

LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Tom Griffiths	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:	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.) Alternative submission method (if applicable): Late submission of the assessment will result in a late penalty mark. 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.		
Academic honesty / referencing:	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.		

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
1. Engagement with Literature Skills	15	9
Engagement with a wide range of literature sources, including sources retrieved independently. Generally sound referencing, with very few inaccuracies or inconsistencies.		
2. Knowledge and Understanding Skills	25	17
Task 1 achieved 68%. Task 2 achieved 70%, Task 3 achieved 66%. Task 4 achieved 68%. Competent knowledge of the basic underlying concepts and principles. Showed excellent understanding the calculated requirements. Some the research work need to be more detailed to show a better understanding of some of the concepts within the report.		
3. Cognitive and Intellectual Skills	15	7.9
Task 1 achieved 55%. Task 4 achieved 50%. Good evaluation of the underlying concepts and principles but were a little bit limited in the evaluation of Task 4.		
4. Practical Application Skills	35	27.7
Task 1 achieved 80%. Task 4 achieved 78%. 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.		
5. Transferable Skills for Life and Professional Practice	10	6.5
Work is accurate, coherent, fluent, well-structured and organised but in some parts the presentation could have been improved by using Tables within Word.		

Assessment Mark (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.)

Late Submission Penalties (tick if appropriate)

Up to 1 week late (40% Max)

Over 1 week late (0%)

68%

**HNC Electrical/Electronic Engineering,
HNC Power Systems Engineering,
HNC Instrumentation Engineering**

**PCEE4001
Level 4 Assignment**

T. GRIFFITHS

2020-2021

[VALERO OIL REFINERY PEMBROKESHIRE]

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Introduction

The aim of this assignment is to develop an understanding of the fundamentals of electrical principles through theoretical and practical applications. The assignment will cover the following areas of Electrical Principles – DC circuits, Capacitors in DC circuits, magnetism and AC circuits. This will be achieved through a range of practical, calculation and research work.

Task 1 – DC Circuits

Figure 1 below shows a combinational arrangement of a DC circuit.

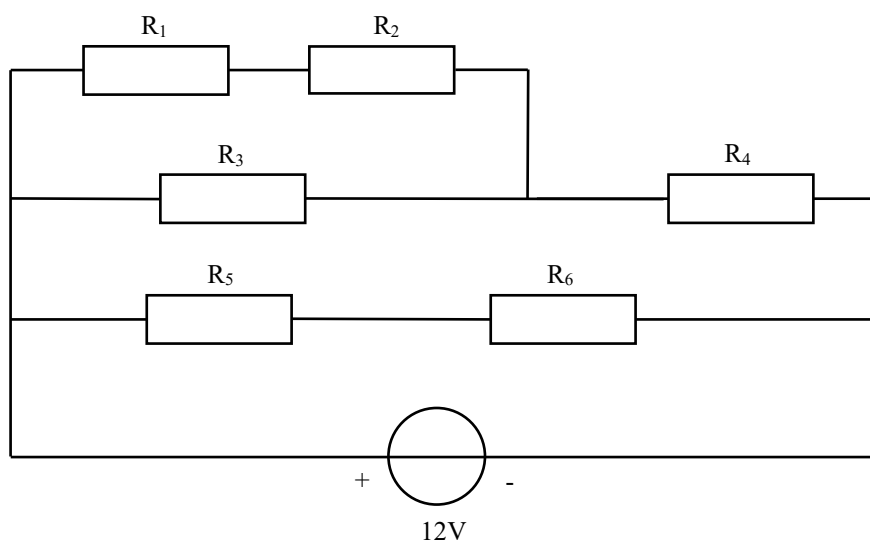


Figure 1 – Resistors in Series/Parallel

To complete the activities for this task you will be given a student number which relates to the resistor values for the combinational circuit. Table 1 shows the student numbers and resistor values.

Table 1 – values for Task 1

Student Number	R ₁ (Ω)	R ₂ (Ω)	R ₃ (Ω)	R ₄ (Ω)	R ₅ (Ω)	R ₆ (Ω)
1	270	560	330	270	330	680
2	390	470	220	330	180	560
3	220	470	330	470	220	680
4	270	680	220	560	330	560
5	330	560	330	470	180	680
6	180	680	220	330	270	560
7	220	560	330	470	220	680
8	330	470	220	560	180	680

Which values are you using?

1. Construct the circuit and measure the total resistance (R_T) before connecting the power supply.
2. Connect a 12V supply and measure the p.d. value across each resistor, the supply current and the current in each resistor.

3. Calculate the
 - total resistance, R_T
 - supply current, I
 - current in each resistor
 - and the p.d. value across each resistor.
 All formulas and workings must be shown.
4. Use Multisim to also produce a set of test results for the voltages and currents.
5. Comment on the practical, calculation and simulation results, discussing any variations when comparing these results and make reference to relative theories such as Kirchhoff's laws.

This should be written in a past tense.

Task 1

1. Construct the circuit and measure the total resistance (R_T) before connecting the power supply.

The circuit as shown in figure 1 (above) was created from using breadboard, resistors and a 12V supply and measured the total the resistance using a Multimetre. From using the Multimetre the total resistance of the circuit which was 387Ω was obtained. ✓

V =	12
R_T =	387
I =	0.031

Must state units.

This should typed into your report.



Figure 1 - Shows the Voltage, Resistance Total and Current

2. Connect a 12V supply and measure the p.d. value across each resistor, the supply current and the current in each resistor.

After the total resistance value without the voltage supply being attached had been obtained, the 12V supply was connected to power up the circuit. After connecting up the voltage supply, a Multimetre was used to measure the potential difference across the resistors, the supply current and the current in each resistor. Figure 2 shows the table of the each resistor current and potential difference values.

		Measured	Simulated	Calculated
V =	12	V1 = 1.22V	1.232V	1.232V
R_T =	387	V2 = 2.62V	2.632V	2.632V
I =	0.031	V3 = 3.84V	3.864V	3.865V
		V4 = 8.12V	8.136V	8.135V
R1 =	220	V5 = 2.93V	2.933V	2.932V
R2 =	470	V6 = 9.04V	9.067V	9.064V
R3 =	330			
R4 =	470			
		Measured	Simulated	Calculated
R5 =	220	I1 = 5.65mA	5.599mA	5.60mA
R6 =	680	I2 = 5.65mA	5.599mA	5.60mA
		I3 = 11.77mA	11.708mA	11.71mA
		I4 = 17.41mA	17.311mA	17.31mA
		I5 = 13.46mA	13.335mA	13.33mA
		I6 = 13.46mA	13.333mA	13.33mA

Use Word to create a table.



Figure 2 - Shows the Table of figures for the Potential difference and Current in each resistor

3. Calculate the

- total resistance, R_T
- supply current, I
- current in each resistor
- and the p.d. value across each resistor.

All formulas and workings must be shown.

