

## LEVEL 4 ASSESSMENT SPECIFICATION

|                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                      |                |
|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|----------------|
| Student name:                   | James Hammond                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 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:                                   | Nigel Richards |
| Assignment Title:               | Electrical Principles                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Word count (or equivalent):                          | 2000           |
| Submission deadline:            | 11/01/23                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Return date of provisional marks & written feedback: | 25/01/23       |
| 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              | 7.8           |
| Engagement with a good range of literature sources, including sources retrieved independently. Generally sound referencing, with very few inaccuracies.                                                                                                                                                          |                 |               |
| <b>2. Knowledge and Understanding Skills</b>                                                                                                                                                                                                                                                                     | 30              | 19.9          |
| Task 1 achieved 66%.<br>Task 2 achieved 70%,<br>Task 3 achieved 60%.<br>Task 4 achieved 70%.<br><br>Knowledge of the basic underlying concepts and principles is competent with a very good understanding in most areas. Excellent work with the calculations but need to make sure that all units are included. |                 |               |
| <b>3. Cognitive and Intellectual Skills</b>                                                                                                                                                                                                                                                                      | 10              | 5.3           |
| Task 1 achieved 58%.<br>Task 4 achieved 48%.<br><br>Good evaluation of the underlying concepts and principles for Task 1 and 4.                                                                                                                                                                                  |                 |               |
| <b>4. Practical Application Skills</b>                                                                                                                                                                                                                                                                           | 35              | 28.9          |
| Task 1 achieved 85%.<br>Task 4 achieved 80%.<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              | 6.5           |
| Work is accurate, coherent, fluent, well-structured and organised.                                                                                                                                                                                                                                               |                 |               |

**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%**



## Module: Electrical Principles

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Author: James Hammond

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## Task 1.

### DC Circuits.

A resistive DC circuit (Figure 1) was constructed, it consisted of resistors in both series and parallel.

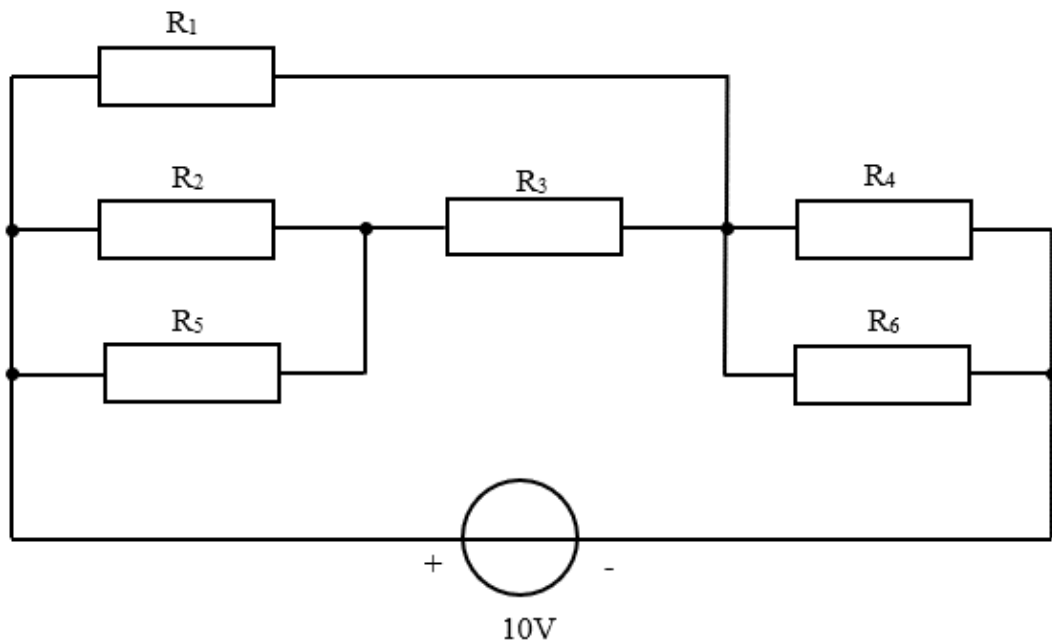


Figure 1 DC circuit with resistors in series/parallel.

The values for each resistor are displayed in Table 1. The circuit consists of resistors arranged in both parallel and series.

| R1            | R2           | R3           | R4           | R5           | R6           |
|---------------|--------------|--------------|--------------|--------------|--------------|
| 5.6k $\Omega$ | 330 $\Omega$ | 330 $\Omega$ | 470 $\Omega$ | 180 $\Omega$ | 680 $\Omega$ |

Table 1 Resistor values

Once the circuit was built and before a power supply was connected a Multimeter was connected to measure the total resistance ( $R_T$ ). The total resistance of the circuit was 688 $\Omega$ .

A 10V supply was then connected to the circuit and the pd value across each resistor, the supply current and the current in each resistor was measured. The potential difference and the current of each resistor are shown in table 2.

Table 2

| Resistor    | R1     | R2     | R3      | R4     | R5     | R6     |
|-------------|--------|--------|---------|--------|--------|--------|
| p.d (V)     | 5.98 ✓ | 1.55 ✓ | 4.39 ✓  | 4.01 ✓ | 1.55 ✓ | 4.01 ✓ |
| Current (A) | 1.07 ✓ | 4.70 ✓ | 13.44 ✓ | 8.53 ✓ | 8.64 ✓ | 5.93 ✓ |

The supply current ( $I_T$ ) was 14.47 amps ✓

### Calculations

The following totals were then calculated to support the results.

- Total resistance
- Supply current ( $I$ )
- Current in each resistor
- The p.d value across each resistor
- Power dissipated across each resistor

This was done using Figure 2 for reference.

