



LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Libby Sheldon	Student ID number:	
Programme:	HNC Electrical/Electronic Engineering, Power Systems Engineering & Instrumentation Engineering		
Module:	Electrical Principles		
Module code:	PCEE4001	Contribution to Overall Module Assessment (%):	100%
Lecturer:	Jason Pointer	Internal Verifier:	Steve Roberts
Assignment Title:	Electrical Principles	Word count (or equivalent):	2000
Submission deadline:	16/01/19	Return date of provisional marks & written feedback:	
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	9.3
Selection of relevant and credible sources, used a variety of books and websites. Generally sound referencing, with no inaccuracies or inconsistencies.		
2. Knowledge and Understanding Skills	25	12.75
Task 1 achieved 42%. Task 2 achieved 50%. Task 3 achieved 62%. Task 4 achieved 50%. Knowledge of the basic underlying concepts and principles is accurate with a good understanding in most areas. There were errors in some the calculation work and did not include your calculations for Task 1.		
3. Cognitive and Intellectual Skills	15	6.6
Task 1 achieved 48%. Task 4 achieved 40%. Limited attempt at evaluation of the underlying concepts and principles, tending towards description.		
4. Practical Application Skills	35	20
Task 1 achieved 65%. Task 4 achieved 50%. A good 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	5
Mostly coherent, organised and accurate work, in a suitable structure and is for the most part clearly expressed. Try to produce all of the work on computer.		

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)

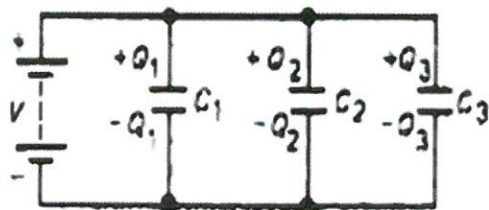
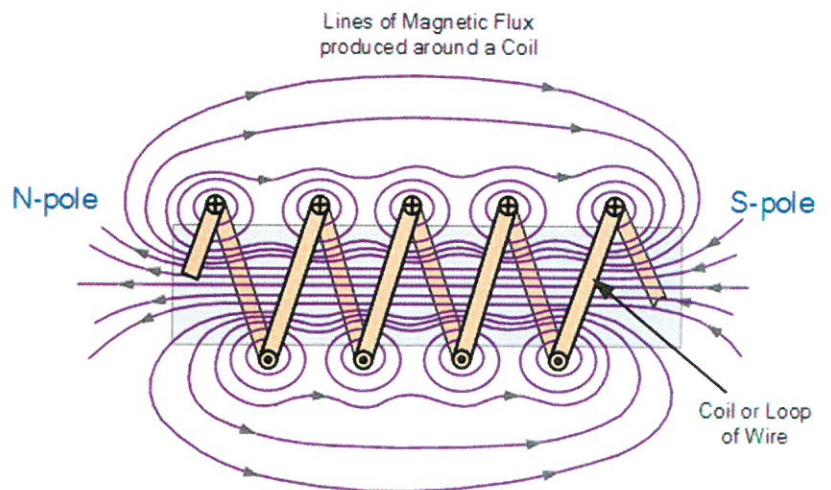
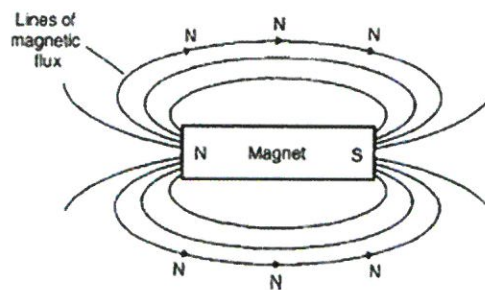
Up to 1 week late (40% Max)

Over 1 week late (0%)

54%

HNC Instrumentation Engineering

Electrical Principles



Lecturer Name: Jason Pointer

Learner Name: Libby Sheldon

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Task 1 – DC circuits

Should have stated the task requirements.

