

Assignment 1

by Rhys Davies

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STATOR MODELLING PART 1 ASSIGNMENT 1



Rhys Davies (1708879)
UNIVERSITY OF WALES TRINITY SAINT DAVID

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Abstract

Whilst creating a finite element simulation stator design using FEMM4.2 software by measuring the total flux verses the angle of 90° . By gathering these figures the flux leakage factor can be worked out, this figure would then show how efficient the motor would be. By using Microsoft excel graphs and tables were made to help produce and reflect on the results. To possibly improve the efficiency of the motor many stator designs could be made such as altering the pole width, the inside diameter of the stator or adjusting the pole face.

Chapter 1 - Introduction

1.1 – DC Motors

DC motors are widely used across the world in various applications such as toys, power tools and heavy industry devices such as elevators. A DC motor converts electrical energy into mechanical energy resulting in a form of rotation. [1] The operation of a DC motor is described as that the armature windings are connected to a DC power source which creates an electrical current within the coils resulting in an electromagnetic force, then the coils would start to rotate.

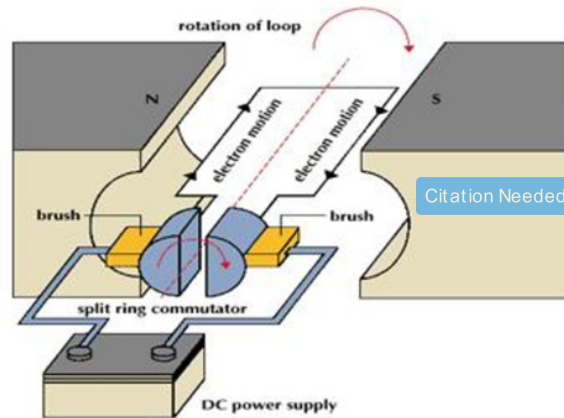


Figure 1 - Operation of a DC Motor

Figure 1 shows that as the coil starts to rotate the commutator rings connect with the opposite polarity resulting on "the left side of the coil the electricity will always flow 'away' and the right side, electricity will always flow 'towards'." [2] This achieves a solid amount of torque therefore the coil would carry on spinning in the same direction. DC motors have stationary magnets located in the stator. The stator allows for a rotating magnetic field that turns a rotating armature, the stator converts the magnetic field into electrical current. [3] As conductors are placed within the slots right on the edge the force that the conductors experience "acts as a twisting or turning force on the armature which is called a torque." [4]

1.2 – Magnetism

The strength of a magnetic field can be increased by either having more coils of wire or by increasing the amount of current flow through the coils. When current is passed through a coil which is in a magnetic field it creates a rotating force, the size of the force could be increased by either increasing the magnetic field strength or by increasing the current flowing through the coils. In a DC motor the

magnetic field is directed from the north to South Pole. Once an electric current travels through a coil which is within a magnetic field it causes a magnetic force that produces a torque which then spins the DC motor. [4]

Magnetic lines of force have a few important characteristics such as each line of force would never cross one another and they all have the same strength. Each line of force takes the path with least resistance between opposite poles, as shown in figure 2 using a single magnet bar the force lines try to create closed loops between poles.

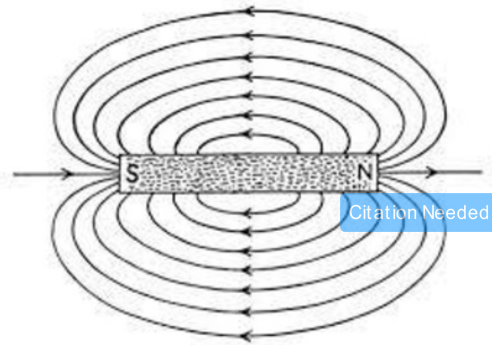


Figure 2 - Magnetic Lines of Force

1.2.1 – Fleming's Left Hand Rule

The direction of rotation of a motor can be demonstrated by the 'Fleming's left hand rule' as shown below in figure 3.

