

## LEVEL 4 ASSESSMENT SPECIFICATION

|                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                      |                  |
|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|------------------|
| Student name:                   | Morgan Layton                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Student ID number:                                   |                  |
| Programme:                      | HNC Electrical/Electronic Engineering & Instrumentation Engineering                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                      |                  |
| Module:                         | Electrical Principles                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                      |                  |
| Module code:                    | PCEE4001                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Contribution to Overall Module Assessment (%):       | 100%             |
| Lecturer:                       | Jason Pointer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Internal Verifier:                                   | Lance Rutherford |
| Assignment Title:               | Electrical Principles                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Word count (or equivalent):                          | 2000             |
| Submission deadline:            | 15/01/20                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Return date of provisional marks & written feedback: | 29/01/21         |
| Submission method:              | <p>All written assessments, where practical and possible, must be submitted via Turnitin unless otherwise instructed by the Lecturer. (Please DO NOT put this assessment specification into Turnitin or it will match many similarities with other students' submissions.)</p> <p><b>Alternative submission method (if applicable):</b></p> <p><b>Late submission of the assessment will result in a late penalty mark.</b> Penalties for late submission: Up to one week late, maximum mark of 40%. Over one week late, 0%. Only the Extenuating Circumstances Panel may approve a change to submission dates.</p> |                                                      |                  |
| Academic honesty / referencing: | <p>Academic honesty is required. In the main body of your submission you must give credit to authors on whose research and ideas your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have used, cited or quoted in order to complete this assessment.</p>                                                                                                                                                                                                                                                                                              |                                                      |                  |

### Module Learning Outcomes (from module syllabus)

1. Produce routine solutions to typical electrical problems.
2. Relate and apply basic electrical theory to collected data.

# STUDENT FEEDBACK FORM

This section details the *extent* to which the assessment criteria are demonstrated by you, which in turn determines your mark. The marks available for each category of skill are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

| Generic Assessment Criteria                                                                                                                                                                                                                                                                                                                                                                                                                | Marks available | Marks awarded |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|---------------|
| <b>1. Engagement with Literature Skills</b>                                                                                                                                                                                                                                                                                                                                                                                                | 15              | 10            |
| Engagement with a wide range of literature sources, including sources retrieved independently. Generally sound referencing, with no inaccuracies or inconsistencies.                                                                                                                                                                                                                                                                       |                 |               |
| <b>2. Knowledge and Understanding Skills</b>                                                                                                                                                                                                                                                                                                                                                                                               | 25              | 14.7          |
| Task 1 achieved 75%.<br>Task 2 achieved 52%,<br>Task 3 achieved 52%.<br>Task 4 achieved 56%.<br><br>Knowledge of the basic underlying concepts and principles is accurate with a good understanding in most areas. Your work for Task 1 was excellent and showed a full understanding but in the other tasks have made some mistakes in the calculation work and in some parts have discussed concepts that were not relative to the task. |                 |               |
| <b>3. Cognitive and Intellectual Skills</b>                                                                                                                                                                                                                                                                                                                                                                                                | 15              | 8.1           |
| Task 1 achieved 58%.<br>Task 4 achieved 50%.<br><br>Good evaluation of the underlying concepts and principles but were a little bit limited in the evaluation of Task 4.                                                                                                                                                                                                                                                                   |                 |               |
| <b>4. Practical Application Skills</b>                                                                                                                                                                                                                                                                                                                                                                                                     | 35              | 26.9          |
| Task 1 achieved 77%.<br>Task 4 achieved 77%.<br><br>An excellent application of practical work for Task 1 and 4, very good use of the test equipment to obtain all of the required results.                                                                                                                                                                                                                                                |                 |               |
| <b>5. Transferable Skills for Life and Professional Practice</b>                                                                                                                                                                                                                                                                                                                                                                           | 10              | 6.6           |
| Work is accurate, coherent, fluent, well-structured and organised.                                                                                                                                                                                                                                                                                                                                                                         |                 |               |

|                                                                                                                                                                                                            |                                                        |  |            |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|--|------------|
| <b>Assessment Mark</b> (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed. ) | <b>Late Submission Penalties (tick if appropriate)</b> |  | <b>66%</b> |
|                                                                                                                                                                                                            | Up to 1 week late (40% Max)                            |  |            |
|                                                                                                                                                                                                            | Over 1 week late (0%)                                  |  |            |

**LEVEL 4 ASSESSMENT SPECIFICATION**

|                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                 |                         |
|----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|-------------------------|
| <b>Student name:</b>                   | <b>Morgan Layton</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>Student ID number:</b>                                       | <b>172325</b>           |
| <b>Programme:</b>                      | <b>HNC Electrical/Electronic Engineering, Power Systems Engineering &amp; Instrumentation Engineering</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                 |                         |
| <b>Module:</b>                         | <b>Electrical Principles</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                 |                         |
| <b>Module code:</b>                    | <b>PCEE4001</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>Contribution to Overall Module Assessment (%):</b>           | <b>100%</b>             |
| <b>Lecturer:</b>                       | <b>Jason Pointer</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>Internal Verifier:</b>                                       | <b>Lance Rutherford</b> |
| <b>Assignment Title:</b>               | <b>Electrical Principles</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>Word count (or equivalent):</b>                              | <b>2000</b>             |
| <b>Submission deadline:</b>            | <b>15/01/21</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>Return date of provisional marks &amp; written feedback:</b> | <b>29/01/21</b>         |
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**Module Learning Outcomes**

**(from module syllabus)**

1. Produce routine solutions to typical electrical problems.
2. Relate and apply basic electrical theory to collected data.