The calculations can be seen below.

$$R1 = 220\Omega \quad V = 12V$$

$$R2 = 470\Omega$$

$$R3 = 330\Omega$$

$$R4 = 470\Omega$$

$$R5 = 220\Omega$$

$$R6 = 680\Omega$$

R

$$R_{12} = R1 + R2 = 220 + 470 = 690\Omega$$

$$R_{123} = \frac{R_{12} \times R3}{R_{12} + R3} = \frac{690 \times 330}{690 + 330} = 223.24\Omega$$

$$R_{1234} = R_{123} + R4 = 223.24 + 470 = 693.24\Omega$$

$$R_{56} = R5 + R6 = 220 + 680 = 900\Omega$$

$$R_T = \frac{R_{1234} \times R_{56}}{R_{1234} + R_{56}} = \frac{693.24 \times 900}{693.24 + 900} = 391.60\Omega$$

C

$$I = \frac{V}{R_T} = \frac{12}{391.60} = 0.031A$$

$$I_{56} = \frac{V}{R_{56}} = \frac{12}{900} = 13.33mA$$

$$I4 = \frac{V}{R_{1234}} = \frac{12}{693.24} = 17.31mA$$

$$I3 = \frac{V3}{R3} = \frac{3.805}{330} = 11.71mA$$

$$I1/I2 = \frac{V3}{R12} = \frac{3.805}{690} = 5.60mA$$

$$I1/I2 = I4 - I3 = 17.31 - 11.71 = 5.60mA$$

V

$$V5 = I5 \times R5 = 13.33 \times 10^{-3} \times 220 = 2.932V$$

$$V6 = I6 \times R6 = 13.33 \times 10^{-3} \times 680 = 9.064V$$

$$V4 = I4 \times R4 = 17.31 \times 10^{-3} \times 470 = 8.135V$$

$$V3 = V - V4 = 12 - 8.135 = 3.865V$$

$$V1 = I1 \times R1 = 5.6 \times 220 = 1.232V$$

$$V2 = I2 \times R2 = 5.6 \times 470 = 2.632V$$

Well done.

Handwritten calculations for a circuit problem:

Resistor combinations:

$$R_{12} = R_1 + R_2 = 220 + 470 = 690$$
$$R_{23} = \frac{R_{12} \times R_3}{R_{12} + R_3} = \frac{690 \times 330}{690 + 330} = 223.24$$
$$R_{234} = R_{23} + R_4 = 223.24 + 470 = 693.24$$
$$R_{56} = 220 + 680 = 900$$

Total resistance and current:

$$R_T = \frac{R_{234} \times R_{56}}{R_{234} + R_{56}} = 391.60\Omega$$
$$I = \frac{V}{R_T} = \frac{12}{391.60} = 0.031A$$

Currents in parallel branches:

$$I_5 = I_6 = \frac{V}{R_{56}} = \frac{12}{900} = 13.33mA$$

Voltages across components:

$$V_5 = I_5 \times R_5 = 13.33 \times 10^{-3} \times 220 = 2.932V$$
$$V_6 = I_6 \times R_6 = 13.33 \times 10^{-3} \times 680 = 9.064V$$
$$V_4 = I_4 \times R_4 = 17.31 \times 10^{-3} \times 470 = 8.135V$$
$$V_3 = V - V_4 = 12 - 8.135 = 3.865V$$
$$V_1 = I_1 \times R_1 = 5.6 \times 220 = 1.232V$$
$$V_2 = I_2 \times R_2 = 5.6 \times 470 = 2.632V$$

Currents in series branches:

$$I_4 = \frac{V}{R_{234}} = \frac{12}{693.24} = 17.31mA$$
$$I_3 = \frac{V_3}{R_3} = \frac{3.865}{330} = 11.71mA$$
$$I_1 = I_2 = I_4 - I_3 = 17.31 - 11.71 = 5.60mA$$

There is no need to show your rough workings.

Figure 3 - Shows my written calculations

4. Use Multisim to also produce a set of test results for the voltages and currents.

As seen in figure 4 you can see the set of voltage test results produced from multisim. These are very close to the measured results and calculated results as seen in the figure 2 table.

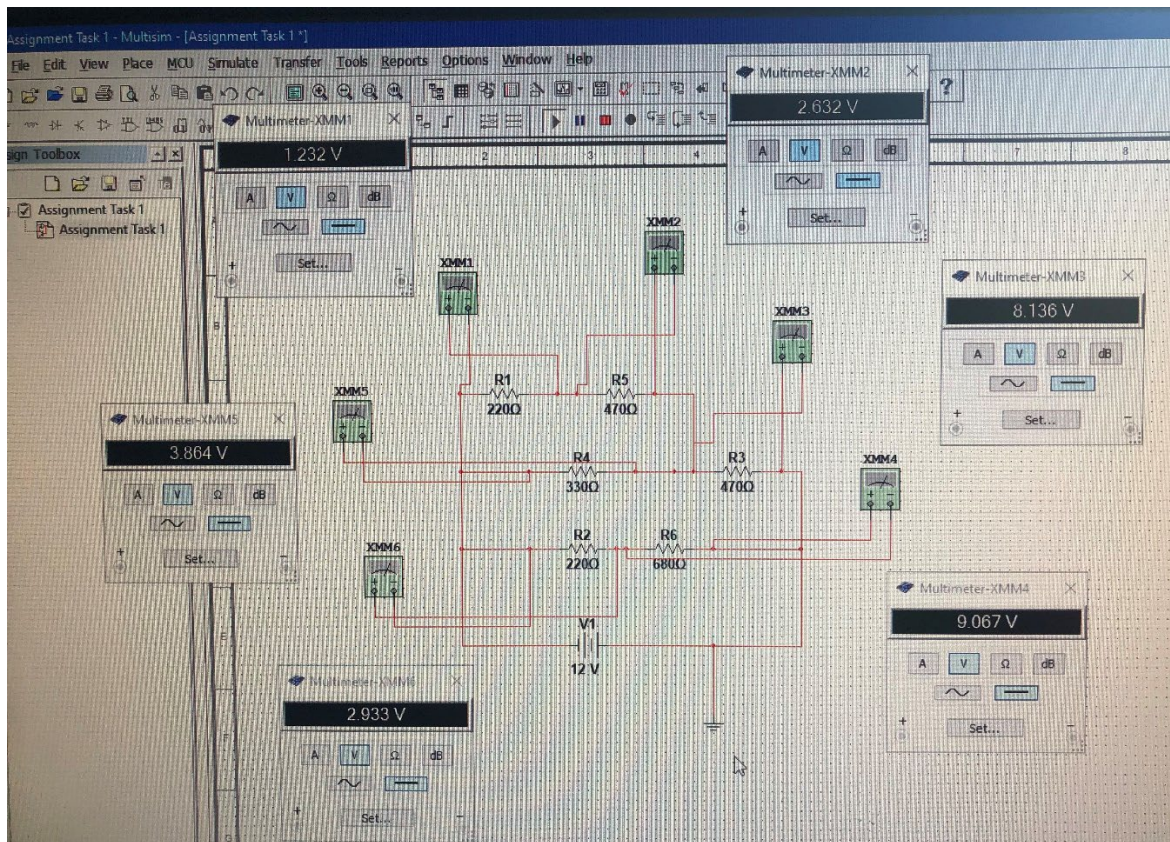


Figure 4 - Shows the Multisim voltage results

Your image is a bit unclear.

As seen in figure 5 you can see the set of current test results produced from multisim. These are very close to the measured results and calculated results as seen in the figure 2 table.