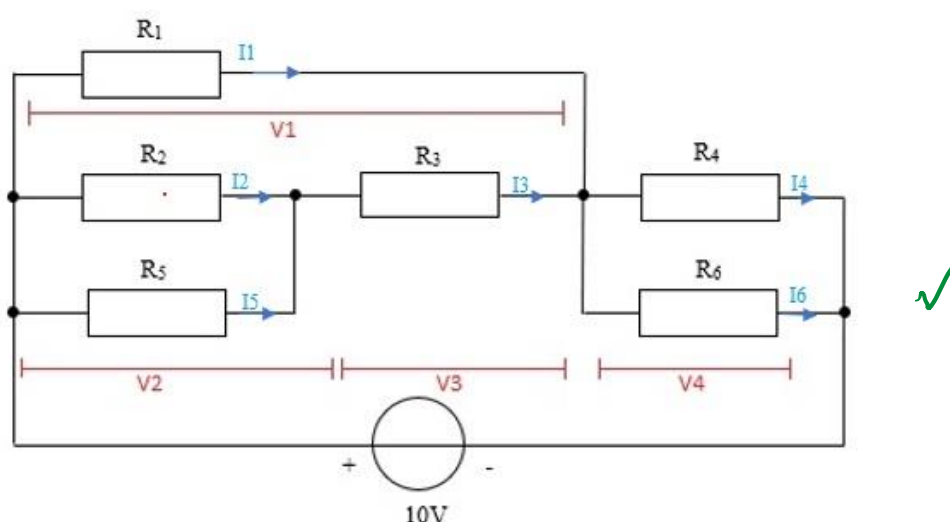


Figure 2

This was started by calculating the Total Resistance

$$R_{2/5} = \frac{R_2 \times R_5}{R_2 + R_5} = \frac{330 \times 180}{330 + 180} = 116.47\Omega$$

$$R_{2/3/5} = R_{2/5} + R_3 = 116.47 + 330 = 446.47\Omega$$

$$R_{1/2/3/5} = \frac{R_{2/3/5} \times R_1}{R_{2/3/5} + R_1} = \frac{446.47 \times 5600}{446.47 + 5600} = 413.50\Omega$$

$$R_{4/6} = \frac{R_4 \times R_6}{R_4 + R_6} = \frac{470 \times 680}{470 + 680} = 277.91\Omega$$

$$\text{Total Resistance} = R_{1/2/3/5} + R_{4/6} = 413.50 + 277.91 = 691.41\Omega$$

$$\text{Total resistance} = 691.41\Omega \quad \checkmark$$

Supply Current.

$$\text{Supply Current} = I = \frac{V}{R_T} = \frac{10}{691.41} = 0.01446 \text{ OR } \underline{14.46\text{mA}} \quad \checkmark$$

The following calculations are for the p.d across the resistors as indicated with **V**, and the current through each resistor indicated by **I**, on Figure 2.

$$V_4 = I \times R_4 = 14.46 \times 10^{-3} \times 277.91 = 4.02\text{V} \quad \checkmark$$

$$I_4 = \frac{V_4}{R_4} = \frac{4.02}{470} = 8.55\text{mA} \quad \checkmark$$

$$I_6 = \frac{V_4}{R_6} = \frac{4.02}{680} = 5.91\text{mA} \quad \checkmark$$

$$V_1 = \text{Supply Voltage} - V_4 = 10 - 4.02 = 5.98\text{V} \quad \checkmark$$

$$I_1 = \frac{V_1}{R_1} = \frac{5.98}{5600} = 1.07\text{mA} \quad \checkmark$$

$$I_3 = I - I_1 = 14.46 - 1.07 = 13.39\text{mA} \quad \checkmark$$

$$V_3 = I_3 \times R_3 = 13.39 \times 10^{-3} \times 330 = 4.42\text{V} \quad \checkmark$$

$$V_2 = V_1 - V_3 = 5.98 - 4.42 = 1.56\text{V} \quad \checkmark$$

$$I_2 = \frac{V_2}{R_2} = \frac{1.56}{330} = 4.73\text{mA} \quad \checkmark$$

*Very well done.*

$$I_5 = \frac{V_2}{R_5} = \frac{1.56}{180} = 8.67\text{mA} \quad \checkmark$$

$$V_5 = V_2 \quad \checkmark$$

$$V_6 = V_4 \quad \checkmark$$

The power dissipated through each resistor is calculated using the formula,

$$P = V \times I \quad \checkmark$$

$$P_1 = V_1 \times I_1 = 5.98 \times 1.07 = 6.40\text{W} \quad \checkmark$$

$$P_2 = V_2 \times I_2 = 1.56 \times 4.73 = 7.38\text{W} \quad \checkmark$$

$$P_3 = V_3 \times I_3 = 4.42 \times 13.39 = 59.18\text{W} \quad \checkmark$$

$$P_4 = V_4 \times I_4 = 4.02 \times 8.55 = 34.37\text{W} \quad \checkmark$$

$$P_5 = V_5 \times I_5 = 1.56 \times 8.67 = 13.53\text{W} \quad \checkmark$$

$$P_6 = V_6 \times I_6 = 4.02 \times 5.91 = 23.76\text{W} \quad \checkmark$$

*These should all be in mW.*

As you can see from Tables 3 and 4 the practical results vary ever so slightly to the calculations, but there are no anomalies. The small variations, could be due to several factors.