Series Circuit

Total resistance = 1.20k

$$270 + 390 + 560 = 1120 \, \Omega \quad \checkmark$$

Voltage

$$R1 = 2.21 \, \text{V} \quad \checkmark$$

$$R2 = 3.17 \, \text{V} \quad \checkmark \quad \text{Must include all units}$$

$$R3 = 4.55 \, \text{V} \quad \checkmark$$

When comparing these results variations can be made, this can be due to human error. Human error is a failure of a planned action to achieve a desired outcome.

Kirchoff developed a set of laws which are used when dealing with a closed circuit. A relative theory for the above results is Kirchhoff's second law (voltage law). The voltage law states that "in any closed network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop", for example this means it is equal to zero. $\checkmark$

$$\text{Current} = 8.15 \, \text{mA} \quad \checkmark$$

- Parallel

$$\text{Total resistance} = 1.21 \, \text{k}\Omega \quad \checkmark$$

$$\text{Supply current} = 8.09 \, \text{mA} \quad \checkmark$$

You have not included calculated results.

$$R1 = 1.08 \, \text{mA} \quad \checkmark$$

$$R2 = 4.55 \, \text{mA} \quad \checkmark \quad \text{Units}$$

$$R3 = 2.56 \, \text{mA} \quad \checkmark$$

One thing to consider when working with resistors is that they have a +/- 5% accuracy rate, this will fluctuate the practical calculations made. Kirchhoff's First Law states that "total current or charge entering a junction or node is exactly equal to the charge leaving the node as it has no other place to go except to leave, as no charge is lost within the node". $\checkmark$

Your comments are limited and should relate more to the results.

Task 2 – Capacitors

1) A capacitor stores electric energy when connected to a charging circuit.

Generally used to maintain a power supply. A capacitor has two terminals, one terminal store negative energy, one terminal store positive energy, these terminals are separated by an insulator. A capacitor also comprises of two metal plates facing each other, As Robertson (2008, p.84) identifies 'A capacitor is an electrical component that is designed to have a specified value of capacitance. In its simplest form it consists of two parallel plates separated by a dielectric.' What Robertson suggests by a dielectric is it has the property of transmitting an electrical force without conduction. An example of a dielectric material is plastic.

When a DC voltage is applied to the two electrodes, they will immediately collect on one side, this causes that electrode (the side collected on) to have a negative charge, To Quote from

https://www.global.tdk.com/techmag/electronics_primer/vol1.htm (14/01/18) 'while electrons on the other electrode will be lacking, this means that it has a positive charge. This condition will remain also when the DC voltage is removed.'

A capacitor can be connected in parallel, this means that the voltage from the voltage source remains the same across all capacitors. In his work in Electrical and electronic principles Knight, A (2014, p.38) confirms that 'When capacitors are wired in parallel, the full circuit voltage V is present across each capacitor, but this time the charges on each capacitor will depend upon the individual capacitance.' Figure one below shows three capacitors connected in parallel, retrieved from Knight, A (2014, p.38). Figure one shows the capacitors which store a charge represented as

Q_1, Q_2 and Q_3 The total charge is shown as $Q_T = (I \times t)$ therefore $Q_T = Q_1 + Q_2 + Q_3$

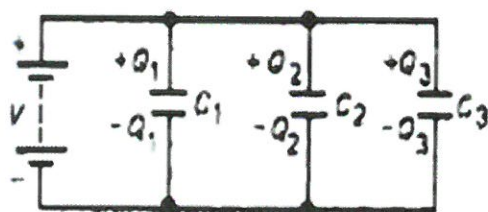


Figure one

Capacitors can also be connected in series. When connected in series, the voltage from voltage source is divided into V_1 and V_2 across the capacitor, this means that the overall charge is the charge of the entire capacitance, therefore the total capacitance is a lesser amount than the individual capacitance of one capacitor in the series. Figure two below shows a capacitor connected in series. Image retrieved from Bird, J (2007, p.84). figure two illustrates individual capacitors shown as $C_1 + C_2 + C_3$ the p.d across the individual capacitors is shown as $V_1 + V_2 + V_3$ the charge in each capacitor is equal to the total charge which is shown as $\frac{Q}{C} t$ ✓