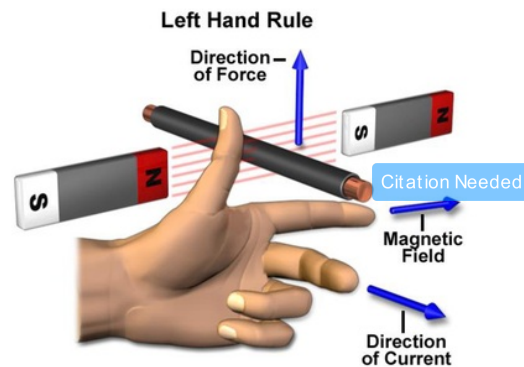


Figure 3 - Fleming's Left Hand Rule

Figure 2 shows the first finger pointing in the direction of the magnetic field and the second finger pointing in the direction of current flow. The thumb states the force direction accomplished by the conductor. [5]

1.3 – FEM (Finite Element Method)

Finite element is a method used to solve mathematical problems for various tasks such as thermodynamics, fluid flow and electromagnetic potential. [7] It is widely used in industry such as aerospace, automobile, nuclear construction and applications of fluid mechanics. This method requires a lot of time spent on a computer therefore can solve problems “in linear and nonlinear regions for one-, two- and three dimensional domains. [8]

1.4 – Specific Problem

As required to create a finite element simulation using FEMM 4.2 software of a DC motor stator circuit. Analysis would be needed and provided on the total amount of flux created within a stator circuit and a flux leakage factor value for the given design. Also a value for the amount of flux cutting the rotor coil as a function of the coil angle would be determined. [9]

Chapter 2 – Methods

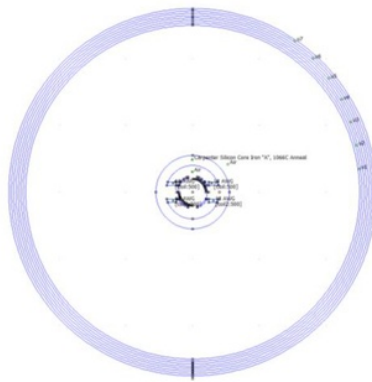


Figure 4 - FEMM 4.2 Original Stator Model

Figure 4 shows the drawn stator using FEMM 4.2 software. The stator consists of 4 coils each valued at 500 turns each and was designed using the materials specified.

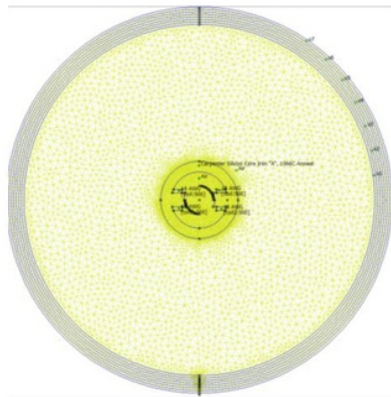


Figure 5 - FEMM 4.2 Original Stator Model Meshed

Figure 5 demonstrates a triangle meshed model showing the lines of flux surrounding the stator. The flux density is a lot less around the stator as it has an air gap between the components.

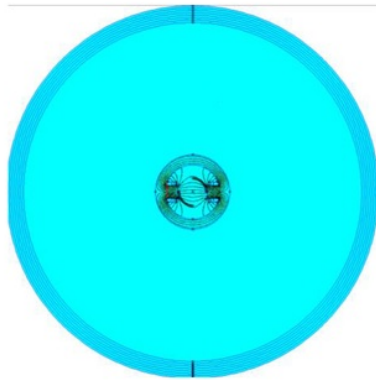


Figure 6 - FEMM 4.2 Original Stator Model Cranked

Once cranked figure 6 shows the flux density strength using the electromagnetic spectrum.