Tolerances in resistors. This is identified by the fourth band on the resistor. This is either Gold – 5%, Silver – 10%, or no colour band with a 20% tolerance. Edward Hughes, (2016) suggests “*This may seem an unexpected range of values, but it reflects the problems in manufacturing resistors with specific resistances.*” “*The variation of resistance values can be compensated with little detriment to circuit performance.*” ✓

Multimeter accuracy. The accuracy of the Multimeter could be questioned, the leads could be dirty, or damaged internally, the metre itself could require calibration. The internal resistance of a Multimeter is between 0.1 ohm and 10Mohm. The internal resistance of the meters will impact the voltage, current, and resistance of the circuit, this is called the loading effect. ✓

Human errors. The human factors such as places of contact when measuring, steadiness of the readings, and the rounding of decimal places when calculating the answers. ✓

Kirchhoff’s current law states, “the sum of the currents in the branches of a parallel network is equal to the supply current” (**Edward Hughes, 2018**). This verifies the data in Table 3, ✓

$$I_T = I_1 + I_2 + I_5$$

$$I_T = I_1 + I_3$$

$$I_T = I_4 + I_6$$
 ✓

Table 3

|              | $I_T$ (mA) | $I_1$ (mA) | $I_2$ (mA) | $I_3$ (mA) | $I_4$ (mA) | $I_5$ (mA) | $I_6$ (mA) |
|--------------|------------|------------|------------|------------|------------|------------|------------|
| Practical    | 14.47      | 1.07       | 4.70       | 13.44      | 8.53       | 8.64       | 5.93       |
| Calculations | 14.46      | 1.07       | 4.73       | 13.39      | 8.55       | 8.67       | 5.91       |

Using Figure 2, Table 4 and Kirchhoff’s voltage law which states that in a series circuit “the sum of the voltages across each of the components is equal to the applied voltage.” (**Edward Hughes, 2018**), it is possible to check that the readings are correct. ✓

$V_t$  is equal to  $V_1 + V_4$  or  $V_6$ .

$V_t$  is equal to  $V_2$  or  $V_5 + V_3 + V_4$  or  $V_6$  ✓

Table 4

|              | $V_T$ (V) | $V_1$ (V) | $V_2$ (V) | $V_3$ (V) | $V_4$ (V) | $V_5$ (V) | $V_6$ (V) |
|--------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Practical    | 9.96      | 5.95      | 1.55      | 4.39      | 4.01      | 1.55      | 4.01      |
| Calculations | 10        | 5.98      | 1.56      | 4.42      | 4.02      | 1.56      | 4.02      |

## Task 2.

### Capacitors.

A capacitor is made up of two or more electrical conductors or plates, separated by an insulator sometimes known as the dielectric. the plates either side of the insulator have terminals or connections coming off them to connect them to the circuit. ✓

The materials differ between capacitors depending on the properties required.

Paper - Capacitors with paper used as the dielectric are cheap, with a high durability. It is easily rolled and is covered with two aluminium sheets acting as the electrodes or plates. To protect the paper from external environment it is covered with wax or oil. In metalized paper capacitors the paper is coated with zinc or aluminium and rolled into a cylinder. The whole cylinder is then coated in a protective surface such as wax. Figure 3 shows the construction of the capacitor in (A) and the complete capacitor in (B). ✓

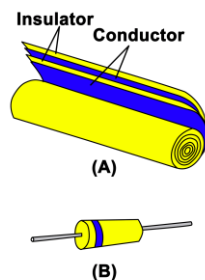


Figure 3 Paper capacitor.

Plastic Film Capacitors. A plastic such as polystyrene have taken the place of paper in general capacitors, this makes them denser than the paper and far more resistant to external environmental contaminants. The plastic film can withstand higher temperatures. ✓

Mica capacitors, or silver Mica capacitors. Mica is a group of natural silicate minerals with good characteristics for capacitors. They can be split into extremely thin elastic plates. Silver Mic capacitors replaced clamped mica capacitors, these were due to the air gaps contained, giving poor precision of the clamped capacitors. These were replaced with the Mica being covered with thin silver strips directly onto the Mica to obtain the desired capacitance. Once the desired capacitance has been achieved with layers then electrodes are added and the whole thing encapsulated. Figure 4 shows the construction of the Mica capacitor and the completed capacitor. ✓

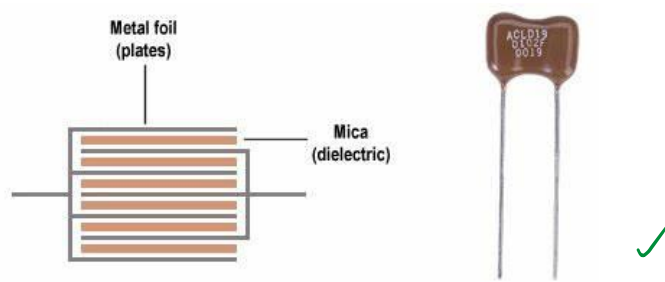


Figure 4 Mica capacitor.

Mica Capacitors are accurate and have low tolerances. The tolerances can be as low as  $\pm 1\%$ .

Ceramic Capacitors, these consist of a ceramic disc as the dielectric, with silver electrodes. Legs are connected either side of the electrodes to allow attachment. Dielectric materials such as barium and strontium titanates mixtures are used to improve the electric properties.

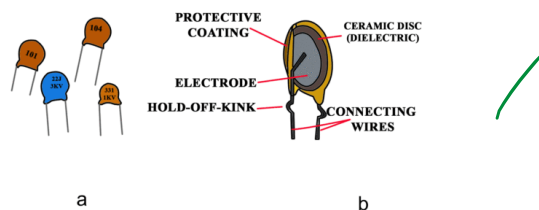


Figure 5 Ceramic disc capacitor and its construction.

There are multiple methods in which to alter the capacitance, they can be increased or decreased by,

- Multiple layers in construction produce greater capacitance.
- Larger plate size will also increase the capacitance.
- The wider the distance between the plates the lower the capacitance.
- The greater the permeability of the dielectric the higher the capacitance.