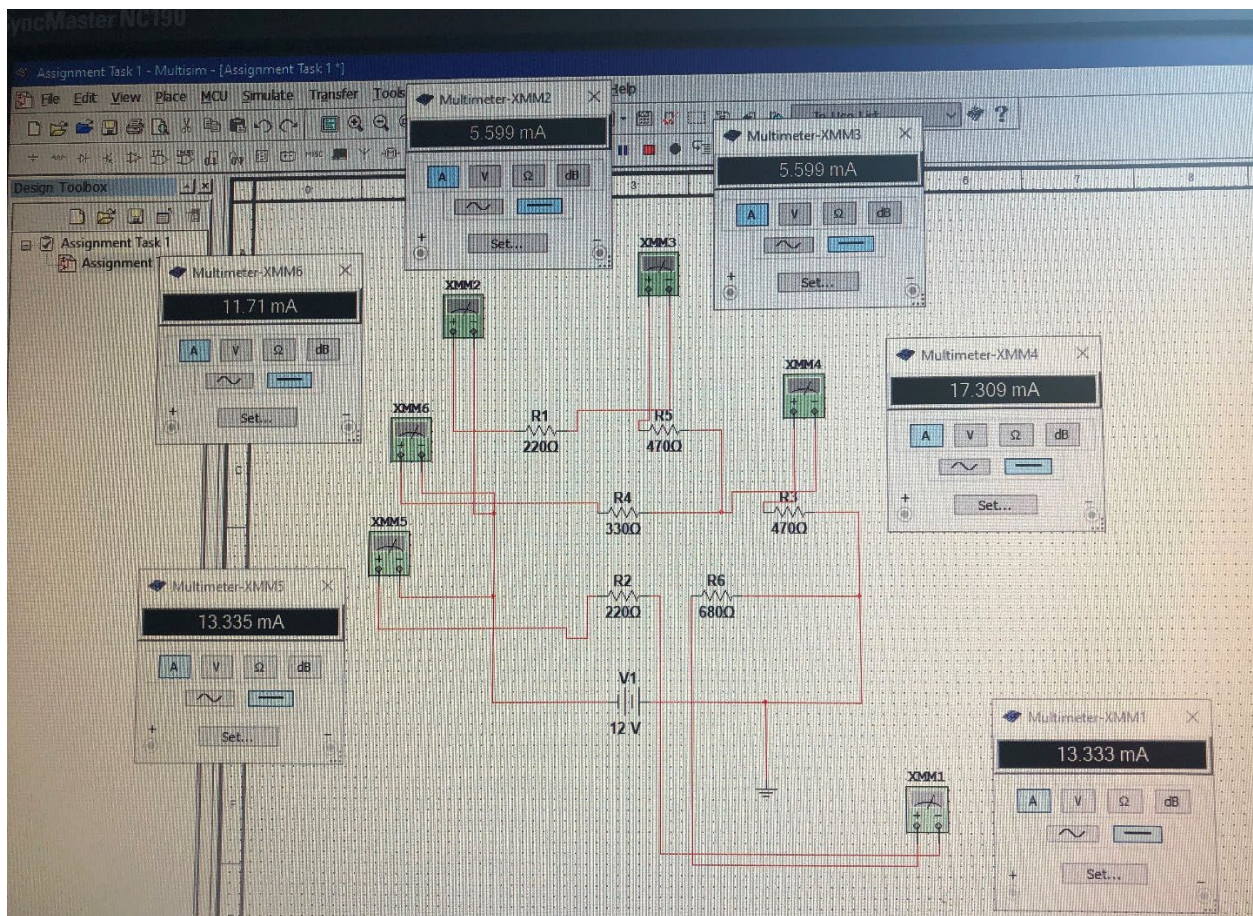


Figure 5 - Shows the current Multisim results

5. Comment on the practical, calculation and simulation results, discussing any variations when comparing these results and make reference to relative theories such as Kirchhoff's laws.

Figure 6 shows us the table of each of the results. These include the simulated, calculated and measured results. From this table it can be seen why they all vary slightly.

		Measured	Simulated	Calculated
V =	12	V1 = 1.22V	1.232V	1.232V
RT =	387	V2 = 2.62V	2.632V	2.632V
I =	0.031	V3 = 3.84V	3.864V	3.865V
		V4 = 8.12V	8.136V	8.135V
R1 =	220	V5 = 2.93V	2.933V	2.932V
R2 =	470	V6 = 9.04V	9.067V	9.064V
R3 =	330			
R4 =	470			
		Measured	Simulated	Calculated
R5 =	220	I1 = 5.65mA	5.599mA	5.60mA
R6 =	680	I2 = 5.65mA	5.599mA	5.60mA
		I3 = 11.77mA	11.708mA	11.71mA
		I4 = 17.41mA	17.311mA	17.31mA
		I5 = 13.46mA	13.335mA	13.33mA
		I6 = 13.46mA	13.333mA	13.33mA

Figure 6 - Shows the table of results

From the table it can be seen that the measured values vary more than the other two set of results, this is because human error may take place and the equipment used to retrieve these results may not be 100% accurate or their tolerances may be higher than other measurement devices. ✓ Kirchhoff's voltage law states that "the sum of the voltage sources around any closed path is equal to the sum of the potential drops around that path" so this means that the results are dependant on the value of the resistors. In Theory the resistances are exactly what they are supposed but in practice there will always be a tolerance +/- % in the value of the resistor, so when dealing with small currents any change in the resistance value will alter the readings. This can be seen from the table above as the simulated and calculated readings are generally the same whereas the measured readings are slightly lower. ✓

There are other factors that could have been considered.

Task 2 – Capacitors

A capacitor is an electronic device that stores electrical charge and is used in a number of electronic applications.

1. Explain the construction and function of a capacitor, listing some of the different types that are available and typical values. Include methods that could be used to alter the value of the capacitor.
2. Figure 2 shows a circuit containing capacitors in series/parallel to a d.c. voltage source.

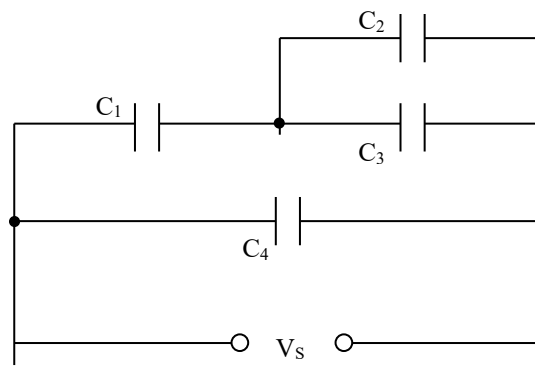


Figure - 2

Using the values stated in Table 2, determine:

- a) the equivalent circuit capacitance
- b) the total charge
- c) the charge in each capacitor
- d) the energy stored in each capacitor
- e) the total energy stored in the circuit.

Table 2 – values for Task 2

Student Number	C ₁ (μF)	C ₂ (μF)	C ₃ (μF)	C ₄ (μF)	V _s (V)
1	12	27	33	4.7	12
2	15	27	39	3.3	15
3	18	27	43	2.2	20
4	22	27	47	2.2	25
5	27	22	43	1.5	30
6	10	22	39	3.3	25

7	12	22	33	4.7	20
9	15	22	39	3.3	15

Again you only need to state your values.

Task 2

1. Explain the construction and function of a capacitor, listing some of the different types that are available and typical values. Include methods that could be used to alter the value of the capacitor.

A capacitor is an electronic component that consists of two metal plates which is separated by an insulating layer called the dielectric. Capacitors have the ability of storing a quantity of electricity as an excess of electrons on one plate and a deficiency on the other. A common way in which capacitors are made are by taking two strips of metal foil and separating them with strips of waxed/oiled paper which are then wound spirally which in effect creates two large surfaces near each other. The metal foil sheets, and the waxed/oil paper are then rolled into a compact form. These wound up components are then soaked in paraffin wax to protect the dielectric from the environment. This type of capacitor is called a Paper capacitor and their typical range values are between 300pF to around 4 μ F. Paper capacitors are used in car audio systems to provide extra power to the amplifiers when needed. They can also be used in power conditioning systems that need to block DC signals and only allow AC signals. They can also be used as sensors to measure air humidity, mechanical strain and fuel levels. Figure 7 shows the diagram of how a paper capacitor is made.