Chapter 3 – Results

3.1 – Total Flux

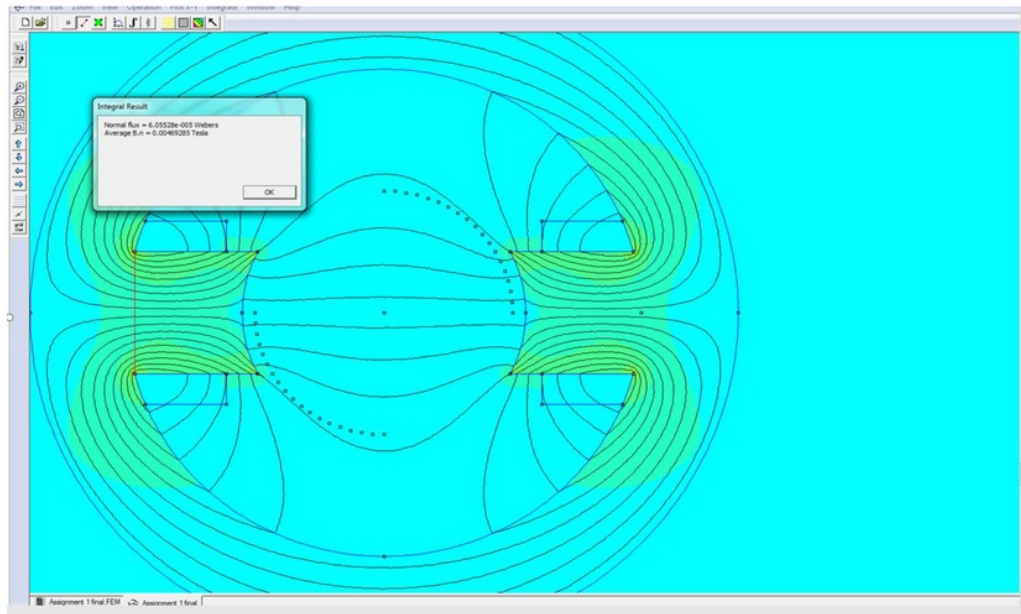


Figure 7 - FEMM 4.2 Total Amount of Flux

The above screenshot shows where the total flux measurement across the width of the armature. Indicating 6.05528e-005 Webers.

3.2 - Flux vs Angle

Table 1 are the results of the total flux vs angle measured between 0 and 90 degrees.

5	Angle	X	Y	Phi (Wb)
6	0	20	0	-4.13E-10
7	5	19.923894	1.743115	2.70E-06
8	10	19.6961551	3.472964	5.49E-06
9	15	19.3185165	5.176381	8.48E-06
10	20	18.7938524	6.840403	1.18E-05
11	25	18.1261557	8.452365	1.55E-05
12	30	17.3205081	10	1.88E-05
13	35	16.3830409	11.47153	2.05E-05
14	40	15.3208889	12.85575	2.13E-05
15	45	14.1421356	14.14214	2.16E-05
16	50	12.8557522	15.32089	2.17E-05
17	55	11.4715287	16.38304	2.17E-05
18	60	10	17.32051	2.14E-05
19	65	8.45236523	18.12616	2.13E-05
20	70	6.84040287	18.79385	2.13E-05
21	75	5.1763809	19.31852	2.11E-05
22	80	3.47296355	19.69616	2.09E-05
23	85	1.74311485	19.92389	2.08E-05
24	90	1.2251E-15	20	2.08E-05

Table 1 - FEMM4.2 Results for Flux vs Angle

Figure 8 shows table 1's results of the flux vs the angle in a line graph format making it easier to read and understand. Figure 8 clearly shows the relationship between the angle and the flux.