Figure 6 shows the dielectric constant figures (K) of some dielectric materials.

*Could include an equation how these factors relate.*

| Material                  | Dielectric Constant |
|---------------------------|---------------------|
| Vacuum                    | 1.0                 |
| Air                       | 1.0006              |
| Dry paper                 | 2.0—2.5             |
| Bakelite                  | 4.5—5.5             |
| Glass                     | 5.0—10.0            |
| Rubber                    | 2.0—3.5             |
| Mica                      | 3.0—7.0             |
| Porcelain                 | 6.0—7.0             |
| Mylar                     | 3.1                 |
| Polyethylene              | 2.25                |
| Polyvinyl chloride        | 3.2                 |
| Teflon(P.T.F.E.)          | 2.1                 |
| Germanium                 | 16.0                |
| Water                     | 80.4                |
| Titanium dioxide (rutile) | 173.0               |

Figure 6 Dielectric constant chart.



Figure 7 shows the circuit containing capacitors in series/parallel to a d.c. voltage source.

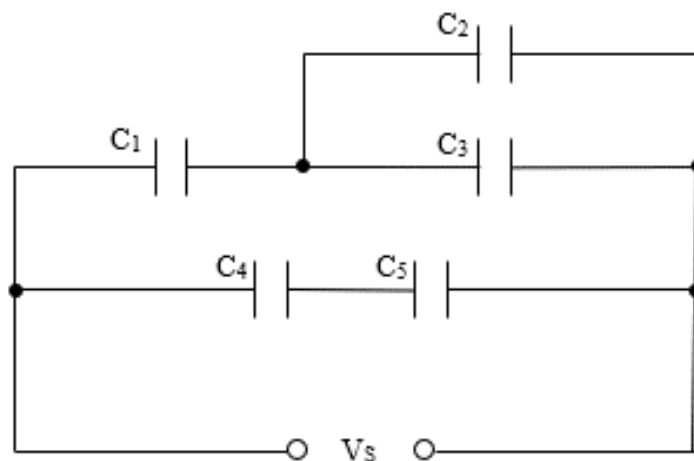


Figure 7 Capacitors in series and parallel DC circuit.

## Calculations

Table 5

| C1 ( $\mu\text{F}$ ) | C2 ( $\mu\text{F}$ ) | C3 ( $\mu\text{F}$ ) | C4 ( $\mu\text{F}$ ) | C5 ( $\mu\text{F}$ ) | Vs (V) |
|----------------------|----------------------|----------------------|----------------------|----------------------|--------|
| 22                   | 27                   | 43                   | 15                   | 33                   | 30     |

Using the values in Table 5, determine:

a) Circuit capacitance

$$C_{2/3} = C_2 + C_3 = 27 + 43 = 70\mu\text{F}$$

$$C_{1/2/3} = \frac{1}{C_1} + \frac{1}{C_{2/3}} = \frac{1}{22} + \frac{1}{70} + \frac{1}{70} = \frac{23}{385} = \frac{385}{23} = 16.74\mu\text{F}$$

$$C_{4/5} = \frac{1}{C_{1/2/3}} + \frac{1}{C_{4/5}} = \frac{1}{15} + \frac{1}{33} = \frac{16}{165} = \frac{165}{16} = 10.31\mu\text{F}$$

$$C_T = C_{1/2/3} + C_{4/5} = 16.74 + 10.31 = 27.05\mu\text{F}$$

b) Total charge

$$Q_T = C_T \times V$$

$$Q_T = 27.05 \times 30$$

$$Q_T = 811.55\mu\text{C}$$

c) The charge in each capacitor, and

d) The energy stored in each capacitor

e) Total energy stored in the circuit.

$$Q_4 \text{ is equal to } Q_5 - Q_{4/5} = C_{4/5} \times V = 10.31 \times 30 = 309.38\mu\text{C}$$

$$Q_1 = Q_T - Q_{4/5} = 811.55 - 309.38 = 502.17\mu\text{C}$$

$$V_1 = \frac{Q_1}{C_1} = \frac{502.17}{22} = 22.83\text{V}$$

$$V_3 = V_T - V_1 = 30 - 22.83 = 7.17\text{V}$$

$$Q_2 = C_2 \times V_3 = 27 \times 7.17 = 193.59\mu\text{C}$$

$$Q_3 = C_3 \times V_3 = 43 \times 7.17 = 308.31\mu\text{C}$$

$$W_1 = \frac{1}{2} C_1 \times V_1^2 = \frac{1}{2} \times 22 \times 22.83^2 = 5733.30\mu\text{J} = 5.73\text{mJ}$$

$$W_2 = \frac{1}{2} C_2 \times V_3^2 = \frac{1}{2} \times 27 \times 7.17^2 = 694.02\mu\text{J}$$

$$W_3 = \frac{1}{2} C_3 \times V_3^2 = \frac{1}{2} \times 43 \times 7.17^2 = 1105.29\mu\text{J}$$

$$V_4 = \frac{Q_4}{C_4} = \frac{309.38}{15} = 20.63\text{V}$$

$$V_5 = V_T - V_4 = 30 - 20.63 = 9.37\text{V}$$

$$W_4 = \frac{1}{2} C_4 \times V_4^2 = \frac{1}{2} \times 15 \times 20.63^2 = 3191.98\mu\text{J}$$

$$W_5 = \frac{1}{2} C_5 \times V_5^2 = \frac{1}{2} \times 33 \times 9.37^2 = 1448.65\mu\text{J}$$

$$W_T = \frac{1}{2} C_T \times V_T^2 = \frac{1}{2} \times 27.05 \times 30^2 = 12172.5\text{mJ}$$

Very well done.