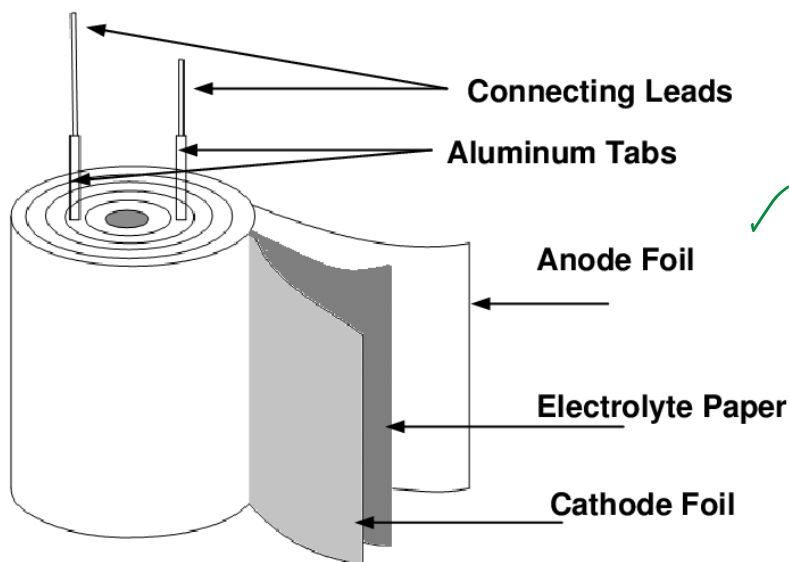


Figure 7 - Shows what a Paper Capacitor consists of

Another common type of capacitor is the Mica capacitor. These types of capacitors contain either of alternate layers of mica and metal foil clamped together tightly or are of thin films of silver sprayed onto the two sides of the Mica sheet. Due to the Mica capacitors high manufacture cost they are usually used within circuits that are of high frequency when a minimum loss in the dielectric is necessary. They are also used in other circuits that need to be precise. The typical range values of a Mica capacitor are between 1pF to 1 μ F. Mica

capacitors are also used in timing and oscillator circuits. Figure 8 shows the components of a Mica capacitor. ✓

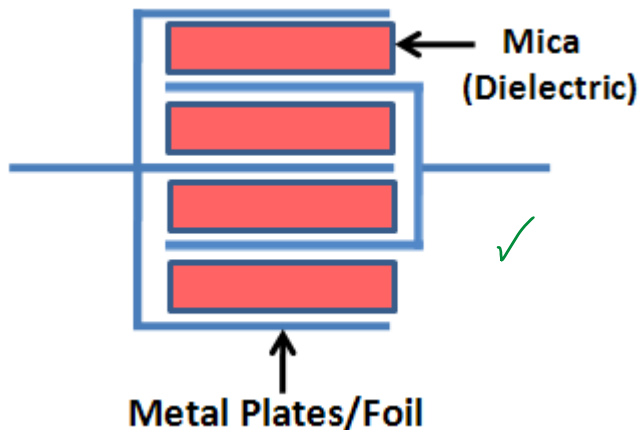


Figure 8 - Shows what a Mica capacitor consists of

Tantalum capacitors are another type of capacitor that is used for bypasses and coupling in circuits and for DC blocking. Tantalum capacitors are an electrolytic capacitor. This means that it is a polarized capacitor whose positive plate is made of a metal that forms an insulating oxide layer through anodization. This oxide layer acts as the dielectric of the capacitor. A solid, liquid, or gel electrolyte then covers the surface of this oxide layer, serving as the cathode or negative plate of the capacitor. There are various types of electrolytic capacitors such as the aluminium electrolytic capacitor. The tantalum capacitor is much smaller than the aluminium electrolytic capacitor. Tantalum capacitors consist of a pressed sintered tantalum powder that has been coated in an oxide layer which acts as the dielectric. The case of the capacitor is commonly made of brass, copper and sometimes silver and this forms the other capacitor plate. Between these plates are layers of manganese dioxide and graphite which for the solid electrolyte. The typical range value for a tantalum capacitor is between $0.001\mu\text{F}$ to $1000\mu\text{F}$. Figure 9 shows the diagram of components used to make a tantalum capacitor. ✓

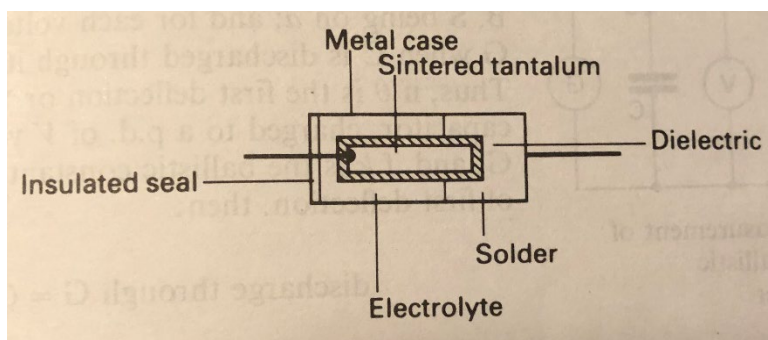


Figure 9 - Shows the Tantalum capacitor components

One way that we could alter the value of a capacitor is by using a variable capacitor. A variable capacitor has the ability to change the values of its capacitance by either electrically changing it or mechanically changing it. Variable capacitors consist of plates made of metals and within these plates there be one that is fixed, and the other plate will be movable. These capacitors can be connected up to each other to increase the capacitance value, when this combination is carried out there will always be one shaft that is sufficient enough so that the other joined up capacitors are variable. Variable capacitors are used so that instead of

deciding the values during the manufacturing period like fixed capacitors such as a mica or a paper capacitor, certain ranges of values are provided with variable capacitors. Variable capacitors are used in tuning circuits such as one used for a radio. The typical range values of a variable capacitor is between 100pF to 500pF. Figure 10 shows the diagram of a variable capacitor. ✓

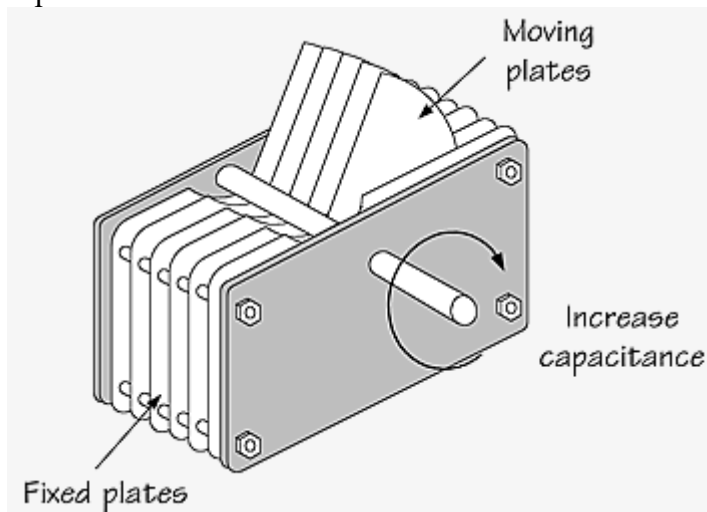


Figure 10 - Shows the diagram for a Variable capacitor

There are other elements that can be changed to alter the value of the capacitor.

2. Figure 2 shows a circuit containing capacitors in series/parallel to a d.c. voltage source.

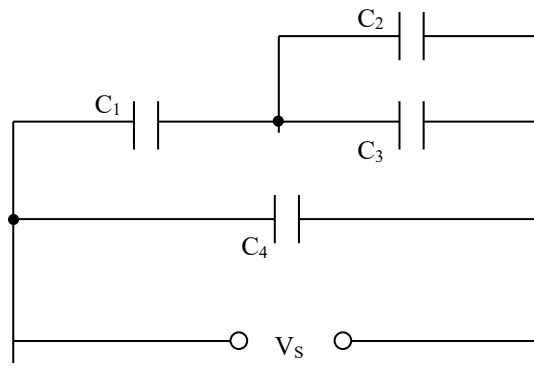


Figure - 2

Using the values stated in Table 2, determine:

- a) the equivalent circuit capacitance
- b) the total charge
- c) the charge in each capacitor
- d) the energy stored in each capacitor
- e) the total energy stored in the circuit.