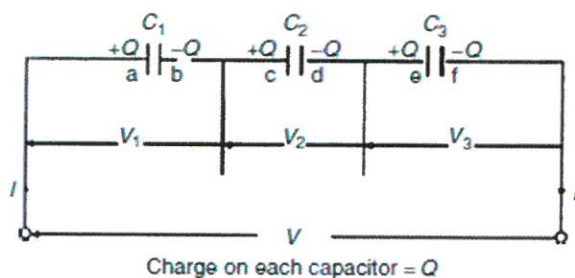


Figure two

There are various types of capacitors that are used in electronic circuits and equipment. As Bird points out (2007, p.57) 'every system of electrical conductors possesses capacitance. For example, there is capacitance between the conductors of overhead transmission lines and also between the wires of a telephone cable.' Expanding Birds point capacitors are used practically in everyday life, different types of capacitors and their applications are characterised by the material used for their dielectric. ✓

One type is a dielectric capacitor, a Dielectric capacitor has a set of fixed plates and a set of movable plates. A dielectric capacitor also has a continuous variation of capacitance which is required for tuning transmitters and receivers. The moving plates determine the overall capacitor value, the capacitance value can go up to 100 000 μ F. Figure three below shows a double ended and single ended dielectric capacitor. Retrieved from Bird, J (2007, p.105). ✓

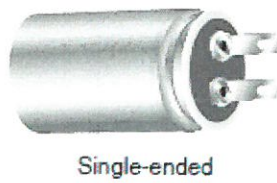


Figure three

Another type of capacitor is a Ceramic capacitor. A ceramic capacitor uses ceramic dielectric, these capacitors unlike other do not give as high a level of capacitance per unit volume. Ceramic capacitors have a high dielectric constant. The value of a ceramic capacitor is 10nF. Ceramic capacitance is 2pF-100nF with the tolerance of $\pm 10\%$

Electrolytic capacitors are used commonly in DC circuits, this is due to having the highest levels of capacitance for a given volume, and a small size used to help reduce the ripple voltage. Electrolytic capacitors are polarised. The construction of these capacitors is two aluminium foils, one of these layers is an oxide layer used as an insulator. Electrolytic has a value of $4.7\mu\text{F}$ and a maximum voltage of 25 volts. The capacitance of an Electrolytic capacitor is 0.1-150 μF with the tolerance of -20 to +80%.

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

(student number 5)

$$C_1 = 22 \mu F$$

$$C_2 = 22 \mu F$$

$$C_3 = 43 \mu F$$

$$V_S = 30 V$$

Again units

a) the equivalent circuit capacitance

$$C_{23} = C_2 + C_3 = 22 + 43 = 65 \mu F$$

$$C_T = \frac{C_1 \times C_{23}}{C_1 + C_{23}} = \frac{22 \times 65}{22 + 65} = \frac{1430}{87} \mu F = 16.43 \mu F$$

b) The total charge

$$Q_T = C_T \times V = 16.43 \times 30 = 492.9 \mu C$$

c) The charge in each capacitor

Charge for C_1 equals Q_T (in series)

$$Q_1 = Q_T = 492.9 \mu C$$

$$\text{So } V_1 = \frac{Q_1}{C_1} = \frac{492.9}{22} = 22.4 V$$

$$\text{and } V_2 = V - V_1 = 30 - \underline{20.4} = 9.6 \text{ V} \quad \text{= } 7.6 \text{ V}$$

$$\text{So } Q_2 = C_2 \times V_2 = 22 \times \underline{9.6} = 211.2 \mu\text{C} \\ = 166.9 \mu\text{F}$$

$$Q_3 = C_3 \times V_2 = 43 \times \underline{9.6} = 412.8 \mu\text{C} \\ = 326.21 \mu\text{F}$$

D) energy stored in each capacitor

$$W_1 = \frac{1}{2} C_1 \times V_1^2 = \frac{1}{2} \times 22 \times \underline{20.4}^2 = 4577.76 \mu\text{J}$$

$$W_2 = \frac{1}{2} C_2 \times V_2^2 = \frac{1}{2} \times 22 \times \underline{9.6}^2 = 1013.76 \mu\text{J}$$

$$W_3 = \frac{1}{2} C_3 \times V_3^2 = \frac{1}{2} \times 43 \times \underline{412.8}^2 = 3663682.56 \mu\text{J} \quad \text{x}$$

e) total energy

$$W_T = W_1 + W_2 + W_3 \quad \checkmark$$

$$= 4577.76 + 1013.76 + 3663682.56$$

$$= 3669274.08 \mu\text{J} \quad \text{x}$$

For some of the calculation work you have shown correct method but obtained the wrong value for V_1 .