### Task 3.

#### Magnetism.

A permanent magnet is a magnet that can hold its magnetic properties for long periods without the need to induce a current. A permanent magnet is a metal where the magnetic field is generated by the internal structure itself. The magnetic field can be detected through the forces they exert. The magnetic fields run from north to south in a magnet, as shown in figure 8. ✓

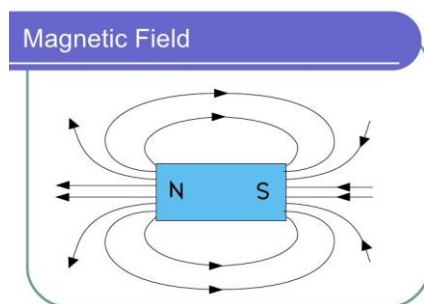


Figure 8

Permanent magnets are not easily demagnetised and the polarity of them will never change. Nevertheless, if a permanent magnetic is heated over the Curie temperature, (the temperature at which magnets operate at) then the magnetic field will decrease or lose the magnetic field altogether. "Permanent magnets can provide stronger fields than electromagnets, require no power source, and do not need cooling" (Fernow, R, 2016). ✓

#### Calculations.

Solve the following problems:

- a) The maximum working flux density of a lifting electromagnet is 1.6T and the effective area of a pole face is circular in cross-section. If the total magnetic flux produced is 550mWb determine the radius of the pole face.

$$B=1.6T$$

$$\Phi=550\text{mWb}$$

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

$$A = \frac{\Phi}{B}$$
 ✓

$$A = \frac{0.55}{1.6} = 343.75 \times 10^{-3} \text{ OR } 0.344\text{m}^2$$

$$A = 0.344\text{m}^2$$

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

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

$$r = \sqrt{\frac{343.75 \times 10^{-3}}{\pi}} = 0.3308\text{m}$$

The radius equals 0.3308m.

- b) An iron toroid having a mean radius of 0.1m and cross-sectional area of  $3.49\text{cm}^2$  is wound with a 1200 turn coil. The coil current results in a flux of 0.2mWb in the toroid.

Using the following data,

|         |     |      |      |      |     |
|---------|-----|------|------|------|-----|
| H(At/m) | 80  | 85   | 90   | 95   | 100 |
| B(T)    | 0.5 | 0.55 | 0.58 | 0.59 | 0.6 |

Determine

- i. the coil current.

$$r = 0.1\text{m}$$

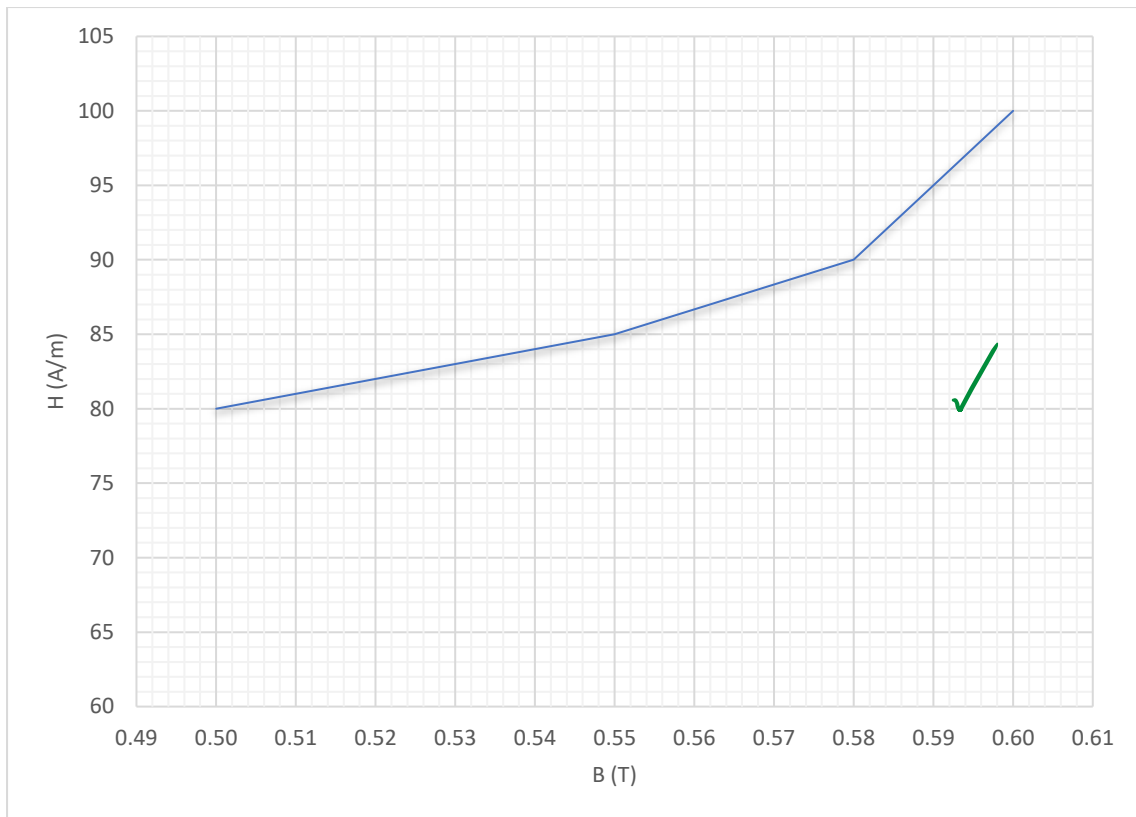
$$A = 3.49\text{cm}^2 \text{ or } 3.49 \times 10^{-4}$$

$$B = \frac{\Phi}{A} = \frac{0.2 \times 10^{-3}}{3.49 \times 10^{-4}} = 0.573$$

$$B = 0.573\text{T}$$

Using the graph below  $B = 0.573$  then  $H = 88\text{A/m}$ .

