UPDATED JAN 2016

20222 Certificate III

Electro-technology Electrician

MAGNETISM
&
ELECTROMAGNETISM

Practicals & Tutorials Only

PHILIPS

UEENEEG101A

Solve problems in electromagnetic devices and related circuits

Subject Purpose: This unit covers determining correct operation of electromagnetic devices and related circuits and providing solutions as they apply to electrical installations and equipment. It encompasses working safely, power circuit problems solving processes, including the use of voltage, current and resistance measuring devices, providing solutions derived from measurements and calculations to predictable problems in electromagnetic devices and related circuits.

STUDENT NAME____________________________________ DATE____________

TEACHER____ CLASS ____________

Duration: Electromagnetic Applications 52 hours

LESSON STRUCTURE

Lesson	Duration	Topic	Practicals	Tutorials
1	4 hours	11.1 Magnetism	Magnets & Magnetism	Magnets & Magnetism
2	4 hours	11.2-3 Magnetic Effect of an Electric Current	Electromagnetism	Electromagnetism
		11.4 The Magnetic Circuit	The relay	The Magnetic Circuit
3	4 hours	11.5 Magnetisation Curves	The Magnetisation Curve (Motor)	Magnetic Curves & Materials
4	4 hours	12.1-4 Electromagnetic Induction & Induction	Ballast	Induction
			Induction & Inductance	Inductance
5	4 hours	12.5-6 Mutual Inductance & LR Circuit	Mutual Inductance	Mutual Inductance
6	4 hours	Theory Test 1	Practical Test 1	MUST PASS
7	4 hours	13.1-4 The DC Generator		
8	4 hours	DC Generators Part 2	Separately Excited Generator	
9	4 hours	13.5 Self Excited Gen	Self Excited Generator	
10	4 hours	14.1-6 The DC Motor	DC Motor	
11	4 hours	DC Motor Characteristics	DC Shunt Motor	
12	4 hours	Specialist Machines	Starting a Shunt Motor	
13	4 hours	Theory Test 2	Practical Test 2	MUST PASS

Assessment Component No.	Type of Assessment	Duration	Weighting %
1	Theory Test 1	2 hour	40
2	Practical Test 1	45 min.	10
3	Theory Test 2	2 hours	40
4	Practical Test 2	45 min.	10
5	Quizzes, Assignments, Tutorials. (optional at teachers discretion)		0
		Total	100

Contents

Practical 1

MAGNETS & MAGNETISM

PURPOSE:

This practical assignment will be used to verify the basic magnetic laws, to examine the effects of magnetic and non-magnetic materials on magnetic fields and to map the magnetic fields of permanent magnets under various conditions.

TO ACHIEVE THE PURPOSE OF THIS SECTION:

At the end of this practical assignment the student will be able to:

- Use a magnetic compass to identify the poles of a bar magnet
- Map the magnetic field of a bar magnet
- Map the magnetic field patterns of permanent magnets under a variety of conditions
- Examine the effects of magnetic screening
- Examine the effects on a magnetic field by magnetic and non-magnetic materials

EQUIPMENT:

- ☐ 1 x magnetic compass
- ☐ 1 x magnetic field demonstration set – with round bar magnets, mild steel and brass rods
- ☐ 2 x rectangular bar magnets
- ☐ 1 x mild steel rings
- ☐ 1 x resistance proportionality panel
- ☐ 1 x various materials – copper strip, mild steel strip, plastic strip
- ☐ 1 x drawing pin

NOTE:
This practical segment is to be completed by students on an individual basis.
The time given per student is to be no longer than 40 minutes at the bench.

REMEMBER
WORK SAFELY AT ALL TIMES
Observe correct isolation procedures

PROCEDURE:

1. DETERMINATION OF MAGNETIC POLARITY

1. Using the magnetic compass identify the polarity of the ends of the round bar magnets, that is north or south, by placing one end of the magnet near the compass.