Task 3 Magnetism

1) A permanent magnet is a magnet that when in the absence of a current or inducing field keeps its magnetic properties, in other words a permanent magnet generates its own persistent magnetic field. A permanent magnet is material such as iron or nickel, this is known as ferromagnetic material. As Robertson, C (2008, p.111) further explains 'Ferromagnetic materials, all of which exhibit very strong magnetic effects.' Exhibiting a strong magnetic field is one of the advantages of a permanent magnet. Permanent magnets also have the ability to provide strong magnetic field over an extensive region for a long time with no persistent energy.

In his work in electrical and electronic principles John Bird explains 'The distribution of a magnet field can be investigated by using some iron filings. A bar magnet is placed on a flat surface covered by, say cardboard, upon which is sprinkled some iron filings. If a number of magnets of different strengths are used, it is found that the stronger the field the closer are the lines of magnetic flux and vice versa. Thus, a magnetic field has the property of exerting a force, the strength of the magnetic field decreases as we move away from the magnet.' (2007, p.72). Following on from this statement lines of magnetic flux do not have physical existence they were created imaginary by Michael Faraday to allow visualisation of the magnetic field's distribution. Figure Three below shows the distribution of a magnetic field investigated by using some iron filings. Retrieved from Bird, J (2007, p.72). 'Electrical and Electronic principles and technology'

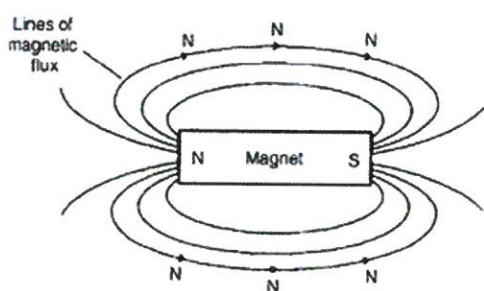


Figure four

Figure four also shows the space that surrounds the magnet and the lines that radiate from north to south pole, these lines don't cross. The line of flux which appears from the N-pole area of the magnet passes back the surrounding space to the S-pole.

2. Solve the following equations

A) flux $\Phi = 120 \mu\text{wb} = 120 \times 10^{-6} \text{wb}$ ✓

Cross sectional area $A = 250 \times 120 = 30000 \text{ mm}^2$ ✓

flux density, $B = \frac{\Phi}{A} = \frac{120 \times 10^{-6}}{30000 \times 10^{-6}} = 4 \text{ mT}$ ✓

B) flux density $B = 1.5 \text{ T}$ and flux $\Phi = 340 \text{ mWb}$
 $= 340 \times 10^{-3} \text{ Wb}$ ✓