The calculations can be seen below.

$$C1 = 18\mu\text{F} \quad V_s = 20\text{V}$$

$$C2 = 27\mu\text{F}$$

$$C3 = 43\mu\text{F}$$

$$C4 = 2.2\mu\text{F}$$

$$\text{a) } C_{23} = C2 + C3 = 27 + 43 = 70\mu\text{F}$$

$$C_{123} = \frac{C1 \times C_{23}}{C1 + C_{23}} = \frac{18 \times 70}{18 + 70} = 14.318\mu\text{F}$$

$$C_T = C_{123} + C4 = 14.318 + 2.2 = 16.518\mu\text{F}$$

$$\text{b) } Q_T = C_T \times V = 16.518 \times 10^{-6} \times 20 = 330.36\mu\text{C}$$

$$\text{c) } Q4 = C4 \times V = 2.2 \times 10^{-6} \times 20 = 44\mu\text{C}$$

$$Q_{123} = C_{123} \times V = 14.318 \times 10^{-6} \times 20 = 286.36\mu\text{C}$$

Or

$$Q_{123} = Q_T - Q4 = 330.36 - 44 = 286.36\mu\text{C} \quad \text{Good.}$$

$Q1 = Q_{123}$ because it is in series

$$Q1 = 286.36\mu\text{C}$$

$$V1 = \frac{Q1}{C1} = \frac{286.36}{18} = 15.908\text{V}$$

$$V_{23} = \frac{Q1}{C_{23}} = \frac{286.36}{70} = 4.091\text{V}$$

Or

$$V_{23} = V - V1 = 20 - 15.908 = 4.091\text{V}$$

$$Q2 = C2 \times V_{23} = 27 \times 4.091 = 110.457\mu\text{C}$$

$$Q3 = C3 \times V_{23} = 43 \times 4.091 = 175.913\mu\text{C}$$

$$\text{d) } W = \frac{1}{2} C V^2$$

$$W1 = \frac{1}{2} C1 \times V1^2 = \frac{1}{2} \times 18 \times 10^{-6} \times 15.908^2 = 2.277\text{mJ}$$

$$W_2 = \frac{1}{2}C_2 \times V_{23}^2 = \frac{1}{2} \times 27 \times 10^{-6} \times 4.091^2 = 0.226 \text{ mJ} \quad \checkmark$$

$$W_3 = \frac{1}{2}C_3 \times V_{23}^2 = \frac{1}{2} \times 43 \times 10^{-6} \times 4.091^2 = 0.359 \text{ mJ} \quad \checkmark$$

$$W_4 = \frac{1}{2}C_4 \times V^2 = \frac{1}{2} \times 2.2 \times 10^{-6} \times 20^2 = 0.44 \text{ mJ} \quad \checkmark$$

e) $W_T = \frac{1}{2}C_T \times V^2 = \frac{1}{2} \times 16.518 \times 20^2 = 3.303 \text{ mJ} \quad \checkmark$

Excellent work.

Or

$$W_T = W_1 + W_2 + W_3 + W_4 = 2.277 + 0.226 + 0.359 + 0.44 = 3.303 \text{ mJ} \quad \checkmark$$

$C_1 = 18 \mu\text{F}$
 $C_2 = 27 \mu\text{F}$
 $C_3 = 43 \mu\text{F}$
 $C_4 = 2.2 \mu\text{F}$
 $V_S = 20 \text{ V}$

a) $C_{23} = C_2 + C_3 = 27 + 43 = 70 \mu\text{F}$
 $C_{123} = \frac{C_1 \times C_{23}}{C_1 + C_{23}} = \frac{18 \times 70}{18 + 70} = 14.318 \mu\text{F}$
 $C_T = C_{123} + C_4 = 14.318 + 2.2 = 16.518 \mu\text{F}$

b) $Q_T = C_T \times V = 16.518 \times 10^{-6} \times 20 = 330.36 \mu\text{C}$

c) $Q_4 = C_4 \times V = 2.2 \times 10^{-6} \times 20 = 44 \mu\text{C}$
 $Q_{123} = C_{123} \times V = 14.318 \times 10^{-6} \times 20 = 286.36 \mu\text{C}$
 OR
 $Q_{123} = Q_T - Q_4 = 330.36 - 44 = 286.36 \mu\text{C}$
 $Q_1 = Q_{123}$ because it is in series
 $Q_1 = 286.36 \mu\text{C}$
 $V_1 = \frac{Q_1}{C_1} = \frac{286.36}{18} = 15.908 \text{ V}$
 $V_{23} = \frac{Q_1}{C_{23}} = \frac{286.36}{70} = 4.091 \text{ V}$
 OR
 $V_{23} = V - V_1 = 20 - 15.908 = 4.091 \text{ V}$
 $Q_2 = C_2 \times V_{23} = 27 \times 4.091 = 110.457 \mu\text{C}$
 $Q_3 = C_3 \times V_{23} = 43 \times 4.091 = 175.913 \mu\text{C}$

Figure 11 - Shows my written calculation workings

d) $W = \frac{1}{2} CV^2$
 $W_1 = \frac{1}{2} C_1 \times V_1^2 = \frac{1}{2} \times 18 \times 10^{-6} \times 15.908^2 = 2.277 \text{ mJ}$
 $W_2 = \frac{1}{2} C_2 \times V_{23}^2 = \frac{1}{2} \times 27 \times 10^{-6} \times 4.091^2 = 0.226 \text{ mJ}$
 $W_3 = \frac{1}{2} C_3 \times V_{23}^2 = \frac{1}{2} \times 43 \times 10^{-6} \times 4.091^2 = 0.359 \text{ mJ}$
 $W_4 = \frac{1}{2} C_4 \times V_{23}^2 = \frac{1}{2} \times 2.2 \times 10^{-6} \times 20^2 = 0.44 \text{ mJ}$
 e) $W_T = \frac{1}{2} C_T \times V^2 = \frac{1}{2} \times 16.518 \times 20^2 = 3.303 \text{ mJ}$
 or
 $W_T = W_1 + W_2 + W_3 + W_4 = 2.277 + 0.226 + 0.359 + 0.44 = 3.302 \text{ mJ}$

Figure 12 - Shows my written calculation workings

Task 3 – Magnetism

1. Explain the principles of permanent magnets including the distribution of magnetic fields.
2. Solve the following problems:
 - a) A magnetic pole face has a rectangular section having dimensions 220mm by 120mm. If the total flux emerging from the pole is $130 \mu\text{Wb}$, calculate the flux density.
 - 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.
1. Explain the principle operation and construction of an electromagnet including the distribution of magnetic fields.
2. A transformer is a device that uses some of the principles associated with electromagnetism. Explain the operation and construction of transformer, include methods to reduce power loss within the transformer.
3. Solve the following problems:
 - a) A 700 turn coil of inductance 2.5H carries a current of 1.6A. Calculate the flux linking the coil and the e.m.f. induced in the coil when the current collapses to zero in 20ms.
 - 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 e.m.f. (ii) If the coil generates 80V, at what speed will the coil rotate?