# Assignment

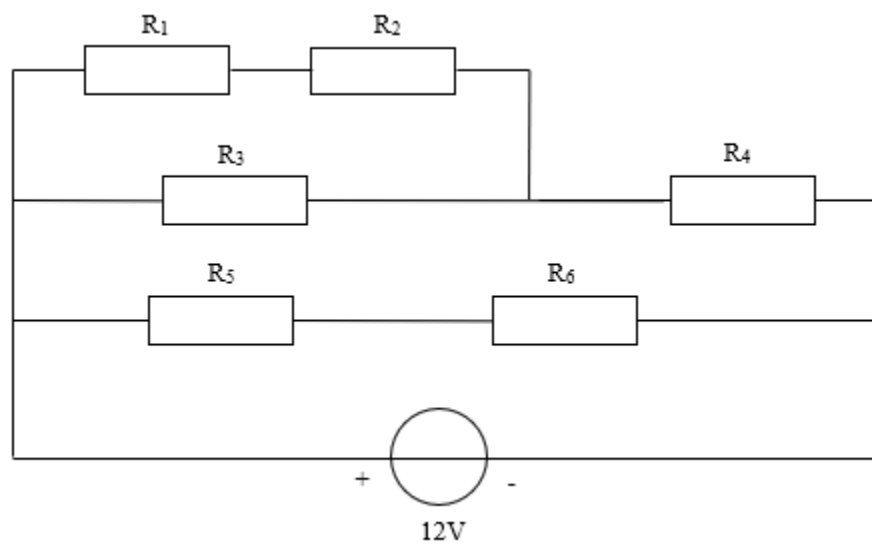
# Electrical Principles

Morgan Layton  
Student Number 172325

## Task 1 – DC Circuits

Below is a diagram of a DC circuit with a 12V supply with a combination circuit of resistors in series and parallel. The value of each resistor are as follows:

- $R_1 = 270\Omega$
- $R_2 = 680\Omega$
- $R_3 = 220\Omega$
- $R_4 = 560\Omega$
- $R_5 = 330\Omega$
- $R_6 = 560\Omega$



## Resistor Calculations

$$R1 + R2 = R12$$
$$270\Omega + 680\Omega = 950\Omega$$

$$\frac{R12 \times R3}{R12 + R3} = R123$$
$$\frac{950\Omega \times 220\Omega}{950\Omega + 220\Omega} = 178.63\Omega$$

$$R123 + R4 = R1234$$
$$178.63\Omega + 560\Omega = 738.63\Omega$$

$$R5 + R6 = R56$$
$$330\Omega + 560\Omega = 890\Omega$$

$$\frac{R56 \times R1234}{R56 + R1234} = R_t$$
$$\frac{890\Omega \times 738.63\Omega}{890\Omega + 738.63\Omega} = 403.64\Omega$$

$$I_t = \frac{V_t}{R_t}$$
$$\frac{12V}{403.64\Omega} = 0.02972A = 29.7mA$$

$$\frac{V56}{R56} = I56$$
$$\frac{12V}{890\Omega} = 0.01348A$$

### Applying Kirchhoff's Laws for Circuit Calculations

V56 must equal 12V as according to Kirchhoff's Voltage Law the sum of the voltage rise minus the sum of the voltage fall must equal 0, giving us a potential difference or voltage across R56 of 12V. Kirchhoff's Current Law states that the sum of all currents entering node are the same as the sum of all currents leaving a node. This means that I56 must be equal to the sum of I5 and I6 due the conservation of charge. (Kramer, 2011)

$$I5 \times R5 = V5$$
$$0.01348A \times 330\Omega = 4.45V$$

$$I6 \times R6 = V6$$
$$0.01348A \times 560\Omega = 7.55V$$

$$\frac{V_{1234}}{R_{1234}} = I_{1234} \quad \checkmark$$

$$\frac{12V}{738.63\Omega} = 0.01625A \quad \checkmark$$

### Applying Kirchhoff's Laws for Circuit Calculations – Continued

$V_{1234}$  must equal 12V as again according to Kirchhoff's Voltage Law the voltage rise minus the voltage fall in a loop must equal 0.

$$I_{1234} \times R_4 = V_4 \quad \checkmark$$

$$0.01625A \times 560\Omega = 9.1V \quad \checkmark$$

$$\frac{V_4}{R_4} = I_4 \quad \checkmark$$

$$\frac{9.1V}{560} = 0.01625A \quad \checkmark$$

$$V_t - V_4 = V_{123} \quad \checkmark$$

$$12V - 9.1V = 2.9V \quad \checkmark$$

$$\frac{V_{123}}{R_3} = I_3 \quad \checkmark$$

$$\frac{2.9V}{220\Omega} = 0.01318A \quad \checkmark$$

$$\frac{V_{123}}{R_{12}} = I_{12} \quad \checkmark$$

$$\frac{2.9V}{950\Omega} = 0.003052A \quad \checkmark$$

*Good work*

### Applying Kirchhoff's Laws for Circuit Calculations – Continued

$I_1$  and  $I_2$  are both equal to  $I_{12}$  as Kirchhoff's Current Law states the sum of all currents entering a node must equal all the currents leaving.  $\checkmark$

$$I_1 \times R_1 = V_1$$

$$0.003052A \times 270 = 0.824V \quad \checkmark$$

$$I_2 \times R_2 = V_2$$

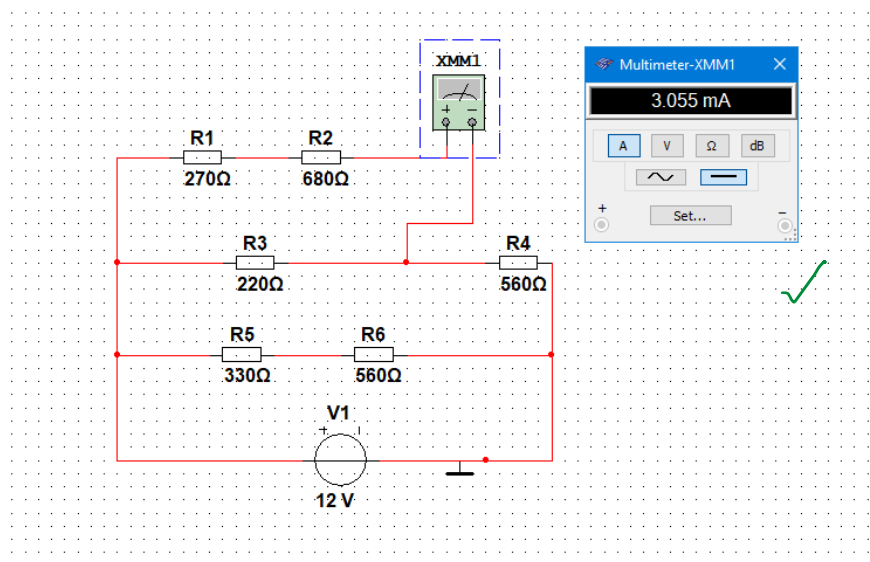
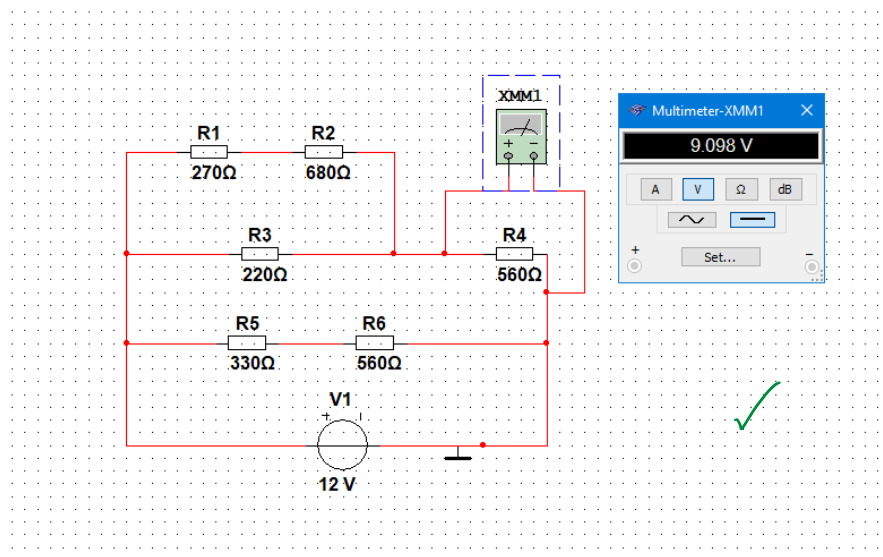
$$0.003052A \times 680 = 2.075V \quad \checkmark$$