since $B = \Phi/A$, cross sectional area $A = \Phi/B$ ✓

i.e. $A = \frac{340 \times 10^{-3}}{1.5} \text{ m}^2 = 0.226 \text{ m}^2$ ✓

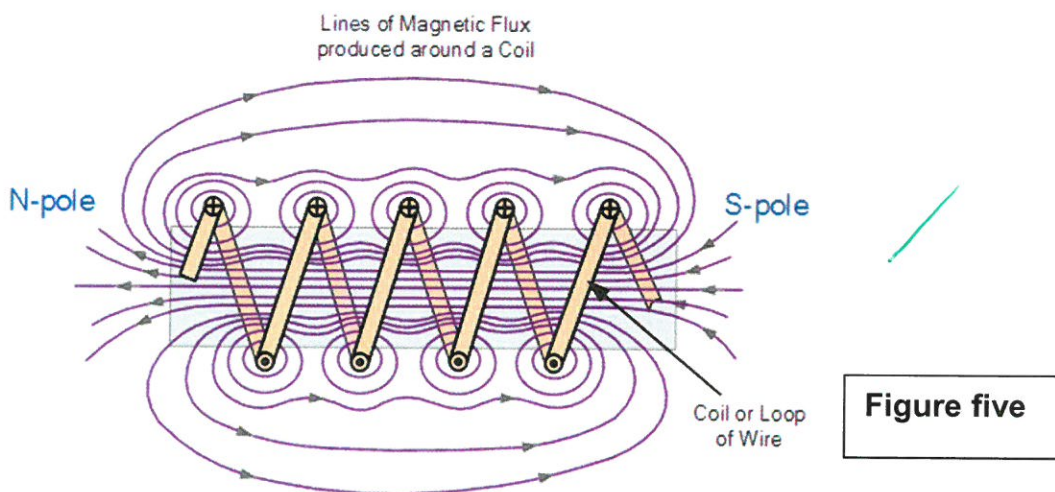
hence $\pi r^2 = 0.226$ ✓

$r = \sqrt{0.226/\pi} = 0.226 \text{ m}$ ✓

the radius of the pole face is 226 m.

3) An electromagnet is a magnetic field which is created by an electric current, in other words runs off electricity, these magnets simply consist of a wire wound into a coil (copper) wrapped around a magnetically soft material such as an iron core. The iron core or whichever magnetically soft material used becomes magnetised when a current is induced through the wire. As Bird, J (2008) points out 'The magnetic flux produced has the same properties as the flux produced by a permanent magnet', the strength of an electromagnet can be changed by the amount of electric current flowing through it, this is the same for a permanent magnet. Figure five below shows an electromagnet including the lines of magnetic flux produced around the coil.

Image retrieved from <https://www.electronicstutorials.ws/electromagnetism/electromagnets.html> (04/01/19)



When a conductor such as Iron carries a current, it produces a magnetic field. The direction of the magnetic field is dependant of the current direction, in other words is perpendicular to the wire. If the direction of the current is reversed, this means the lines of flux direction is also reversed. Magnetic flux extends the entire length of a conductor. Flux means the action of flow. The flux pattern extends outwards with concentric circles.

The screw rule is a way of determining the direction of a magnetic field. If a right-handed screw is along the axis of a solenoid and is rotated in the direction of the current it will move in the direction of the magnetic field inside the solenoid. A solenoid is an electromagnet that's purpose is to maintain a controlled magnetic field.

Flemings left hand rule also known as the motor rule can determine the direction of a force exerted by a conductor. in his work in electromagnetism John bird states 'Let the thumb, first finger and second finger of the left hand be extended such that they are all right angles to each other, if the first finger points in the direction of the magnetic field, the second finger points in the direction of the current, then the thumb will point in the direction of the motion of the conductor.' Summarizing this statement...

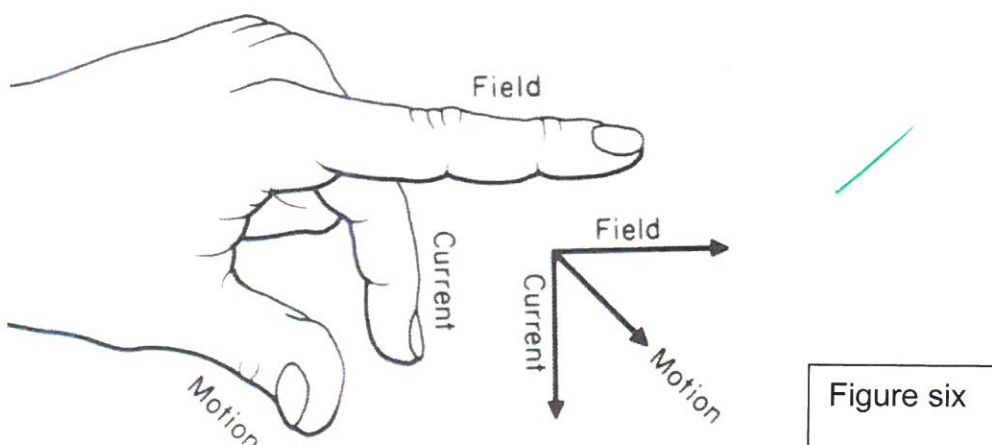
First finger – Field

SeCond finger – Current

ThuMb – Motion

Figure six below shows the motor rule. Image retrieved from

<https://physicsmax.com/flemings-left-hand-rule-motor-rule-7873> (02/01/19)