Task 3

1. Explain the principles of permanent magnets including the distribution of magnetic fields.

Magnetic Fields are produced by permanent magnets. When magnets produce a magnetic field the lines of force produced radiate from the north pole of the magnet to the south pole of the magnet. These lines of force never cross and the same poles repel whilst the opposite poles will attract one another. ✓

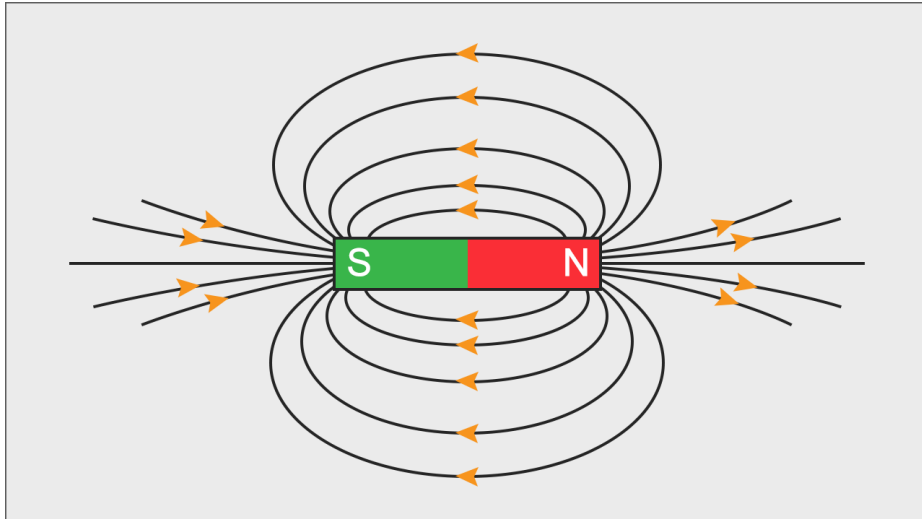


Figure 13 - Shows how the magnetic field lines radiate

could have included other diagrams to show attraction and repulsion.

2. Solve the following problems:

- A magnetic pole face has a rectangular section having dimensions 220mm by 120mm. If the total flux emerging from the pole is $130\mu\text{Wb}$, calculate the flux density.
- 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 61 mWb determine the radius of the pole face.

- A magnetic pole face has a rectangular section having dimensions 220mm by 120mm. If the total flux emerging from the pole is $130\mu\text{Wb}$, calculate the flux density.

$$L = 220\text{mm} = 0.22\text{m}$$

$$H = 120\text{mm} = 0.12\text{m}$$

$$\Phi = 130\mu\text{Wb}$$

$$A = L \times H = 0.22 \times 0.12 = 0.026 \text{ m}^2$$

$$B = \frac{\Phi}{A} = \frac{130 \times 10^{-6}}{0.026} = 5 \times 10^{-3} \text{ T} = 5\text{mT}$$

$$\begin{aligned}
 L &= 220\text{mm} = 0.22\text{m} \\
 H &= 120\text{mm} = 0.12\text{m} \\
 A &= L \times h = 0.22 \times 0.12 = 0.026 \\
 \Phi &= 130\mu\text{Wb} \\
 B &= \frac{\Phi}{A} = \frac{130 \times 10^{-6}}{0.026} = 5 \times 10^{-3} \text{ T} = 5\text{mT}
 \end{aligned}$$

Figure 14 - Shows my workings for Task 3 (2a)

- 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.

$$B = 1.9\text{T}$$

$$\Phi = 611\text{mWb}$$

$$B = \frac{\Phi}{A} = A = \frac{\Phi}{B}$$

$$A = \pi r^2$$

$$A = \frac{611 \times 10^{-3}}{1.9} = 0.3216\text{m}^2$$

$$0.3216\text{m}^2 = \pi r^2$$

$$r^2 = \frac{0.3216}{\pi}$$

$$r = \frac{\sqrt{0.3216}}{\pi} = 0.32\text{m}$$

$$r = 320\text{mm}$$

$$\begin{aligned}
 B &= 1.9\text{T} \\
 \Phi &= 611\text{mWb} \\
 B &= \frac{\Phi}{A} = A = \frac{\Phi}{B} \\
 A &= \pi r^2 \\
 A &= \frac{611 \times 10^{-3}}{1.9} = 0.3216\text{m}^2 \\
 0.3216\text{m}^2 &= \pi r^2 \\
 r^2 &= \frac{0.3216}{\pi} \\
 r &= \frac{\sqrt{0.3216}}{\pi} = 0.32\text{m} \\
 r &= 320\text{mm}
 \end{aligned}$$

Figure 15 - Shows my workings for Task 3 (2b)

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

An electromagnet is made when a conductor carries a current which ultimately produces a magnetic field around the conductor. Electromagnets follow Faradays Law of *← This is for induction*
 Electromagnetic induction and this law is commonly broken down into two parts. These parts are that the value of emf induced in a circuit or conductor is directly proportional to the rate of change of the magnetic flux linking with it and that the polarity of such emf induced by an increasing flux is the opposite to that induced by a decreasing flux. This means that if a magnet is to be moved back and forth through a coil of wire an emf will be induced in the coil causing current to flow. The magnitude of the induced emf is directly proportional to the value of the magnetic flux so the rate at which this flux links with the coil and the number of turns on the coil. *No*

The magnetic field of an electromagnet has the form of concentric circles along the entire length of the conductor and the direction of the magnetic field is dependant on the direction of the current. So clockwise if the current is flowing away from the person looking at the conductor or anticlockwise if the current is flowing towards the person looking down the conductor. The direction of the magnetic field can be seen below. ✓

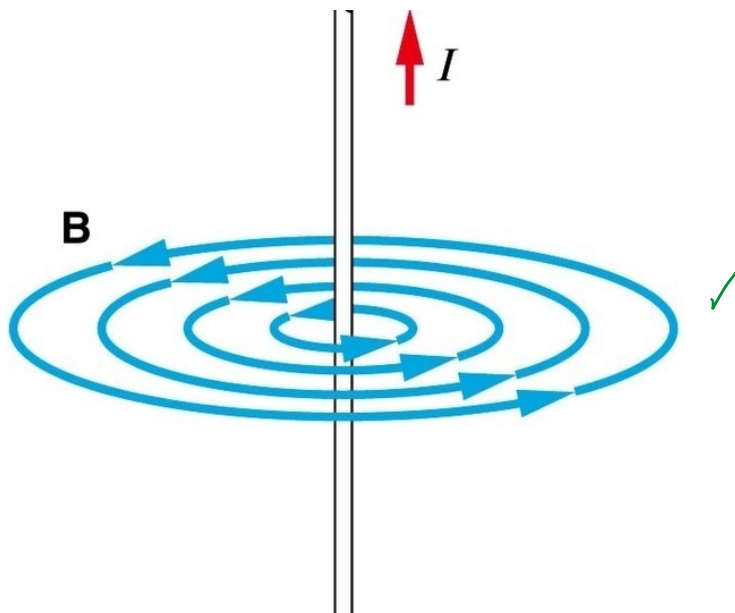


Figure 16 - Shows the magnetic field direction

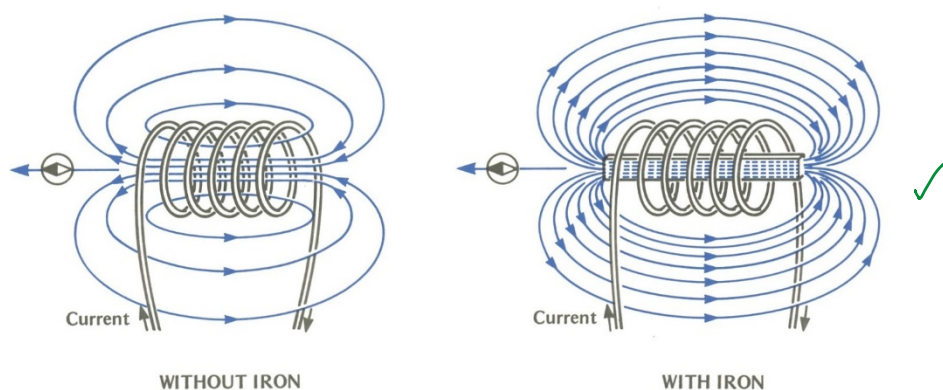


Figure 17 - Shows and electromagnet field with and without an iron conductor

2. A transformer is a device that uses some of the principles associated with electromagnetism. Explain the operation and construction of transformer, include methods to reduce power loss within the transformer.