$$H = 88\text{A/m}$$



$$H = \frac{N \times I}{l}$$

$$\text{And } l = 2\pi r$$

$$l = 2\pi \times 0.1 = 0.628\text{m}$$

$$I = \frac{l \times H}{N} = \frac{0.628 \times 88}{1200} = 0.46077\text{A} \quad \begin{aligned} &= 0.46\text{A} \\ &= 46.08\text{mA} \end{aligned}$$

$$I = 0.46077\text{A}$$

ii. The relative permeability of the toroid under these conditions.

$$\mu_0 \times \mu_r = \frac{B}{H}$$

$$\mu_0 = 4\pi \times 10^{-7}$$

$$\mu_r = \frac{B}{\mu_0} = \frac{0.573}{4\pi \times 10^{-7} \times 88} = 5181.579$$

$$\mu_R = 5181.59$$

## Electromagnets.

An electromagnet consists of a magnetic material (the core) surrounded by a coil of which an electrical current is passed through, therefore magnetising the core. This allows the electromagnet to be turned not only on and off but controlling the strength and reversing the polarity. Once the current is passed through the coil then the core becomes magnetic and the fields of flux react the same way as a normal magnet, the flow from north to south and the current will enter in the south and leave from the north of the electromagnet, this can be seen in Figure 9. ✓

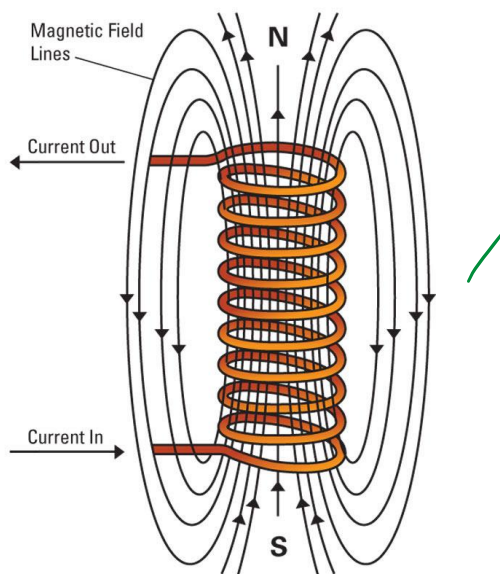


Figure 9 Electromagnet with fields.

Electromagnets are used for a wide variety of devices such as,

- Motors or generators
- Relays
- Loudspeakers
- MRI machines
- Locks
- Induction heaters. ✓

Due to Amperes circuital law which states “The magnetic field created by an electric current is proportional to the size of that electric current with a constant of proportionality equal to the permeability of free space.” The electric current flowing through the wire creates the magnetic field around the wire. This is then concentrated by wrapping the wire around the core material. The magnetic core is usually made of iron or steel. Before a current is present the poles on the core will not exist and the domains will remain random, but on the presence of current then ✓

these domains will align parallel to the magnetic field. Once the current has been switched off then the core will lose its magnetism and return to normal. The electromagnet can be strengthened by adding more turns on the coil around the core. It can also be increased by a greater current produced. Adding a soft iron core will increase the strength of the electromagnet ~~also~~. ✓

## Transformers.

Like in an electromagnet when a current is passed through a coil a flux surrounds it. With a transformer when an alternating current is passed through the coil then an alternating flux surrounds the coil or winding in a transformer. If another winding is then brought into this field or flux then it will incorporate the second winding. If the secondary winding is a closed circuit, then an EMF will be induced to it from the primary winding and a current will flow through the secondary winding, this is proven by Faradays law of electromagnetic induction ✓

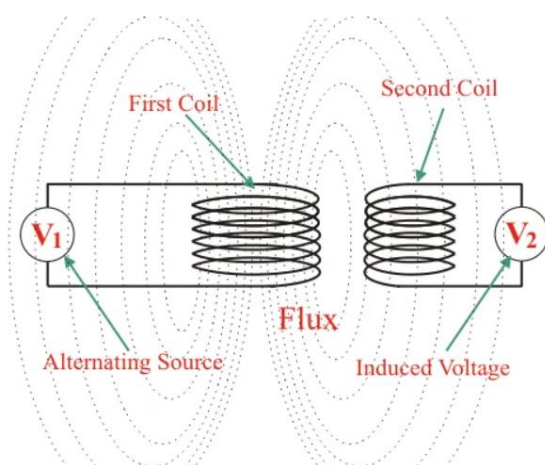


Figure 10 Transformer theory.

Figure 10 shows the alternating source  $V_1$  through the primary coil, producing the flux, which is cut by the secondary coil and inducing a voltage in  $V_2$ .

The transformer can be either a step-up or step-down transformer. These voltage increases or decreases are determined by the number of coils in the secondary windings. If the number of coils is less in the secondary windings, then it is a step-down transformer. With the air gap between the primary and secondary coils in figure 10, only a small amount of flux gets to the secondary windings. To rectify this then a core type transformer can be introduced, with a low reluctance as they are common to both. ✓

Figure 11 shows the core joining the primary and secondary windings providing a low reluctance path, allowing maximum flux to be passed. ✓

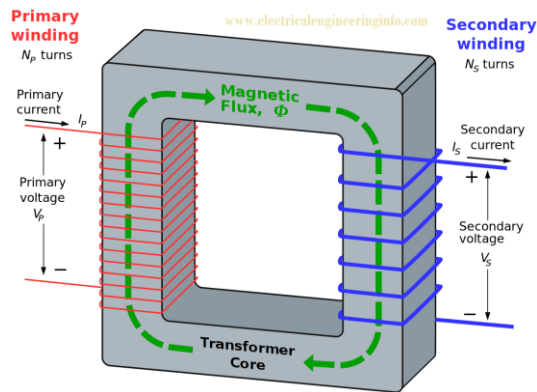


Figure 11 Core type transformer.