$$I_3 \times R_3 = V_3$$

$$0.01318A \times 220 = 2.899V \quad \checkmark$$

## Simulated Measurements

Using an electrical circuit simulation programme called Multsim, a simulated set of results was produced to replicate using a physical multi-meter on the circuit. Below are two screen shots of a voltage measurement and a current measurement being taken using the software's simulated multi-meter.



## Results

### Calculated Results

| Resistors | R Values | Currents | Current Values | Voltages | Voltage Values |
|-----------|----------|----------|----------------|----------|----------------|
| Rt        | 403.64   | It       | 29.72mA        | Vt       | 12V            |
| R1        | 270      | I1       | 3.05mA         | V1       | 0.82V          |
| R2        | 680      | I2       | 3.05mA         | V2       | 2.08V          |
| R3        | 220      | I3       | 13.18mA        | V3       | 2.89V          |
| R4        | 560      | I4       | 16.25mA        | V4       | 9.10V          |
| R5        | 330      | I5       | 13.48mA        | V5       | 4.45V          |
| R6        | 560      | I6       | 13.48mA        | V6       | 7.55V          |

### Simulated Results

| Resistors | R Values | Currents | Current Values | Voltages | Voltage Values |
|-----------|----------|----------|----------------|----------|----------------|
| Rt        | 403.64   | It       | 29.73mA        | Vt       | 12V            |
| R1        | 270      | I1       | 3.05mA         | V1       | 0.83V          |
| R2        | 680      | I2       | 3.05mA         | V2       | 2.08V          |
| R3        | 220      | I3       | 13.19mA        | V3       | 2.90V          |
| R4        | 560      | I4       | 16.25mA        | V4       | 9.10V          |
| R5        | 330      | I5       | 13.48mA        | V5       | 4.45V          |
| R6        | 560      | I6       | 13.48mA        | V6       | 7.56V          |

### Practical Results

| Resistors | R Values | Currents | Current Values | Voltages | Voltage Values |
|-----------|----------|----------|----------------|----------|----------------|
| Rt        | 401.38   | It       | 29.37mA        | Vt       | 11.98V         |
| R1        | 269.84   | I1       | 3.04mA         | V1       | 0.82V          |
| R2        | 680.12   | I2       | 3.04mA         | V2       | 2.08V          |
| R3        | 221.01   | I3       | 13.08mA        | V3       | 2.88V          |
| R4        | 560.03   | I4       | 16.07mA        | V4       | 9.10V          |
| R5        | 329.96   | I5       | 13.51mA        | V5       | 4.41V          |
| R6        | 560.14   | I6       | 13.57mA        | V6       | 7.56V          |

## Evaluation of Results

When taking measurements in a simulation, variables are controlled e.g. Does not account for human error when taking readings. As these results are recorded in a perfect environment it is logical to assume that the calculated readings should be identical. However, the results are not identical due to the use of rounding up during the calculations which results in small differences in some of the results for example the simulation might work to higher decimal point than a calculator causing some minor discrepancies. In this instance these slight variances in results do not matter greatly due to the relatively small size of the voltages and currents in question. Although it is worth pointing out when applying this to larger measurements these differences in calculations would be amplified and be of more importance. (U. A Bakshi, 2009) ✓

However, when comparisons between measurements taken using a multi-meter the results vary considerably more than the simulated and calculated results. This could be due to several factors for example the resistors used in the circuit all have tolerances. This means that they will have degree of allowable error when measuring its resistance although this is usually quite a small figure it can still certainly affect results. (Herrick, 2003) Also, the components and/or testing equipment used could be affected by conditions such as temperature or humidity degrading components over time. This will result in any tolerances set by the manufacturer being surpassed. The only way to ensure that this is not the case would be to inspect and calibrate each component individually before building the circuit. (Gill, 2016) ✓

Leakage is where an unintentional electrical connection occurs between the ground and the circuit. This can easily occur when taking measurements for example if the individual taking reading on the multi-meter is touching the probe while it is taking a reading. Another cause of inconsistent measurements in a circuit is the quality of contacts within the circuit for example dust gathering in the bread board preventing a clean connection with the circuit rails and components. (Acton, 2011) Thermal errors can also occur where two different metals are used as a connection or junction in a circuit. The connection of two different metals will generate a thermoelectric voltage which is also influenced by the temperature their temperature. (Callegaro, 2013) Electromagnetic fields can affect the readings taken as voltage can be induced by magnetic fields given off by other electrical equipment or even the earths own magnetic field which can generate several hundred millivolts alone. (Schieber, 2012) ✓