A transformer is an electrical device that contains two coils, these are the primary windings and the secondary windings, and they sit on the same steel/Iron core. Transformers will only work with an alternating current (AC) voltage. When an AC voltage is applied to the primary windings, this sets up an alternating magnetic flux throughout the steel/Iron core. This magnetic flux then induces an emf into the second winding. Both of these windings are linked by the same magnetic flux which means that the emf in both windings are proportional to the number of turns, so $\frac{V_p}{N_p} = \frac{V_s}{N_s}$. Transformers will always have eddy current losses which cannot be completely eliminated but can be reduced greatly. One way in which these losses can be reduced is by reducing the thickness of the steel/Iron core. To do this the magnetic core material is split up into many thin pressed steel shapes also known as laminations. By splitting the core metal into thin steel laminations eddy current is reduced as well as heat loss. To reduce heat loss even further most transformers are filled with transformer oil which cools and reduces the temperature of the transformers again. The diagram for a transformer can be seen in figure 18. ✓

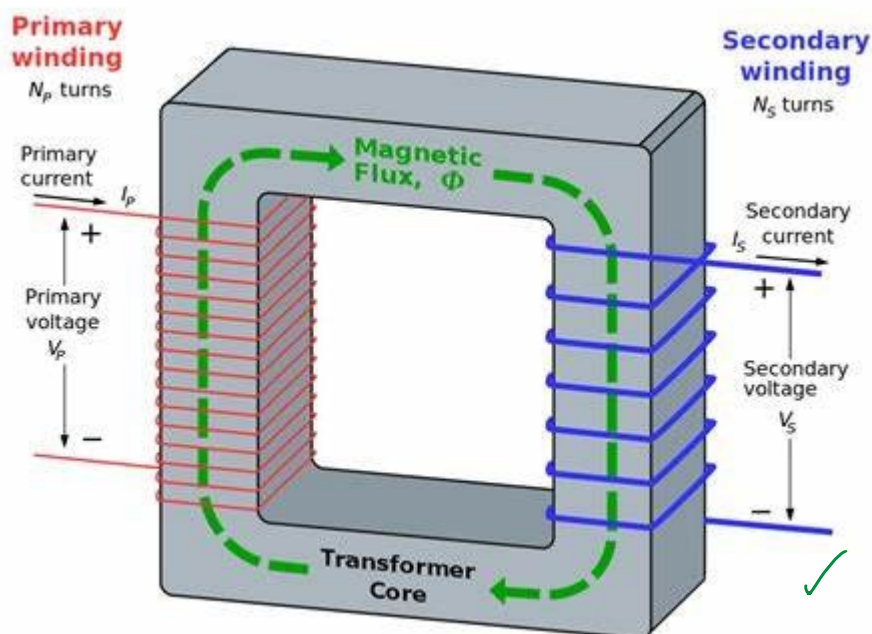


Figure 18 - Shows the principle of a Transformer

3. Solve the following problems:

- a) A 700 turn coil of inductance 2.5H carries a current of 1.6A. Calculate the flux linking the coil and the e.m.f. induced in the coil when the current collapses to zero in 20ms.
- 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 e.m.f. (ii) If the coil generates 80V, at what speed will the coil rotate?

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

$$N = 700 \text{ turns}$$

$$I = 1.6\text{A}$$

$$L = 2.5\text{H}$$

$$Dt = 20\text{ms}$$

Coil inductance =

$$L = \frac{N\Phi}{I} \checkmark$$

$$\Phi = \frac{L \times I}{N} = \frac{2.5 \times 1.6}{700} = 5.714 \times 10^{-3} \text{Wb} = 5.7\text{mWb} \checkmark$$

$$e = \frac{Nd\Phi}{dt} = \frac{-700 \times 5.714 \times 10^{-3}}{20 \times 10^{-3}} = -199.99\text{V} = -200\text{V} \checkmark$$

Handwritten calculations for Task 3(a):

$$N = 700 \text{ turns} \quad I = 1.6\text{A}$$

$$L = 2.5\text{H} \quad dt = 20\text{ms}$$

Coil inductance $L = \frac{N\Phi}{I}$

$$\Phi = \frac{L \times I}{N} = \frac{2.5 \times 1.6}{700} = 5.714 \times 10^{-3} \text{Wb} = 5.7\text{mWb}$$

$$e = \frac{Nd\Phi}{dt} = \frac{-700 \times 5.714 \times 10^{-3}}{20 \times 10^{-3}}$$

$$e = -199.99\text{V} = -200\text{V}$$

Figure 19 - Shows my workings for Task 3, 3(a)

- 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 e.m.f. (ii) If the coil generates 80V, at what speed will the coil rotate?

Generated emf =
 $E = 2 \times NBL \sin \theta$

$N = 70$ turns

$B = 1.2\text{T}$

$L = 10\text{cm} = 0.1\text{m}$

$v(\text{rpm}) = 1200 \text{ rev/min}$

$$v(\text{m/s}) = \omega r = \left(\frac{1200 \times 2\pi}{60} \right) \times \left(\frac{0.06}{2} \right) = 3.77 \text{ m/s}$$

(i) Maximum emf = $\theta = 90^\circ$

$$E = 2 \times 70 \times 1.2 \times 0.1 \times 3.77 \times \sin 90^\circ = 63.336 \text{ V}$$

(ii) $E = 80 \text{ V}$
 $\sin 90^\circ = 1$

$$v(\text{m/s}) = \frac{E}{2NBL} = \frac{80}{2 \times 70 \times 1.2 \times 0.1} = 4.761 \text{ m/s}$$

$$v(\text{rpm}) = \frac{v(\text{m/s}) \times 60}{2\pi} \times \frac{2}{0.06} = \frac{4.761 \times 60 \times 2}{2\pi \times 0.06} = 1515.47 \text{ rev/min}$$

Well done.

Generated emf = $E = 2 \times NBLv \sin \theta$

$N = 70$ turns $L = 10 \text{ cm} = 0.1 \text{ m}$
 $B = 1.2 \text{ T}$ $v = 1200 \text{ rev/min}$

$v = \omega r = \left(\frac{1200 \times 2\pi}{60} \right) \times \left(\frac{0.06}{2} \right)$

$v = 3.77 \text{ m/s}$

Maximum emf = $\theta = 90^\circ$

(i) $E = 2 \times 70 \times 1.2 \times 0.1 \times 3.77 \times \sin 90^\circ$
 $E = 63.336 \text{ V}$

(ii) $E = 80 \text{ V}$ $\sin 90^\circ = 1$

$v = \frac{E}{2NBL} = \frac{80}{2 \times 70 \times 1.2 \times 0.1}$

$v = 4.761 \text{ m/s}$

$v(\text{rpm}) = \frac{v \times 60}{2\pi} \times \frac{2}{0.06}$

$= \frac{4.761 \times 60 \times 2}{2\pi \times 0.06}$

$= 1515.47 \text{ rev/min}$

Figure 20 - Shows my workings for Task 3, 3(b)

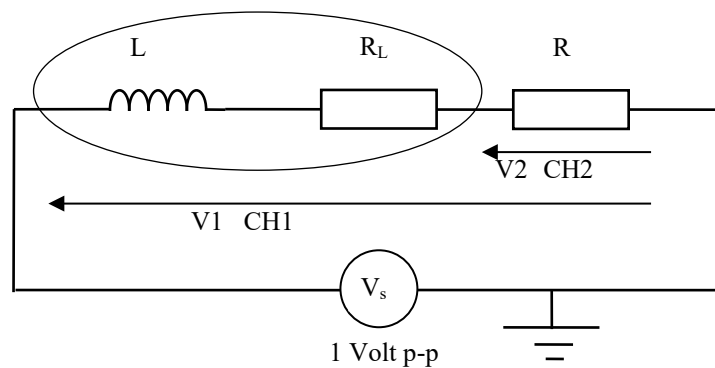
Task 4 – AC Circuits

1. Using the oscilloscope measurements for a sine wave stated in table 3 perform the following calculations
 - a) Peak voltage
 - b) Frequency
 - c) Average voltage
 - d) Root mean square (rms) voltage.