The formula for a transformer is,  $\frac{V_{in}}{V_{out}} = \frac{N_p}{N_s}$

This shows that the  $\frac{\text{Voltage in}}{\text{Voltage out}}$  is equal to  $\frac{\text{Number of turns on the primary windings}}{\text{Number of turns on the secondary windings}}$

The efficiency of a transformer is worked out by the following formula,

$$\text{Efficiency} = \frac{\text{Output power}}{\text{Output power} + \text{Losses}} \times 100\%$$

Transformers are an essential part of the National Grid and the transfer of electricity. This allows the National Grid to take electricity from power stations (approx. 10-30 kilovolts) to use step-up transformers (400,000 volts or 400kV) to transfer the electricity through high voltage transfer lines. With this step up in voltage the current is stepped down, this voltage increase is essential to allow for less energy loss through heat with a lower current and allowing transfer across the country. "The very high voltage keeps the current low but causes insulation problems. To prevent current leaking to the ground the cables hang from tall towers called pylons (Avison, J, 2014). The transmission lines have a larger cross-sectional area, giving a low resistance, thus not heating up as much. Once the electricity has reached the consumers then this requires a step-down transformer to reverse the process. This will drop the voltage but increase the current. Allowing the voltage to be dropped to a safe voltage of 230V this will then be distributed directly into homes and businesses in that area. These transformers allow for power stations and wind farms to be built away from towns and cities and allow the national grid to transport it to wherever is necessary. Without them there would need to be power stations or other energy generators in the middle of towns, cities and even villages.

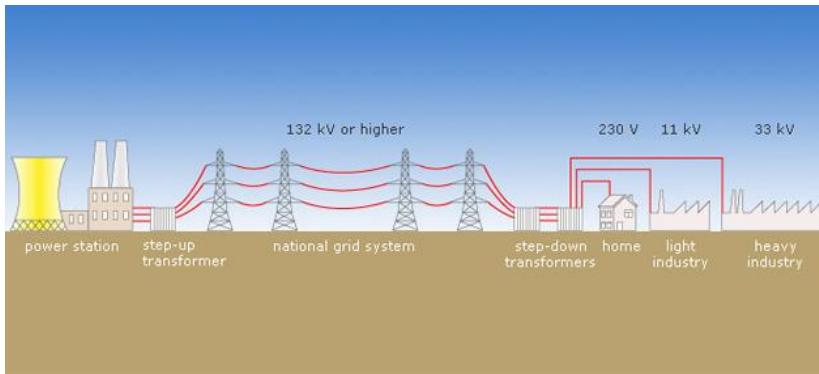


Figure 11

Figure 11 shows the distribution route from supply (power stations) to the demand (homes and business. The step-up and step-down transformers can be seen either side of the pylons.

Solve the following problems:

- a) An iron ring of cross-sectional area  $8.4\text{cm}^2$  and mean diameter  $25\text{cm}$ , contains an air gap  $3\text{mm}$  wide. It is required to produce a flux of  $1.4\text{mWb}$  in the air gap. Calculate the mmf required, given that the relative permeability of the iron is  $1200$  under these operating conditions.

$$A = 8.24\text{cm}^2 = 8.4 \times 10^{-4}\text{m}^2$$

$$D = 25\text{cm} = 0.25\text{m}$$

$$\text{Air gap} = 3\text{mm} = 0.003\text{m} = 3 \times 10^{-3}\text{m} (l_a)$$

$$l_{\text{iron}} = \pi d$$

For Iron.

$$S_i = \frac{l_{\text{iron}}}{\mu_0 \times \mu_r \times A} = \frac{0.25 \times \pi}{4\pi \times 10^{-7} \times 8.4 \times 10^{-4}} = 620039.7$$

$$S_i = 620039.7 \text{ A/Wb}$$

For Air.

$$S_a = \frac{l_a}{\mu_0 \times \mu_r \times A} = \frac{3 \times 10^{-3}}{4\pi \times 10^{-7} \times 8.4 \times 10^{-4}} = 2842052.5$$

$$S_a = 2842052.5 \text{ A/Wb}$$

Total  $S_i + S_a$

$$\text{Total} = S_i + S_a = 620039.7 + 2842052.5 = 3462092.255 \text{ A/Wb}$$

MMF.

$$S = \frac{mmf}{\Phi} \quad \checkmark$$

$$mmf = S \times \Phi = 3462092.255 \times 1.4 \times 10^{-3} = 4846.929$$

$$mmf = 4846.929At \quad \checkmark$$

*Well done.*

- 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 80 turns and rotates at 1200rev/min. (i) Calculate the maximum generated e.m.f. (ii) If the coil generates 100V, at what speed will the coil rotate?

