

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. An emerging awareness of different stances and ability to use evidence to support the argument. Valid conclusions and recommendations, where relevant

17.4

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A very good application of a range of methods, materials, tools and/or techniques. Very good consideration of the context of the application, with perceptive use of examples, where relevant. Evidence of some innovation and creativity.

20.4

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 effectively in a suitable format, but may have minor errors. Mostly coherent work and is in a suitable structure.

2.75