2. Record your results in Table 1. Identify the poles of the magnets by their colour.

   Note 1: The end of the magnet which attracts the marked end of the compass needle is the **south pole** of the magnet. See Figure 1.

   Note 2: The other end of the magnet should attract the unmarked end of the compass needle.

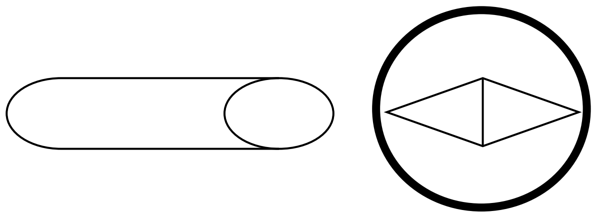

Table 1		
	North Pole	South Pole
Magnet 1		
Magnet2		

3. **<u>Do not proceed</u>** until the teacher checks your results and completes the progress table.

Progress Table 1

Attempt 1	Attempt 2	Attempt 3
A	B	C

2. MAPPING MAGNETIC FIELDS

1. Shake the oil filled container until all the iron filings are in suspension.

2. Place one of the circular magnets into the centre tube of the container, with the north pole of the magnet to the left as shown in Figure 2.

3. Allow the iron fillings to settle in the form of the magnetic field around the magnet. Sketch the field pattern in Figure 2.

Figure 2

4. Remove the magnet from the centre tube, then shake the oil filled container until all the iron filings are in suspension.

5. Place the two circular magnets into the centre tube of the oil filled container, arranged as shown in Figure 3, with unlike poles facing. Be sure not to let the magnets touch one another.

6. Allow the iron filings to settle in the form of the magnetic field around the magnets.

Figure 3

7. Remove the magnets from the centre tube, then shake the oil filled container until all the iron filings are in suspension.

8. Place the two circular magnets into the centre tube of the oil filled container, arranged as shown in Figure 4, with like poles facing.

9. Allow the iron filings to settle in the form of the magnetic field around the magnets. Sketch the field in Figure 4.

Figure 4

10. Remove the magnets from the centre tube, then shake the oil filled container until all the iron filings are in suspension.

11. Place one circular magnet and a mild steel rod into the centre tube of the oil filled container, arranged as shown in Figure 5.

12. Allow the iron filings to settle in the form of the magnetic field around the magnet and rod. Sketch the field in Figure 5.

Figure 5

13. Repeat the procedure using a combination of one circular magnet and a brass rod, arranged as shown in Figure 6.

Figure 6

14. **<u>Do not proceed</u>** until the teacher checks your results and completes the progress table.

Progress Table 2

Attempt 1	Attempt 2	Attempt 3
A	B	C

3. FUNDAMENTAL LAWS OF MAGNETISM

1. Place two rectangular bar magnets approximately 100mm apart on the bench, as shown in Figure 7. The magnets must be arranged to have **<u>unlike poles</u>** facing.

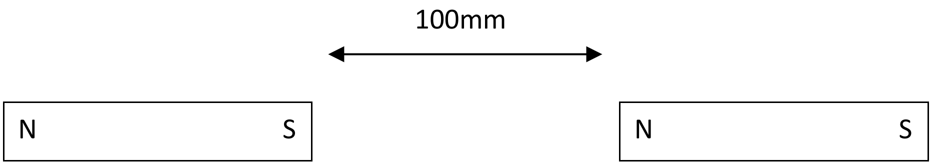

Figure 7

2. Move the magnet on the left towards the magnet on the right and note the effect as the magnets get close to one another.

3. Record you results in Table 2.

Table 2

	Pole Arrangement		
	Unlike Poles Facing	Like Poles Facing	
	North to South	North to South	South to South
Effect			

4. Repeat the procedure with like poles facing, say north to north. Observe and record your results in Table 2.

5. Repeat the procedure, again with poles facing, but this time arranged south to south.

6. Return all equipment to its proper place, safely and carefully.

4. MAGNETIC SCREENING

1. Place a steel ring against any pole of one of the rectangular bar magnets, then drop a drawing pin into the centre of the ring as shown in Figure 8.