- i. Maximum generated e.m.f.

$$V = WR = \frac{nr}{60} \times 2\pi \times \frac{6 \times 10^{-2}}{2} \quad \checkmark$$

$$= \frac{1200}{60} \times 2\pi \times \frac{6 \times 10^{-2}}{2} = 3.770m/s \quad \checkmark$$

$$V=3.770m/s \quad \checkmark$$

$$E = 2 \times B \times l \times V \times N \quad \checkmark$$

$$E = 2 \times 1.2 \times 10 \times 10^{-2} \times 3.770 \times 80 = 72.384$$

$$E=72.384V \quad \checkmark$$

- ii. Coil rotation speed.

$$E=100V$$

$$V = \frac{E}{2 \times B \times l \times N} = \frac{100}{2 \times 1.2 \times 10 \times 10^{-2} \times 80} = 5.208m/s \quad \checkmark$$

$$W = \frac{V}{r} = \frac{5.208}{\frac{6 \times 10^{-2}}{2}} = 173.6 \quad \checkmark$$

$$\text{Speed} = W \times \frac{60}{2\pi} = 173.6 \times \frac{60}{2\pi} = 1657.759 \quad \checkmark$$

$$\text{Speed} = 1657.759 \text{ RPM} \quad \checkmark$$

*Good work.*

## Task 4

### AC Circuits

- Using the oscilloscope measurements for a sine wave stated in table 6 perform the following calculations

Table 6

| Oscilloscope Settings |                   | Grid Spacing            |                      |
|-----------------------|-------------------|-------------------------|----------------------|
| Volts/Div             | Timebase (ms/Div) | Vertical (peak to peak) | Horizontal (1 cycle) |
|                       |                   |                         |                      |
| 5                     | 5                 | 4.8                     | 4.8                  |

$$V_{PP} = 5 \times 4.8 = 24V$$

$$T = 5 \times 4.8 = 24ms$$

#### a) Peak voltage

$$V_p = V_m = \frac{V_{p-p}}{2} = \frac{24}{2} = 12$$

$$V_p = 12V$$

#### b) Frequency

$$F = \frac{1}{T} = \frac{1}{24 \times 10^{-3}} = 41.66Hz$$

$$F = 41.66Hz$$

#### c) Average voltage

$$V_{av} = 0.637 \times V_m$$

$$= 0.637 \times 12 = 7.64$$

$$V_{av} = 7.64V$$

#### d) Root mean square (rms) voltage.

$$V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{12}{\sqrt{2}} = 8.49$$

$$V_{rms} = 8.49V$$

### Measured Values

| Frequency<br>(f) | CH1 (V)                    | CH2 (V)                    | Time                                                     | Phase                |
|------------------|----------------------------|----------------------------|----------------------------------------------------------|----------------------|
| (kHz)            | <i>pk to pk</i><br>Voltage | <i>pk to pk</i><br>Voltage | Difference<br>( <i>between peaks</i> )<br><br>( $\mu$ s) | Angle ( $^{\circ}$ ) |
| 1                | 1.62                       | 1.22                       | 58                                                       | 20.88                |
| 2                | 1.9                        | 1.2                        | 56                                                       | 40.32                |
| 3                | 2.2                        | 1.14                       | 47                                                       | 50.76                |
| 4                | 2                          | 0.92                       | 39.6                                                     | 57.02                |
| 5                | 1.68                       | 0.96                       | 32.8                                                     | 59.04                |
| 6                | 2.44                       | 0.84                       | 30                                                       | 64.80                |
| 7                | 3.04                       | 0.84                       | 25.2                                                     | 63.50                |
| 8                | 3.14                       | 0.78                       | 23.2                                                     | 66.82                |
| 9                | 3.24                       | 0.72                       | 20.8                                                     | 67.39                |

### Calculated Values

L=  R=  RI=

| Frequency<br>(f - kHz) | $X_L$ ( $\Omega$ ) | $R_T$ | $Z$ ( $\Omega$ ) | Current (A) | Phase Angle<br>( $^{\circ}$ ) |
|------------------------|--------------------|-------|------------------|-------------|-------------------------------|
| 1                      | 14.01              | 32.98 | 35.83            | 0.112       | 23.02                         |
| 2                      | 28.02              | 32.98 | 43.28            | 0.092       | 40.35                         |
| 3                      | 42.03              | 32.98 | 53.43            | 0.075       | 51.88                         |
| 4                      | 56.05              | 32.98 | 65.03            | 0.062       | 59.53                         |
| 5                      | 70.06              | 32.98 | 77.43            | 0.052       | 64.79                         |
| 6                      | 84.07              | 32.98 | 90.31            | 0.044       | 68.58                         |
| 7                      | 98.08              | 32.98 | 103.48           | 0.039       | 71.41                         |
| 8                      | 112.09             | 32.98 | 116.84           | 0.034       | 73.60                         |
| 9                      | 126.10             | 32.98 | 130.34           | 0.031       | 75.34                         |

Calculations.

Example of calculated results.

When  $f = 5\text{kHz}$

$$X_L = 2\pi fL = 2\pi \times 5 \times 2.23 = 70.06 \Omega$$

$$R_T = R + R_L = 26.7 + 6.28 = 32.98 \Omega$$

$$Z = \sqrt{R_T^2 + X_L^2} = \sqrt{32.98^2 + 70.06^2} = 77.43 \Omega$$

$$I = \frac{V}{Z} = \frac{4}{77.43} = 0.052 \text{ A}$$

$$\theta = \tan^{-1}\left(\frac{X_L}{R_T}\right) = \tan^{-1}\left(\frac{70.06}{32.98}\right) = 64.79^\circ$$

*Must include all units.*

After reviewing the practical results and comparing them to the calculated result I can see there are very slight variations. There are several factors that could cause this. The test equipment, and how accurate the metres themselves are and the leads could have poor continuity. The poor continuity could be a result of dirty or degradation in the leads. The meters calibration dates, have they been calibrated recently or are they out of date for calibration. The loading effect of the meters will add additional resistance to the results. ✓

Human factors could play a part in these variations, rounding the figures when calculating results can lead to slight errors further along the results. These human errors also exist in the practical results due to the pixelation of the oscilloscope, with poor quality of screen then this error in reading results could be throughout the results. The cursor lines are down to human interpretation also, these could vary causing the results to alter very slightly. ✓

There are similarities in results, although the results differ the phase angles all follow the same trend, increasing as the frequency was increased. These subtle differences in phase angles could be due to the factors/differences discussed previous. ✓

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