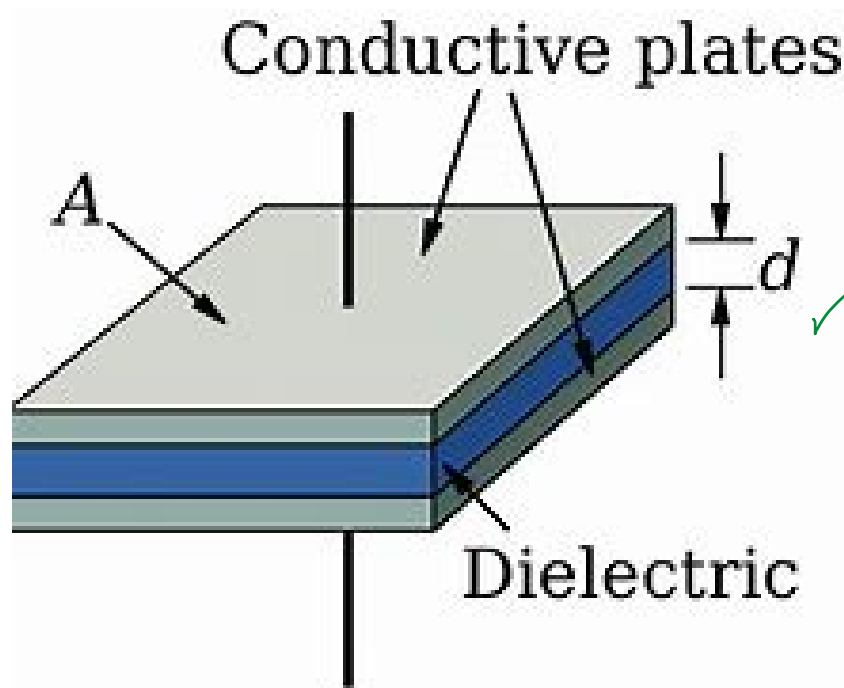
All of these variables mean that when Kirchhoff's laws (Please see calculations) are applied to a physical circuit they do not always give a one-hundred percent accurate representation of results that would be recorded when compared with the measurements obtained with a multi-meter for instance. This is because Kirchhoff's laws are theoretical and require an ideal circuit which is not always possible in the real world where extraneous variables are present as previously discussed. Therefore, it is important to consider as many of these variables and control or negate as is practically possible for reliable and consistent measurement of electrical readings in a circuit. ✓

## Task 2 – Capacitors

*would be better to start this section on a new page.*

A Capacitor is an electrical component that is used to store energy by creating a potential difference or static voltage between two conductors separated by a dielectric which is a non-conductive insulating layer between them. Unlike batteries where charge is generated at a steady rate through chemical reactions and stores charge for long periods of time, a capacitor is designed to rapidly hold charge in an electric field and is rapidly discharged again. As shown in the image below the conductive plates are separated by a dielectric which is an insulator or poor conductor and resists

electrical flow. This resistance allows a potential difference to form between the two conductive plates which once reaches its maximum capacitance releases its charge. (Schulz, 2010) ✓



A Capacitors dielectric material can be made of a wide range of insulating materials such as commonly used glass, ceramic, plastic, mica, vacuum, nitrogen, air, oil etc. The material used as the dielectric can influence the capacitance greatly depending on that materials relative permittivity which is the measure of that materials polarizability so the higher a materials permittivity the higher its capacitance. (Elert, 2020) Another factor that can influence a capacitors capacitance is the area of the conductor and dielectric as the larger the area the larger the charge. Therefore, if you were to break into most capacitors you would find the conductors and dielectric coiled around each other many times over. The thickness of the dielectric also influences capacitance as the conductors are closer together, they attract each other more which enables the capacitor to store more charge. It also allows for a larger surface area which gives more opportunity for charge to be stored. The equation for parallel plate capacitors shows the relationship between these variables: ✓

$$C = \epsilon \frac{A}{d} \quad \checkmark$$

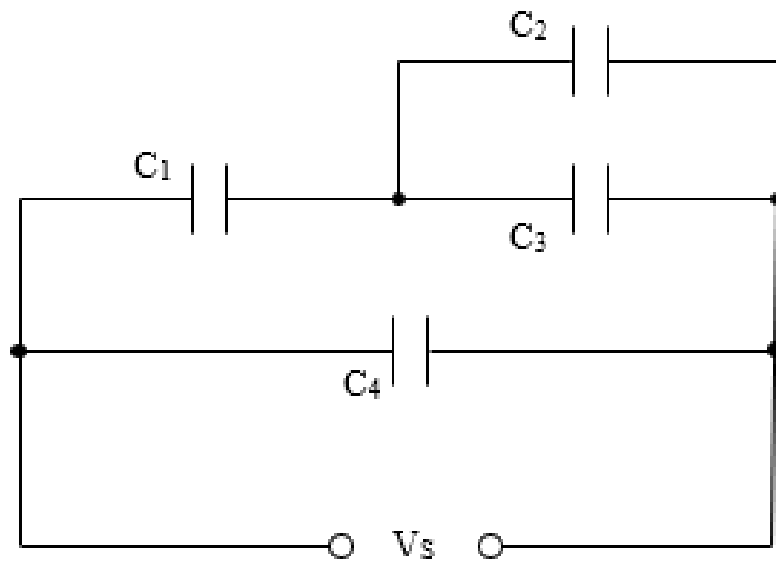
Where C = Capacitance  $\epsilon$  = Dielectric permittivity A = Surface Area and d = dielectric thickness. (Kaiser, 2012)

As you can see in the image below capacitors come in all shapes and sizes depending on many factors including quality of the material used as dielectric and the capacitors purpose. For instance, the small orange ceramic capacitor at the bottom with a 7 on it has a capacitance of 7 picofarads whereas the large blue electrolytic capacitor has a capacitance of 4700 microfarads which is substantially larger. This is because as previously mentioned a larger surface area leads to a higher capacitance. The quality of dielectric is also substantially different as although ceramic is a good and very commonly used material in capacitors, an electrolytic dielectric uses a conductor that has an oxidised surface which acts as an incredibly thin dielectric allowing for increased capacitance. (Dale ✓

R. Patrick, 2008) A super capacitor is even bigger again with capacitance values of 10-100 times that of an electrolytic capacitor and used in instances where a very high voltage needs to be released very quickly for example in cranes and elevators using regenerative braking. (Reif, 2014) ✓