If a conductor is moved across a magnetic field, cutting through the lines of flux the emf is produced in the conductor. if said conductor forms part of a closed circuit then the emf will cause the current to flow round the circuit, this is 'electromagnetic induction'. Faradays law of electromagnetic induction explains the electric circuit and magnetic field. Faradays law has two crucial parts which are...

- 1) The value of electromotive force (emf) induced in a circuit or conductor is directly proportional to the rate of change of magnetic flux linking with it.
- 2) The polarity is of such an emf, induced by an increasing flux, is opposite to that induced by a decreasing flux.

The following equations used to the magnitude of the induced emf and self-inductance are retrieved from Bird, J (2007, p.91), Electrical and Electronic principles and technology.

The magnetic flux value is proportional to the magnitude of the induced emf, this is shown the the following equation

$$e = \frac{-Nd\Phi}{dt}$$

The average value of the induced emf in a circuit dependable on the rate of change of flux, and the number of turns of coil. Hence is the average induced emf is shown as

$$E = - \frac{\Phi_2 - \Phi_1}{t} \times N$$

The minus symbol is used to indicate that the emf is a back emf and opposes the rate of change of current.

Self Inductance is the property of a coil in which a change in current and flux, produces an emf in that coil. The average induced emf in such a circuit is shown by...

$$E = \frac{-L(I_2 - I_1)}{t}$$

The unit of inductance is H henry and it is defined as a circuit is said to possess an inductance of 1 henry when an emf of 1 volt is induced in that circuit by a current changing at the rate of 1 ampere per second.

There are various everyday applications for electromagnetism. For example, electric door bells. One type of electric door bell is a single stroke bell circuit. The current passes through the coil when the bell is pressed. The iron armature is connected to the electromagnet, the electromagnet generates a magnetic field which is what powers the door bell sound. when the circuit is broken the coil is demagnetised and the spring steel strip pulls the armature back to original position.

Another application where electromagnetism is used is in a coil sound system. Speakers are used to convert electrical signals into sound waves. The inside of a speaker is fixed to an iron coil and it comprises a permanent magnet. When the speaker is connected an electric signal gets fed into the iron coil, this turns the iron coil into a temporary electromagnet. The Electricity flows through the cables which produces a force allowing the electromagnet to attract or repel the permanent magnet.



4. Solve the following problems.

a) calculate the magnitude of the force exerted on the conductor.

$$L = 320 \text{ mm} = 0.32 \text{ m}$$

$$I = 8 \text{ A}$$

$$R = 60 \text{ mm} = 0.06 \text{ m}$$

$$\Phi = 0.4 \text{ mWb}$$

$$F = BIL \quad \checkmark$$

$$A = \pi r^2 = \pi \times 0.06^2 = 0.0113 \text{ m}^2 \quad \checkmark$$

$$B = \frac{\Phi}{A} = \frac{0.4 \times 10^{-3}}{0.0113} = 0.353 \quad \checkmark$$

$$F = 0.353 \times 8 \times 0.32 \quad \checkmark$$

$$F = 0.9036 \text{ N} \quad \checkmark$$

B) determine the diameter of the pole face.