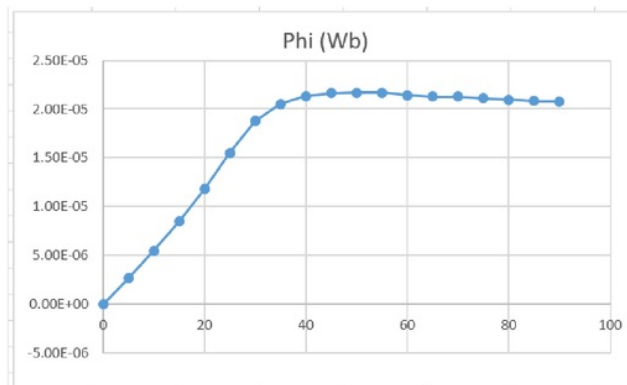


Figure 8 - FEMM 4.2 Line Graph for Flux vs Angle

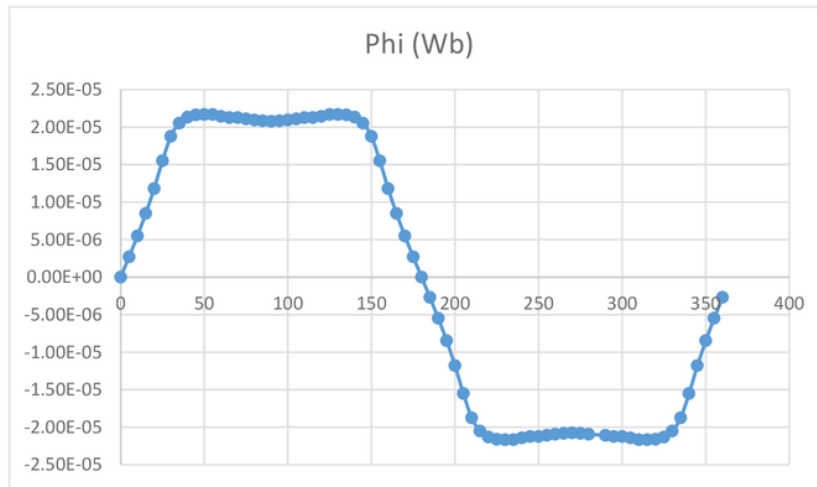


Figure 9 - Flux vs Angle 1 complete Cycle 360 degrees.

As shown above as figure 9 from continuing the same method to obtain 0 to 90° a clear line graph was developed to display the results for a full 360° cycle.

3.3 – Flux Leakage Factor

Total Flux	6.06E-05
Useful Flux	2.17E-05
Flux Leakage Factor	64%

Table 2 - FEMM 4.2 Flux Leakage Factor Table

Chapter 4 – Discussion

It can be seen in figure 7 that the flux density is greater when the flux was measured across the two poles of the stator, as is shown the flux density is indicating a pale green colour around the sharper edges of the stator suggesting that a stronger magnetic flux density in these areas. By measuring across the armatures of the stator a total flux value could be achieved which was 6.05528e-005 Webers.

By placing nodes only 90 degrees around the stator the total number of flux could be measured at certain points. As shown in table 1 a flux value was recorded at every angle from 0 to 90 degrees with its peak values indicating at angles 50 – 55 degrees. Figure 8 clearly shows how the amount of flux increases up to a 55 degrees rotation and then slowly levels off before the following 90 degrees rotation occurs.

The flux leakage factor is worked out using the formula as shown below.

$$= \frac{(Total\ Flux - Useful\ Flux)}{Total\ Flux}$$

As shown in table 2 the total flux was the value measured across the gap of the stator and the useful flux is the most amount of flux measured.

$$= \frac{(6.06E - 05 - 2.17E - 05)}{6.06E - 05} = 0.6437 \times 100 = 64\%$$

The above equation shows that this design is extremely inefficient as 64% of flux is leaked away as waste such as heat.

Referring back to figure 7 it's clearly shown that the rotor would only cut through 6 lines of flux out of a possible 16. This clearly suggests that the efficiency of this design would be very inefficient.

Table 1 shows the X and Y co-ordinates points around the stator which were derived from the following formulas.