## Capacitor Calculations



Values

$$C_1 = 22\mu F$$

$$C_2 = 27\mu F$$

$$C_3 = 47\mu F$$

$$C_4 = 2.2\mu F$$

$$V_s = 25V$$

A) The equivalent circuit capacitance

$$C_2 + C_3 = C_{23} \quad \checkmark$$

$$27\mu F + 47\mu F = 74\mu F \quad \checkmark$$

$$\frac{C_1 \times C_{23}}{C_1 + C_{23}} = C_{123}$$

$$\frac{22\mu F \times 74\mu F}{22\mu F + 74\mu F} = 16.958\mu F \quad \checkmark$$

$$C_{123} + C_4 = C_t \quad \checkmark$$

$$16.958\mu F + 2.2\mu F = \underline{22.158\mu F} \quad \times$$

B) The Total Charge

$$C_t \times V_s = Q_t \quad \checkmark$$

$$\underline{22.158} \times 10^{-6} F \times 25V = 553.95\mu C \quad \times$$

*Correct method but use  
have used the wrong value.*

C) The Charge in each capacitor

$$C_4 \times V = Q_4 \quad \checkmark$$

$$2.2 \times 10^{-6} F \times 25V = 55\mu C \quad \checkmark$$

$$Q_t - Q_4 = Q_{123} \quad \checkmark$$

$$\underline{553.95\mu C} - 55\mu C = \underline{498.95\mu C} \quad \times$$

$$Q1 = Q123 \quad \checkmark$$

$$Q1 = \underline{498.95\mu C}$$

$$\frac{Q1}{C1} = V1 \quad \checkmark$$

$$\frac{\underline{498.95} \times 10^{-6} C}{22 \times 10^{-6} F} = \underline{22.68V} \quad \times$$

$$Vs \times V1 = V23$$

$$25V - \underline{22.68V} = 2.32V \quad \times$$

$$C2 \times V23 = Q2$$

$$27 \times 10^{-6} F \times \underline{2.32V} = 62.64\mu C \quad \times$$

$$C3 \times V23 = Q3$$

$$47 \times 10^{-6} F \times \underline{2.32V} = 109.04\mu C \quad \times$$

D) The energy stored in each capacitor (W = Work-done)

$$\frac{CV^2}{2} = W \quad \checkmark$$

$$\frac{C1V1^2}{2} = W1 \quad \checkmark$$

$$\frac{22 \times 10^{-6} F \times \underline{22.68V}^2}{2} = 5.658mJ \quad \times$$

$$\frac{C2V2^2}{2} = W2$$

$$\frac{27 \times 10^{-6} F \times \underline{2.32V}^2}{2} = 72.662\mu J \quad \times$$

$$\frac{C3V3^2}{2} = W3$$

$$\frac{47 \times 10^{-6} F \times \underline{2.32V}^2}{2} = 126.486\mu J \quad \times$$

$$\frac{C4V4^2}{2} = W4$$

$$\frac{2.2 \times 10^{-6} F \times 25V^2 \checkmark}{2} = 687.5\mu J \quad \checkmark$$

You have shown the correct method throughout but your answer for  $C1$  was incorrect.

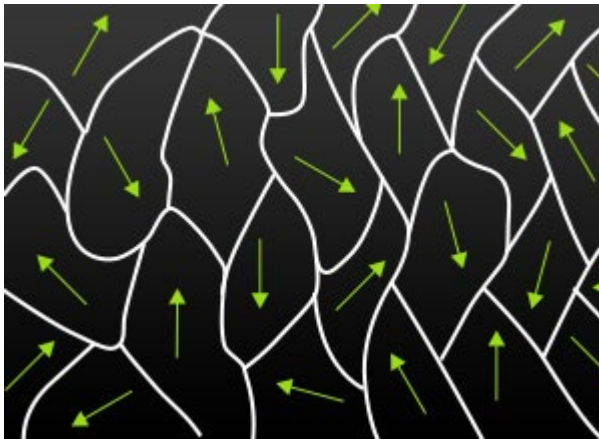
E) The total energy stored in the circuit.

$$\frac{CtVt^2}{2} = Wt$$

$$\frac{\underline{22.158} \times 10^{-6} F \times 25V^2}{2} = 6.924mJ \quad \times$$

## Task 3 – Magnetism

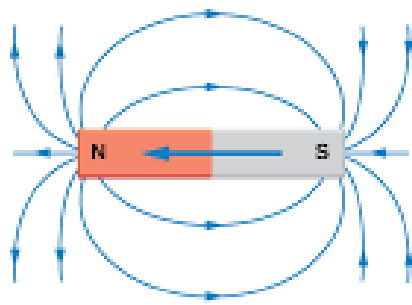
A permanent magnet generates its own magnetic field due to free electrons at atomic level which are constantly rotating generating their own very small magnetic field. These atoms group together into individual “magnetic domain’s” whose fields are polarised in different directions as shown in the image below. ✓



A magnet is created when an external magnetic force is applied to these domains which will then align with the external magnetic force in a consistent North-South polarisation in what is known as anisotropic alignment. ✓

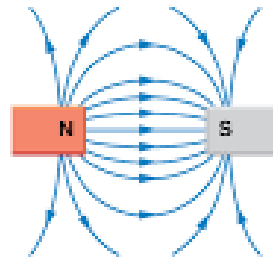


Many materials can become magnetised but far fewer can maintain this magnetised state when taken away from the external magnetic force. Only 5 elements can hold onto this alignment and they are Iron, Nickel, Cobalt, Gadolinium and Dysprosium. This magnetisation causes magnetic field lines to travel from one pole to the opposite pole to form a complete loop. These lines never cross each other and are elastic in nature as when the lines are distorted they will return to their original positions once the cause has been removed. (Campbell, 1996) As shown in the diagram below the magnetic force travelling along these lines travels from north to south so when a separate magnet is placed with its south pole facing the others north pole the magnetic field lines align and cause an attraction whereas when two like poles for example two north poles are placed near each other these lines are distorted and the magnets repel each other. The volume of these lines of force are known as flux and are measured in Weber’s and Flux density refers to the volume of lines per meter and are measured in Tesla’s. (John Oatley, 1976) ✓



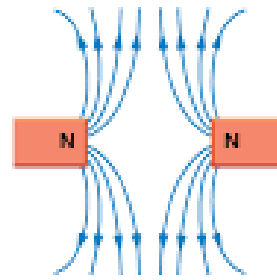
Magnetic field lines of a bar magnet

(a)