$$L = 400 \text{ mm} = 0.4 \text{ m}$$

$$I = 25 \text{ A}$$

$$\Phi = 1.27 \text{ mWb}$$

$$F = 80 \text{ N}$$

$$B = \frac{F}{IL} = \frac{80}{25 \times 0.4} = 8T \quad \checkmark$$

$$\text{and } B = \frac{F}{a} \Rightarrow a = \frac{F}{B} = \frac{1.27 \times 10^{-3}}{8} \quad \checkmark$$

$$= 1.5875 \times 10^{-4} \text{ m}^2 \quad \checkmark$$

$$A = \pi r^2 \Rightarrow r^2 = \frac{a}{\pi} \Rightarrow r = \sqrt{\frac{a}{\pi}} \quad \times$$

$$\textcircled{A} = \sqrt{1.5875 \times 10^{-4}} = 0.0125 \times 10^{-3} \text{ m} \quad \times \quad r = \sqrt{\frac{a}{\pi}}$$

$$B = \frac{F}{a} = \frac{1.271}{0.0125 \times 10^{-3}} = 101600 \text{ N} \quad ?$$

Started off correct but got lost at the end.

Task 4 - AC Circuits

1. using the oscilloscope measurements for a sine wave stated in table 3 perform the following calculations.
(Student number 5)

a) peak voltage

$$= \frac{1}{2} V_{p-p}$$

$$\frac{1}{2} \times 5 \times \underline{4.4 - 4.4} \text{ why?}$$

$$= 6.6 \text{ V } \times$$

b) $1/T = 1/5 = 0.2 \text{ ms}$

The ~~peak~~ frequency equals 0.2 ms

c) Average voltage

$$0.637 \times V_{p-p}$$

$$0.637 \times 5 \times \underline{4.4} = 14.014 \text{ V} = 2 \text{ V}$$

$\nwarrow$ this gives V_{p-p}

d) Root mean square (rms) voltage

$$V_p \sqrt{2} = \underline{5 \times 4.4} \sqrt{2} = 20\sqrt{2} = 28.28 \text{ V } \times$$

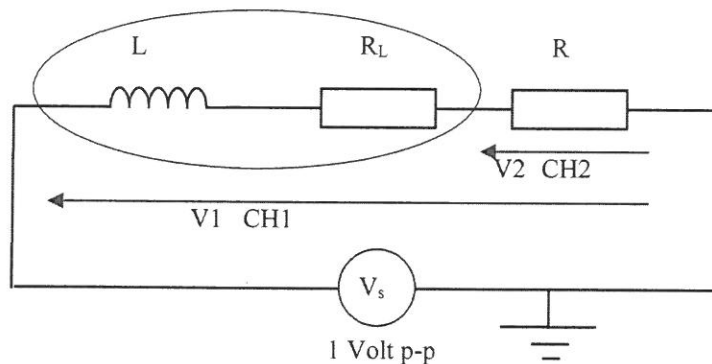
Task 4 – AC Circuits

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	4
2	2	20	7	4.4
3	2	10	7.6	4.4
4	5	10	5	4.6
5	5	5	4.4	4.8
6	2	5	6.8	4
7	2	20	5.4	5.2
8	0.5	20	6.4	5.2
9	0.5	10	5.2	5.4
10	0.5	10	7.4	5.6
11	0.5	5	6.6	5.8
12	5	5	5.6	6

2. Below is a RL circuit:



$L = 1\text{mH}$, $R = 10\Omega$, $R_L = ?\Omega$ (measure this value)

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

$L = 1\text{mH}$ / $R = 9.97\Omega$ / $R_L = 2.65\Omega$ /

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	228.00	168.00	72.05	0.001	0.072	25.92
2	284.00	160.00	64.05	0.0005	0.128	46.08
3	352.00	156.00	44.05	0.000333	0.132	47.52
4	420.00	148.00	36.05	0.00025	0.144	51.84
5	484.00	144.00	40.05	0.0002	0.2	72
6	840.00	140.00	30.05	0.000162	0.18	64.8
7	592.00	132.00	26.05	0.000143	0.182	65.52
8	640.00	124.00	24.05	0.000125	0.192	69.12
9	676.00	120.00	24.05	0.000111	0.216	77.76