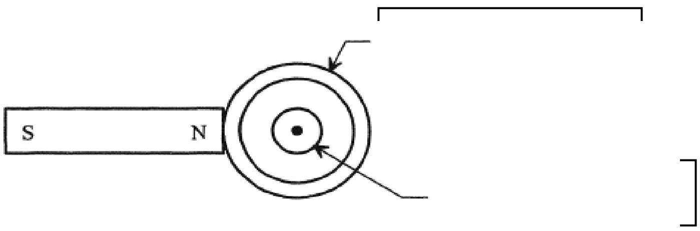

Figure 8

2. Carefully remove the ring in an upward direction, observe the result and record the effect on the drawing pin in Table 3.

Table 3

	Magnet/Ring Arrangement	
	Ring in Place	Ring Removed
Effect on Drawing Pin		

5. MAGNETIC & NON-MAGNETIC MATERIALS

1. Place a rectangular bar magnet and a mild steel strip approximately 100mm apart on the bench as shown in Figure 9.

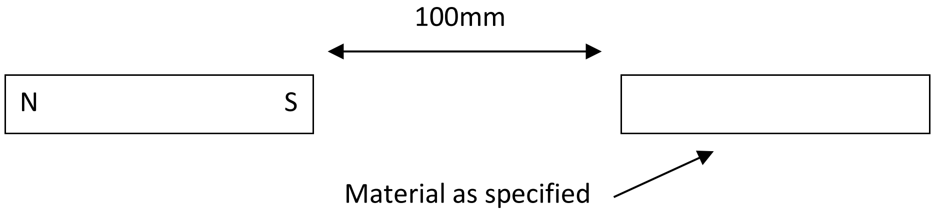

Figure 9

2. Move the magnet until it touches the steel, then move the magnet back to its original position. Observe and record in Table 4, the effect of the magnet on the steel strip.

Table 4

	Type of Material			
	Mild Steel	Copper	Plastic	Wood
Effect Produced by Magnet on the Material				

3. Repeat the procedure for each of the materials shown in Table 4.

4. Please return all equipment to its proper place.

END

6. OBSERVATIONS:

1. What is the magnetic polarity of the marked end of a magnetic compass?

____
____

2. Is the magnetic field surrounding a magnet three dimensional? Base you answer on observations made during this practical assignment.

____
____
____

3. Of the four materials tested, mild steel, copper, plastic and wood, which were magnetic and which were non-magnetic?

____
____

4. How can you identify if a material is magnetic or non-magnetic using a bar magnet?

____
____
____

5. If a magnetic material is placed in a magnetic field, does it have any effect on the magnetic field?

____
____

6. If a non-magnetic material is placed in a magnetic field, does it have any effect on the magnetic field?

____
____

7. Did the metal ring around the drawing pin in procedure 4 provide magnetic screening? If so, how?

____
____
____

Tutorial 1 Multiple Choice - Chapter 11

MAGNETS & MAGNETISM

SECTION A In the following statements one of the suggested answers is best.

1. Magnets are classified as either ________ magnets or ________ magnets.

   (a) temporary, electro-
   (b) electro-, induced
   (c) permanent, temporary
   (d) induced, temporary

2. Magnetic properties state that like magnetic poles __________ each other, whilst _________ poles _________ each other.