Table 3 – values for Task 4

Student Number	Oscilloscope Settings		Grid Spacing	
	Volts/Div	Timebase (ms/Div)	Vertical (peak to peak)	Horizontal (1 cycle)
1	5	20	6.8	4
2	2	20	7.2	4.4
3	2	10	7.8	4.4
4	5	10	5.4	4.6
5	5	5	4.8	4.8
6	2	5	6.6	4
7	2	20	5.2	5.2

2. Below is a RL circuit:



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

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

$$L = \dots\dots\dots R = \dots\dots\dots R_L = \dots\dots\dots$$

4. Produce a table of measurements as shown below:

Frequency (f) (kHz)	CH1 (V) pk to pk Voltage	CH2 (V) pk to pk Voltage	Time Difference (between peaks) (T2-T1)	Calculated values		
				Time for 1 cycle (T) =1/f	Fraction of cycle (T2-T1)/T	Phase Angle (°) (fraction x 360)
1						
2						
3						

4						
5						
6						
7						
8						
9						

5. Produce a table of calculations as shown below:

Frequency (f - kHz)	$X_L (\Omega)$ ($2\pi fL$)	R_T ($R + R_L$)	$Z (\Omega)$	Current (A)	Phase Angle ($^\circ$)
1					
2					
3					
4					
5					
6					
7					
8					
9					

Show clearly **one full example of your method** for calculating for $X_L (\Omega)$, $Z (\Omega)$, Current (A) and Phase Angle ($^\circ$) for a chosen frequency.

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

Task 4

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

a) Peak voltage

$$V_p = \frac{2 \times 7.8}{2} = \frac{39}{5} = 7.8V$$

b) Frequency

$$F = \frac{1}{T} = \frac{1}{44 \times 10^{-3}} = 22.73Hz$$

c) Average voltage

$$V_{av} = 0.637 \times V_p \checkmark$$

$$V_{av} = 0.637 \times 7.8 = 4.969V \checkmark$$

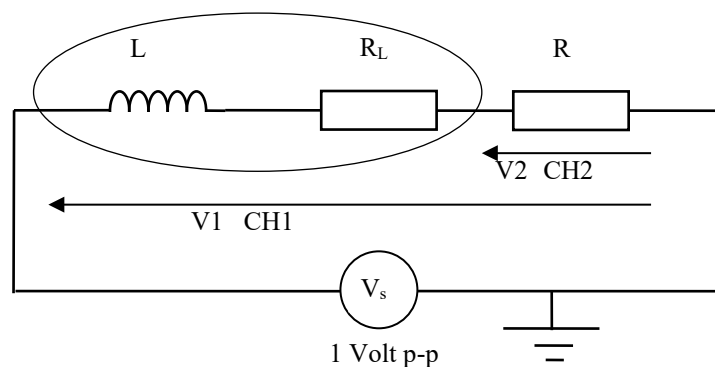
d) Root mean square (rms) voltage.

$$V_{rms} = \frac{V_p}{\sqrt{2}} = \frac{7.8}{\sqrt{2}} = 5.515V \checkmark$$

Table 3 – values for Task 4

Student Number	Oscilloscope Settings		Grid Spacing	
	Volts/Div	Timebase (ms/Div)	Vertical (peak to peak)	Horizontal (1 cycle)
1	5	20	6.8	4
2	2	20	7.2	4.4
3	2	10	7.8	4.4
4	5	10	5.4	4.6
5	5	5	4.8	4.8
6	2	5	6.6	4
7	2	20	5.2	5.2

2. Below is a RL circuit:



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

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

$$L = 0.985mH \quad R = 17.89\Omega \quad R_L = 2.38\Omega \checkmark$$

4. Produce a table of measurements as shown below:

Frequency (kHz)	CH1 (V) pk to pk Voltage (V)	CH2 (V) pk to pk Voltage (V)	Time Difference (between peaks) (μ S)	<i>Calculated values</i>		
				Time for 1 cycle (T) $1/f$	Fraction of cycle ($T_2 - T_1$)/ T	Phase Angle ($^\circ$) (fraction $\times 360$)
1	1	0.69	38.5	1.0	0.03851981	13.8671
2	1	0.80	37.9	0.5	0.07586497	27.3114
3	1	0.84	34.2	0.3	0.10268159	36.9654
4	1	0.89	31.6	0.3	0.12657687	45.5677
5	1	0.92	28.7	0.2	0.14351183	51.6643
6	1	0.96	27.3	0.2	0.16402164	59.0478
7	1	0.95	24.3	0.1	0.16984994	61.146
8	1	0.97	22.8	0.1	0.18272791	65.782
9	1	0.97 ✓	20.3 ✓	0.1 ✓	0.1826893 ✓	65.7681 ✓

5. Produce a table of calculations as shown below:

Frequency (f - kHz)	$X_L (\Omega)$ ($2\pi fL$)	R_T ($R + R_L$)	$Z (\Omega)$	Current (A)	Phase Angle ($^\circ$)
1	6.19	20.27	21.19	0.047	16.98
2	12.38	20.27	23.75	0.042	31.41
3	18.57	20.27	27.49	0.036	42.49
4	24.76	20.27	32.00	0.031	50.69
5	30.94	20.27	36.99	0.027	56.77
6	37.13	20.27	42.31	0.024	61.37
7	43.32	20.27	47.83	0.021	64.93
8	49.51	20.27	53.50	0.019	67.74
9	55.70 ✓	20.27 ✓	59.27 ✓	0.017 ✓	70.00 ✓

Show clearly **one full example of your method** for calculating for $X_L (\Omega)$, $Z (\Omega)$, Current (A) and Phase Angle ($^\circ$) for a chosen frequency.

$$L = 0.985\text{mH} \quad R = 17.89\Omega \quad R_L = 2.38\Omega \quad \checkmark$$

$$\text{Reactance } (X_L) = 2\pi fL = 2 \times \pi \times 5 \times 10^3 \times 0.985 \times 10^{-3} = 30.94\Omega \quad \checkmark$$

$$\text{Total Resistance } (R_T) = R + R_L = 17.89 + 2.38 = 20.27\Omega \quad \checkmark$$

$$\text{Impedance (Z)} = \sqrt{R_T^2 + X_L^2} = \sqrt{20.27^2 + 30.94^2} = 36.99\Omega \quad \checkmark$$

$$\text{Current (I)} = \frac{V}{Z} = \frac{1}{36.99} = 0.027\text{A} \quad \checkmark$$

$$\text{Phase Angle (}\phi\text{)} = \tan^{-1} \frac{X_L}{R_T} = \tan^{-1} \frac{30.94}{20.27} = 56.77^\circ \quad \checkmark$$

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

Human error may affect the results, as sometimes the exact number from the oscilloscope has not been taken. Variations in the results may also occur because some of the results are rounded up to the nearest decimal point which will decrease the accuracy again. Not only that but because an oscilloscope and function generator are not designed to be 100% accurate by the manufacture there will always be a slight discrepancy. When the equipment has been used for a long period of time it will start to generate heat which can cause the equipment to lose accuracy and cause other bits of circuitry to become less accurate. Also, when a resistor starts to heat up, its value of resistance will change and vary from its stated value. From the results it can be seen that as the reactance increases it is proportional to the frequency which means that for every 1kHz the frequency increases the reactance increases by around 6Ω. ✓

There are other factors that could also be considered.

Well done Tom, you have produced a good assignment that covered all of the tasks.

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