5. Produce a table of calculations as shown below:

Frequency (f - kHz)	X _L (Ω) (2πfL)	R _T (R + R _L)	Z (Ω)	Current (A)	Phase Angle (°)	Check with b) above
1	6.28	12.57	14.05	0.0712	26.56	
2	12.57	12.57	17.77	0.0563	44.99	
3	18.85	12.57	22.66	0.0441	56.30	
4	25.13	12.57	28.10	0.0356	63.43	
5	31.42	12.57	33.84	0.0291	68.19	
6	37.70	12.57	39.74	0.0119	71.56	
7	43.98	12.57	45.74	0.0193	74.05	
8	50.27	12.57	51.81	0.0173	75.96	
9	56.55	12.57	57.93	0.0156	77.47	

Show clearly **one full example of your method** for calculating for X_L (Ω), Z (Ω), Current (A) and Phase Angle (°) for a chosen frequency (use the space below).

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

using frequency 5

$$X_L(\Omega) = 2\pi fL = 2\pi \times 5 \times 1 = 10\Omega = 31.41\Omega$$

$$R_T = 9.97\Omega + 2.6\Omega = 12.57\Omega$$

$$Z(\Omega) = \sqrt{R_T^2 + X_L^2} = \sqrt{12.57^2 + 31.41^2} = 394.82\Omega$$

$$\text{Current } A = \frac{V}{Z} = \frac{10}{394.82} = 0.025\text{A}$$

$$\text{Phase angle } (\theta) = \tan^{-1} \frac{X_L}{R_T} = \tan^{-1} \frac{31.41}{12.57} = 68.19^\circ$$

Task 4 – AC Circuits

6. There are slight variations with the phase angle shown between the tables in questions 4 and 5 for example frequency 1 on table 5 = 26.56° whereas on table 4 the frequency 1 = 25.92° . as the frequency increases the variation between the phase angles on table 4 and 5 also vary, for example when the frequency is 6, on table 4 the phase angle = 64.8° however on table 5 the phase angle = 68.19° .

Variations using the Oscilloscope can be caused by parallax error. Parallax error is caused by viewing an object at an oblique angle, this can cause people to view the object in a different position. Another reason for slight variations in these results is if the oscilloscope is not calibrated. If the device used isn't calibrated the precision and accuracy may be off causing errors in the result.

Reference Page

Books

- Bird, J (2007). Electrical and Electronic principles and technology, Third Edition. The Netherlands: Elsevier Ltd.
- Robertson, C (2008). Fundamental Electrical and Electronic Principles, Third Edition. Slovenia: Elsevier Ltd.
- Knight, A (2014). Electrical and Electronic Principles. Second Edition. England: British Library Cataloguing in publication data.

Website or webpage

- https://www.global.tdk.com/techmag/electronics_primer/vol1.htm (14/01/19)

Images

Figure one, three capacitors connected in parallel (Knight, A, 2014, p.38)

Figure two, capacitors connected in series (Bird, J, 2007, p.84).

Figure three, a double ended and single ended dielectric capacitor (Bird, J, 2007, p.105).

Figure four, distribution of a magnetic field. (Bird, J, 2007, p.72).

Figure five, <https://www.electronicstutorials.ws/electromagnetism/electromagnets.html> (04/01/19)

Figure six, <https://physicsmax.com/flemings-left-hand-rule-motor-rule-7873> (02/01/19)

Bibliography

Books

- Bird, J (2007). Electrical and Electronic principles and technology, 3rd Edition. The Netherlands: Elsevier Ltd.
- Robertson, C (2008). Fundamental Electrical and Electronic Principles, Third Edition. Slovenia: Elsevier Ltd.
- Knight, A (2014). Electrical and Electronic Principles. Second Edition. England: British Library Cataloguing in publication data.
- Furlani, E (2001). Permanent Magnet and electromechanical devices. New York: Elsevier Ltd.
- Hughes E, Hiley J, Brown K, Mackenzie-Smith I (2008). Hughes Electrical and Electronic Technology, 10th Edition. Pearson: London.
- Bird, J (2017). Electrical Circuit Theory and Technology, 6th Edition. Routledge.

Website or webpage

https://www.electronics-tutorials.ws/capacitor/cap_1.html. (14/01/19)

<https://opentextbc.ca/physicstestbook2/chapter/capacitors-in-series-and-parallel/>.
(14/01/19)