   (a) repel, unlike, attract
   (b) attract, unlike, repel
   (c) repel, equal, attract
   (d) repel, neutral, attract

3. The north pole of a magnet is said to be:

   (a) north repelling, repelling the earth's north magnetic pole
   (b) north seeking, pointing to the earth's north magnetic pole
   (c) south seeking, pointing to the earth's north magnetic pole
   (d) south repelling, seeking the earth's south magnetic pole

4. An example of a material which will have a magnetic field induced into it whilst under the influence of an adjacent magnet is:

   (a) copper
   (b) wood
   (c) soft iron
   (d) aluminium

5. Magnetic flux is measured in:

   (a) Webers
   (b) Teslas
   (c) Henries
   (d) Ohm's

6. Flux density is a measure of the amount of:

   (a) magnetic flux
   (b) reluctance per unit area
   (c) magnetic flux per unit area
   (d) inductance flux per unit area

7. Flux density is measured in:

   (a) Henries
   (b) Ohm's
   (c) Webers
   (d) Teslas

8. Retentivity is an indication of how much:

   (a) magnetism is required to magnetise a material
   (b) residual magnetism a material will have
   (c) magnetism is required to de-magnetise a material
   (d) residual magnetism a material will lose

Tutorial 1 Short Answer and Diagrams - Chapter 11

For the following questions, complete the statements with the word or phrase you think fits best.

1. Magnetic lines of force have certain characteristics; can you list five of them?

   (a) ____
   (b) ____
   (c) ____
   (d) ____
   (e) ____

2. Where on a magnet will you find the greatest concentration of flux
   ____.

3. Laws of magnetism state the ____________ poles repel, and ________ ___poles will ________________ each other.

4. List three materials that are:
   (a) Ferromagnetic ____
   (b) dia-magnetic ____
   (C) Paramagnetic ____

5. Show the field pattern produced by the permanent magnet, and label all magnetic poles.

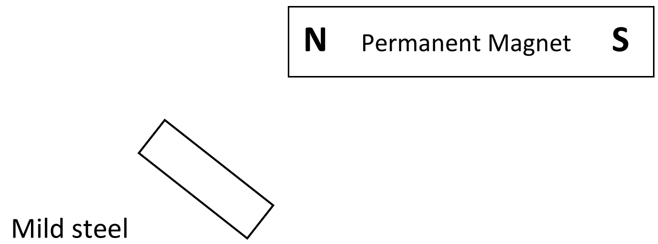

Figure 1

5. Flux density is measured in ______________ and is a measure of the amount of _______

   ______________ for a given ______ _______.

6 Describe the precautions you should take when storing permanent magnets.

   ____

7. Describe what is meant by magnetic screening.

   ____
   ____
   ____

Tutorial 1 Calculations - Chapter 1

The following problems are to be solved with the aid of a calculator. Any working for a problem is to be fully shown.

1. A magnetic pole face is 16mm wide and 8mm high, determine the C.S.A of the pole. ($128mm^2$)

2. The flux produced by a magnet is 10mWb. Determine the flux density if the area of the pole is $250mm^2$. (40T)

3. For the magnet in question 2, determine the flux density away from the pole if the flux now spreads out to an area of $600mm^2$. (16.67T)

4. Determine the flux of a magnet if the flux density at the poles is 2T, and the area of the poles is $300mm^2$. (600µWb)

5. Calculate the area of a magnetic pole with a flux density of 25T produced from a flux of 8mWb ($320mm^2$.)

6. Many of the following equations will be encountered in work on magnetism. Transpose the equations as required:

(a) $mmf = IN$ — $I = ?$ (Note: mmf stands for "magneto-motive-force")

(b) $H = \frac{IN}{l}$ — $N = ?$

(c) $\phi = \frac{mmf}{S}$ — $S = ?$

(d) $B = \frac{\phi}{A}$ — $\phi = ?$

(e) $L = \frac{\mu N^2 A}{l}$ — $N = ?$

(f) $e = N\frac{\Delta\phi}{\Delta t}$ — $N = ?$ (Note: Δ (delta) means a "change in" ie change in time)

(g) $L = N\frac{\Delta\phi}{\Delta I}$ — $\Delta I = ?$

Practical 2

ELECTROMAGNETISM

PURPOSE:

This practical assignment will be used to verify the basic magnetic laws associated with solenoids and electromagnets.