$$R \cdot \cos(\theta) = X \text{ and } R \cdot \sin(\theta) = Y$$

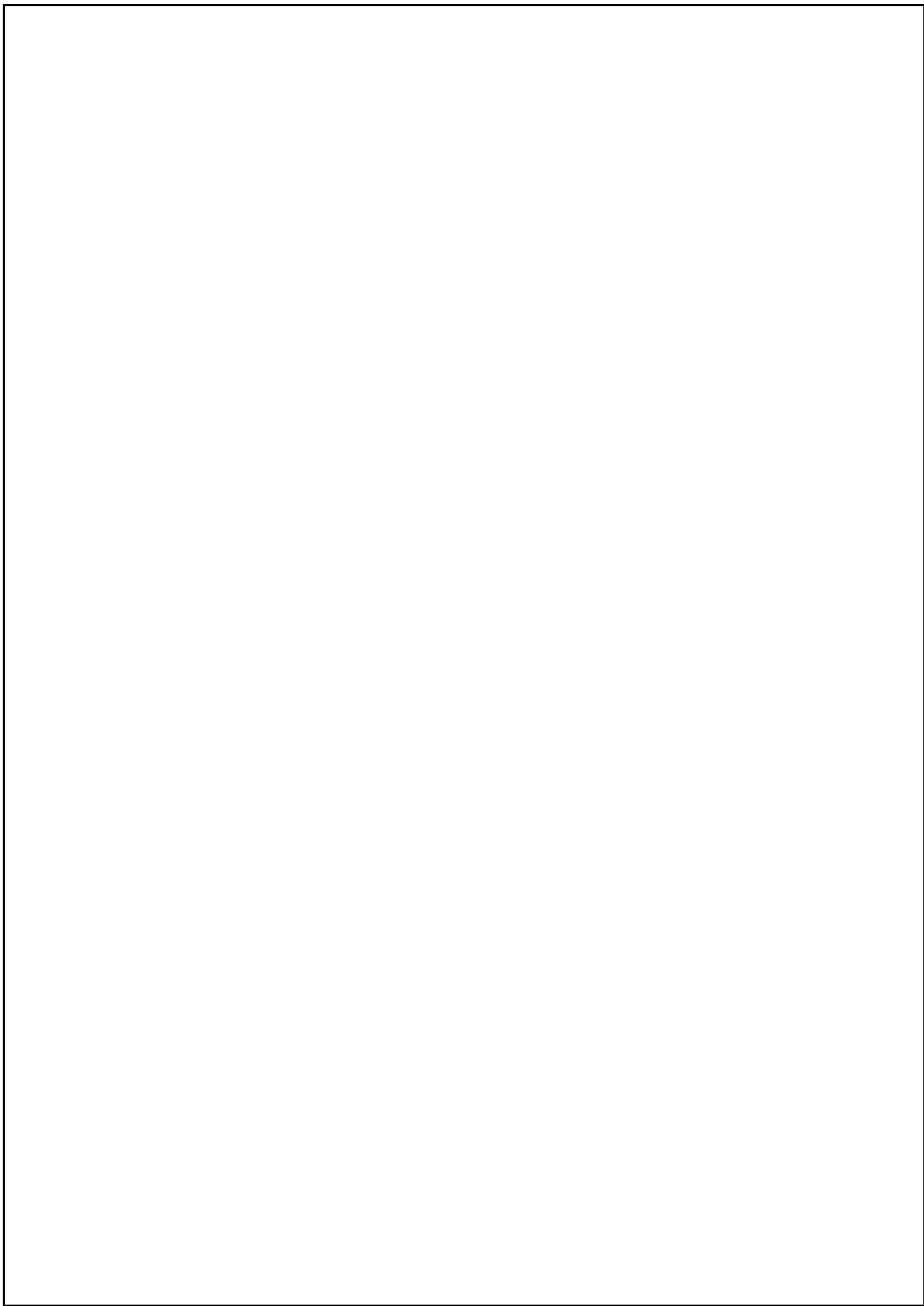
$$R=20$$

Chapter 5 – Conclusion

After reviewing the results it is clearly shown that the most useful flux is achieved between angles 50° - 55° , this suggests that the rotor is cutting through more lines of flux at these angles. Flux will travel the easiest route and with the path with least resistance. With the flux leakage being around 64% the motor is very inefficient so improvements regarding the design of the stator and rotor is needed, possible ideas could be to change the size and shape of the stator or adjusting the position of the coils.

Bibliography

- [1] K. Daware, "How A DC Motor Works?," [Online]. Available: <https://www.electriceasy.com/2014/01/basic-working-of-dc-motor.html>. [Accessed March 2019].
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- [9] D. S. Mosey, "Stator Modelling Part 1," UWTSD.



Assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

66/100

PAGE 1

PAGE 2

PAGE 3



Comment 1

Good abstract, but you should include more information about what you have done and the results you gained and the conclusions you have made.

QM

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Comment 2

As opposed to "liquid amount of torque" or "gas amount of torque"?

Does this adjective correctly describe the torque generated by the motor?

PAGE 4

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RHYS DAVIES

66

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



Inclusion of a wide range of research-informed literature, including sources retrieved independently. Selection of relevant and credible sources. Very good use of referencing conventions, consistently applied.

6.2

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.

20.1

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.



Sound, logical, analytical thinking; synthesis and evaluation. Ability to devise and sustain persuasive arguments, and to review the reliability, validity & significance of evidence. Ability to communicate ideas and evidence accurately and convincingly. Sound, convincing conclusions

20.4

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A very good application of a range of methods, tools and techniques. Very good consideration of the context of the application. Evidence of some creativity.

13.2

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.

6.1