Magnetic field lines between unlike poles

(b)



Magnetic field lines between like poles

(c)



A) A Magnetic pole face has a rectangular section having dimensions 220mm by 120mm. If the total flux emerging from the pole is 130μWb, calculate the flux density.

$$B = \frac{\phi}{A} \quad \checkmark$$

$$A = 220\text{mm} \times 120\text{mm}$$

$$A = 0.0264\text{m}^2 \quad \checkmark$$

$$\frac{0.00013\text{Wb}}{0.0264\text{m}^2} = 4.924\text{mT} \quad \checkmark$$

B) The maximum working flux density of a lifting electromagnet is 1.9T and the effective area of a pole face is circular in cross-section. If the total magnetic flux produced is 611mWb determine the radius of the pole face.

$$A = \frac{\phi}{B} \quad \checkmark$$

$$\frac{0.611\text{Wb}}{1.9\text{T}} = 0.322\text{m}^2 \quad \checkmark$$

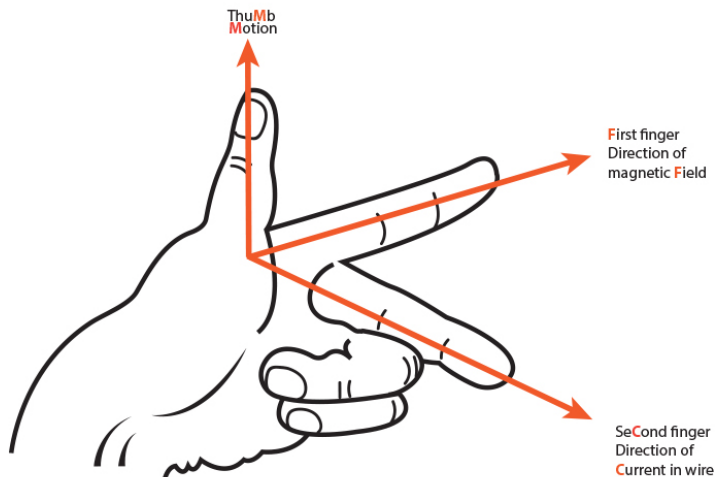
$$r = \sqrt{\frac{A}{\pi}}$$

$$\sqrt{\frac{0.322\text{m}^2}{\pi}} = 0.102\text{m} \quad \checkmark$$

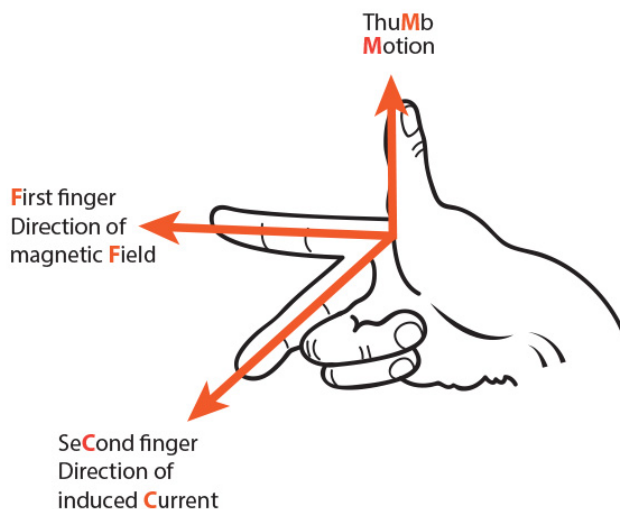
Explain the principle operation and construction of an electromagnet including the distribution of magnetic fields.

When an electrical current flows through a conductor a magnetic field is produced creating an electromagnet. This magnetic field forms concentric circles along the conductor's length the direction of which depend on the direction of current known as the screw rule. The direction of rotation to tighten a screw in the direction of the current flow indicates the direction of the magnetic field around the conductor. These magnetic fields behave in the same they do in a normal magnet so if a conductor is placed parallel to another conductor which has current flowing in the same direction then these magnetic fields will align and the conductors forced together while if the second conductor has a current flowing in the opposite direction the magnetic fields would oppose

one and other forcing the conductors apart as shown in Fleming's left hand rule. (Avison, 1989)



When a conductor with current flowing through it is placed into magnetic field a force is exerted onto the conductor measured in Newtons (N) the direction of which can be seen in Flemings left hand rule above. If you were to force a conductor to pass through this magnetic field where it is cutting across the flux a current would be generated and flow along the conductor. The direction of the current in this instance is explained by Flemings right hand rule as below. (Avison, 1989)

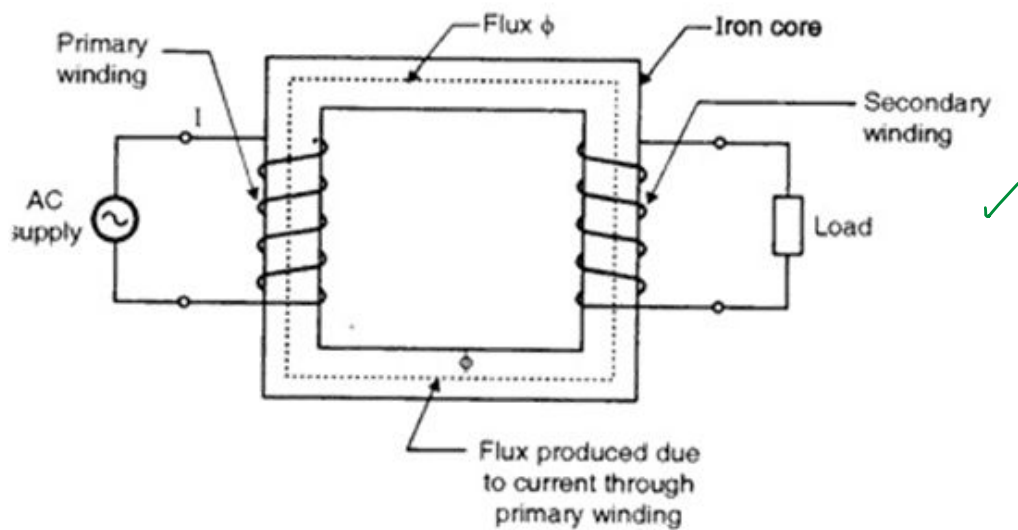


*This does not affect the magnetic fields.*

Explain the operation and construction of transformer, include methods to reduce power loss within the transformer.