TO ACHIEVE THE PURPOSE OF THIS SECTION:

At the end of this practical assignment the student will be able to:

- Use a magnetic compass to identify the poles of a bar magnet
- Map the magnetic field of a bar electromagnet
- State the effect on the magnetic field produced of varying the number of turns on a solenoid
- State the effect on the magnetic field produced of varying the current flowing in a solenoid
- Examine the effects on the magnetic field of an electromagnet by magnetic and non-magnetic materials

EQUIPMENT:

- ☐ 1 x DC power supply
- ☐ 1 x 0 – 1A DC ammeter
- ☐ 1 x magnetic compass
- ☐ 1 x length of 16mm PVC conduit
- ☐ 1 x length of 25mm PVC conduit
- ☐ 2 x metal rods – 1 x mild steel strip and 1 x brass
- ☐ 4mm connecting leads

NOTE:
This practical segment is to be completed by students on an individual basis.
The time given per student is to be no longer than 40 minutes at the bench.

REMEMBER
WORK SAFELY AT ALL TIMES
Observe correct isolation procedures

PROCEDURE:

1. SINGLE LAYER SOLENOID

1. Connect the circuit as shown in Figure 1. **Note:** Be sure to connect the coil so the start of the coil is positive.

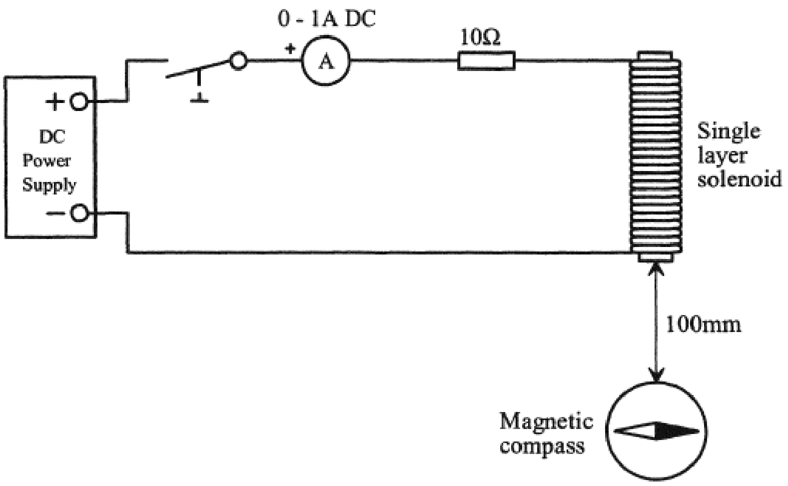

Figure 1

4. Turn on the power supply, close the circuit switch and then adjust to give a circuit current of 0.2A.

5. Open and close the circuit switch, observe any effect on the compass needle when the switch is closed. **Note**: This step may need to be repeated several times in order to observe the effect. Record your observations in Table 1

Table 1

	Effect on Compass Needle				
	0.2A	0.4A	0.6A	0.8A	1A
Single Layer Solenoid					

10. Repeat the procedure for each of the current values shown in Table 1.

11. **Do not proceed** until the teacher checks your results and completes the progress table.