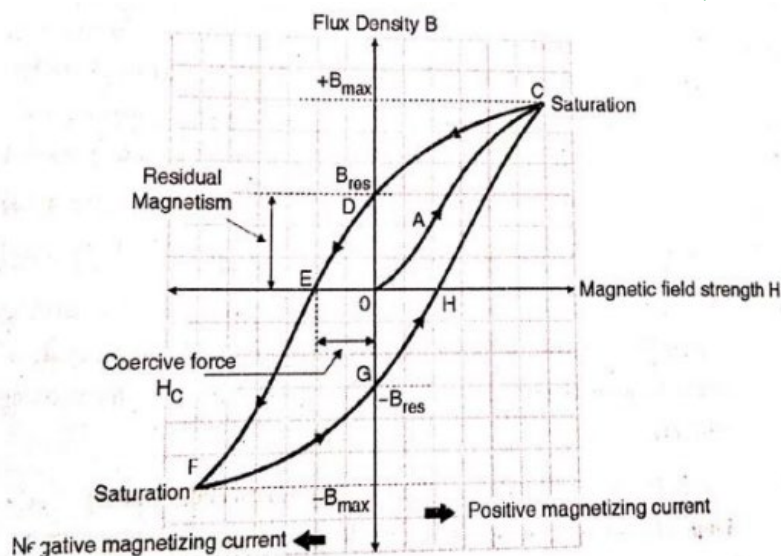
A transformer is an electrical device that enables the step down or step-up transfer of electrical energy from one electrical circuit to another. A basic transformer is made up of two coils of wire wrapped around a ferromagnetic core. When a current is passed through one of these wires a

fluctuating electromagnetic field is generated which in turn magnetises the core. ✓



This fluctuation of the magnetic field enables Faraday's law of induction or electromagnetic induction to take place where a second current is induced into the second coil, where depending on the number of coils in relation to the first wire will either produce a higher or lower voltage. (Harlow, 2007) ✓

This transfer of energy however is not perfect, and losses take place. As the core is subject to alternating electromagnetic forces each cycle of this alternating force results in a hysteresis loop where energy is lost in the form of heat. Hysteresis loss can be reduced by using a material that has a small area of the hysteresis loop such as silicon steel. ✓



Another cause of loss is Eddy current's where due to the core being a conductive material an electromagnetic force causes a current to circulate within the core itself and not the second wire resulting in a loss. This can be negated by building the core in a layered structure where an insulating strip is placed between the conductive material reducing the size of the conductive material in turn reducing the magnetic flux. (Harlow, 2007) ✓

A) A 700-turn coil of inductance 2.5H carries a current of 1.6A. Calculate the flux linking the coil and the electromagnetic force induced in the coil when the current collapses to zero in 20ms.

$$\phi = \frac{L \times I}{N} \quad \checkmark$$

$$\frac{2.5H \times 1.6A}{700 \text{ turns}} = 5.714mWb \quad \checkmark$$

$$e = \frac{N \times \phi}{t} \quad \checkmark$$

$$\frac{700 \text{ turns} \times 5.714 \times 10^{-3}Wb}{20 \times 10^{-3}s} \Rightarrow 200V \quad \checkmark$$

B) A rectangular coil of sides 10cm and 6cm is rotated in a magnetic field of flux density 1.2T, the longer side of the coil actually cutting this flux. The coil is made up of 70 turns and rotates at 1200rev/min. (i) Calculate the maximum generated electromagnetic force. (ii) If the coil generates 80V, at what speed will the coil rotate?

i)

$$\frac{1200rpm \times 2\pi}{60s} = 40\pi \quad \checkmark$$

$$40\pi \times \frac{0.06m}{2} = 3.77mps \quad \checkmark$$

$$E = 2NB l v \sin\theta \quad \checkmark$$

$$2 \times 70 \text{ turns} \times 1.2T \times 0.1m \times 3.77mps \times 1 = 63.336V \quad \checkmark$$

ii)

$$V = \frac{E}{2NB l \sin\theta} \quad \checkmark$$

$$\frac{80V}{2 \times 70 \text{ turns} \times 1.2T \times 0.1m \times 1} = 4.76mps \quad \checkmark$$

$$Vrpm = \frac{Vmps \times 60}{2\pi} \times \frac{2}{0.06} \quad \checkmark$$

$$\frac{4.76mps \times 60}{2\pi} \times \frac{2}{0.06} = 1515.155rpm \quad \checkmark$$

Good.

## Task 4 – AC Circuits

Again start on new page.

- Using the oscilloscope measurements for a sine wave stated in table 3 perform the following calculations.

A) Peak Voltage

$$V_p = \frac{V_{pp}}{2}$$

$$\frac{5.4V}{2} = 2.7V \quad \checkmark$$

B) Frequency

$$f = \frac{1}{T_{\text{base}}}$$

$$\frac{1}{0.01} = 100\text{Hz} \quad \checkmark \quad T = 4.6 \times 10^{-3}$$

C) Average Voltage

$$V_a = \frac{2V_p}{\pi} \quad \checkmark$$

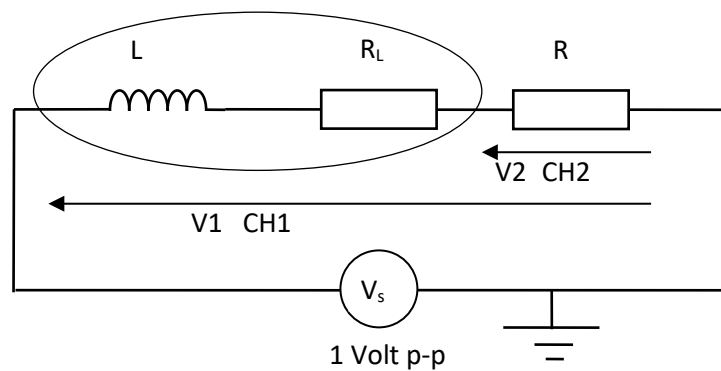
$$\frac{2 \times 2.7V}{\pi} = 1.719V \quad \checkmark$$

D) Root Mean Square Voltage

$$V_p \frac{1}{\sqrt{2}} = V_{\text{rms}} \quad \checkmark$$

$$2.7 \frac{1}{\sqrt{2}} = 1.9V \quad \checkmark$$

2. Below is a RL circuit:



$L = 1\text{mH}$ ,  $R = 18\Omega$ ,  $R_L = ?\Omega$  (measure this value)

3. Measure and record the value of each of the component.

$L = 1.05\text{mH}$   $R_L = 2.58\Omega$   $R = 18.01\Omega$   $\checkmark$

4. Produce a table of measurements.

| Frequency<br>(f)<br>(kHz) | CH1 (V)<br>pk to pk<br>Voltage | CH2 (V)<br>pk to pk<br>Voltage | Time<br>Difference<br>(between<br>peaks)<br>(T2-T1)<br>(μS) | Calculated values               |                                       |                                              |
|---------------------------|--------------------------------|--------------------------------|-------------------------------------------------------------|---------------------------------|---------------------------------------|----------------------------------------------|
|                           |                                |                                |                                                             | Time for<br>1 cycle<br>(T) (mS) | Fraction<br>of cycle<br>(T2-<br>T1)/T | Phase<br>Angle<br>(°)<br>(fraction<br>x 360) |
| 1                         | 1                              | 0.7                            | 41.1                                                        | 1.000                           | 0.0411                                | 14.796                                       |
| 2                         | 1                              | 0.82                           | 40.6                                                        | 0.500                           | 0.0812                                | 29.232                                       |
| 3                         | 1                              | 0.84                           | 35.4                                                        | 0.333                           | 0.1062                                | 38.232                                       |
| 4                         | 1                              | 0.89                           | 32.5                                                        | 0.250                           | 0.13                                  | 46.8                                         |
| 5                         | 1                              | 0.92                           | 29.6                                                        | 0.200                           | 0.148                                 | 53.28                                        |
| 6                         | 1                              | 0.96                           | 27.8                                                        | 0.167                           | 0.1668                                | 60.048                                       |
| 7                         | 1                              | 0.96                           | 24.8                                                        | 0.143                           | 0.1736                                | 62.496                                       |
| 8                         | 1                              | 0.98                           | 23.5                                                        | 0.125                           | 0.188                                 | 67.68                                        |
| 9                         | 1                              | 0.96                           | 20.1                                                        | 0.111                           | 0.1809                                | 65.124                                       |

5. Produce a table of calculations as shown below.

| Frequency (f<br>- kHz) | Reactance,<br>X <sub>L</sub> (Ω)<br>(2πfL) | Total<br>resistance,<br>R <sub>T</sub><br>(R + R <sub>L</sub> ) | Impedance, Z<br>(Ω) | Current<br>(mA) | Phase<br>Angle<br>(°) |
|------------------------|--------------------------------------------|-----------------------------------------------------------------|---------------------|-----------------|-----------------------|
| 1                      | 6.31                                       | 20.59                                                           | 21.54               | 46.43           | 17.05                 |
| 2                      | 13.19                                      | 20.59                                                           | 24.46               | 40.89           | 32.65                 |
| 3                      | 19.79                                      | 20.59                                                           | 28.56               | 35.01           | 43.87                 |
| 4                      | 26.39                                      | 20.59                                                           | 33.47               | 29.88           | 52.04                 |
| 5                      | 32.99                                      | 20.59                                                           | 38.89               | 25.72           | 58.03                 |
| 6                      | 39.58                                      | 20.59                                                           | 44.62               | 22.41           | 62.52                 |
| 7                      | 46.18                                      | 20.59                                                           | 50.56               | 19.78           | 65.97                 |
| 8                      | 52.78                                      | 20.59                                                           | 56.65               | 17.65           | 68.69                 |
| 9                      | 59.38                                      | 20.59                                                           | 62.84               | 15.91           | 70.87                 |

Reactance

$$X_L = 2\pi fL$$

$$2\pi \times 1000\text{Hz} \times 0.001005\text{H} = 6.31\Omega$$

Total Resistance

$$R + RL = RT \quad \checkmark$$

$$18.01\Omega + 2.58\Omega = 20.59\Omega \quad \checkmark$$

Impedance

$$Z = \sqrt{Rt^2 + XL^2} \quad \checkmark$$

$$\sqrt{20.59\Omega^2 + 6.31^2} = 21.54\Omega \quad \checkmark$$

Current

$$I = \frac{V}{Z} \quad \checkmark$$

$$\frac{1V}{21.54\Omega} = 0.04643A \quad \checkmark$$

Phase Angle

$$\theta = \tan^{-1}\left(\frac{XL}{Rt}\right)$$

$$\tan^{-1}\left(\frac{6.31}{20.59}\right) = 17.05^\circ \quad \checkmark$$

6. Comment on the practical and calculation results, discussing any variations when comparing these results.

In these results we can see that the reactance has a positive correlation with frequency. We would expect to see this as the frequency increases the number of times the direction of the flow current changes meaning the amount of back emf increases resulting in a larger impedance of the circuit. This is different from a DC circuit where current flows in one direction so therefore reactance does not occur as there is not a continual change of direction of current.

Another interesting aspect of these results is the fact that current has a negative correlation with frequency in this circuit. The current decreases as the frequency increases in this circuit because it is an inductive circuit meaning as the frequency increases as previously discussed the back emf generated increases also meaning impedance is greater. This has the effect of reducing current it is proportional to resistance. If the circuit were capacitive then the impedance would be inversely proportional to frequency meaning a higher frequency would mean the amount of current would increase. (Herman, 2011) ✓

Although very close the practical results do not match up exactly with those calculated. This is because the calculated results are theoretical and do not take into account extraneous variables for example human error. When the signal generator was adjusted

for the next kHz frequency how exact was it? Depending on the viewpoint of the individual setting the frequency it could have been slightly above or slightly below. It is also worth asking how accurate the digital display on both the oscilloscope and signal generator are when setting values and taking readings. If the frequency was not exact, then this could explain differences between the practical and calculated results. ✓

Another variable that was not taken into account would be the oscilloscope used to take the measurements. The probes used to take the measurement themselves have a degree of capacitance, inductance and resistance meaning when they are introduced to the circuit they will disturb or load the circuit. The room the measurements were taken in also had several other electrical devices and power supplies all generating electromagnetic fields which can cause small amounts of induced current in the circuit which can mean measurements are imperfect. The environment of the room can also have influence through electrochemical effects for example dirt on the end of probes or a high humidity causing poor connection. (Josep Altet, 2002) ✓

*A good attempt, you did make some mistakes in your calculation work.*

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