Progress Table 2

Attempt 1	Attempt 2	Attempt 3
A	B	C

2. THREE LAYER SOLENOID

1. Connect the circuit as shown in Figure 2. **Note**: Be sure to connect the coil so the start of the coil is positive.

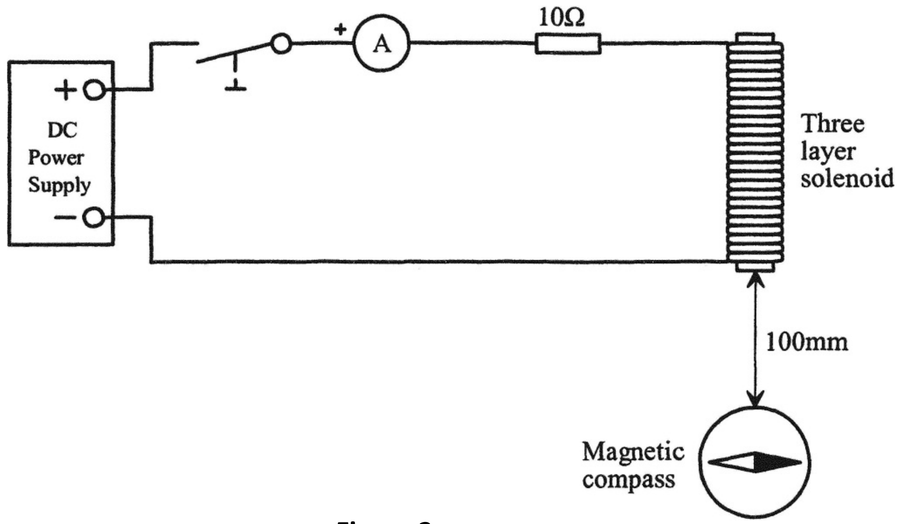

Figure 2

2. Turn on the power supply, close the circuit switch and then adjust to give a circuit current of 0.2A.

3. Open and close the circuit switch, observe any effect on the compass needle when the switch is closed. **Note**: This step may need to be repeated several times in order to observe the effect. Record your observations in Table 2

Table 2

	Effect on Compass Needle				
	0.2A	0.4A	0.6A	0.8A	1A
Three Layer Solenoid **Air Core**					
Three Layer Solenoid **Brass Core**					

10. Repeat the procedure for each of the current values shown in Table 2.

11. Insert the **brass rod** into the conduit and repeat steps 6 to 9.

12. Replace the brass rod with a **mild steel rod** and repeat steps 6 to 8.

13. Record which end of the compass needle is attracted to the electromagnet, that is, north or south.

14. Record you observations in Table 3.

Table 3

	Effect on Compass Needle					
	0.2A	0.4A	0.6A	0.8A	1A	End of Compass Needle Attracted
Three Layer Solenoid **Mild Steel Core**						
Reversed Polarity Three Layer Solenoid **Mild Steel Core**						

15. Reverse the polarity of the coil connections and observe the effect on the compass needle.

16. **<u>Do not proceed</u>** until the teacher checks your results and completes the progress table.

Progress Table 3

Attempt 1	Attempt 2	Attempt 3
A	B	C

3. RIGHT HAND SOLENOID RULE

1. Apply the right hand solenoid rule to predict which end of the single layer solenoid would have a north magnetic polarity. Assume that current is flowing into the start of the winding.

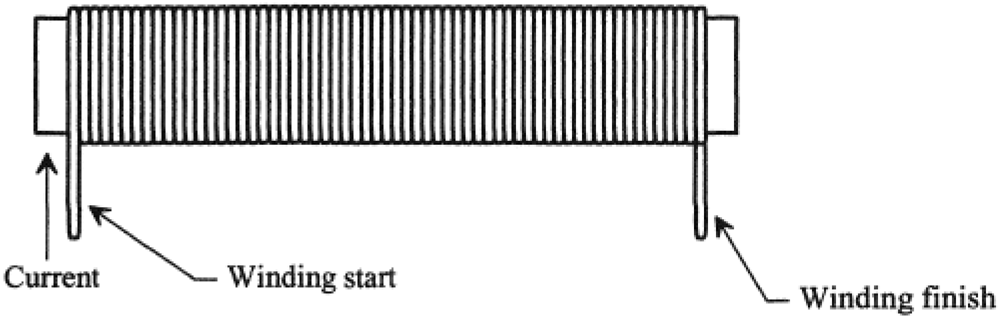

Figure 3

2. Connect the solenoid in circuit as shown in Figure 4.

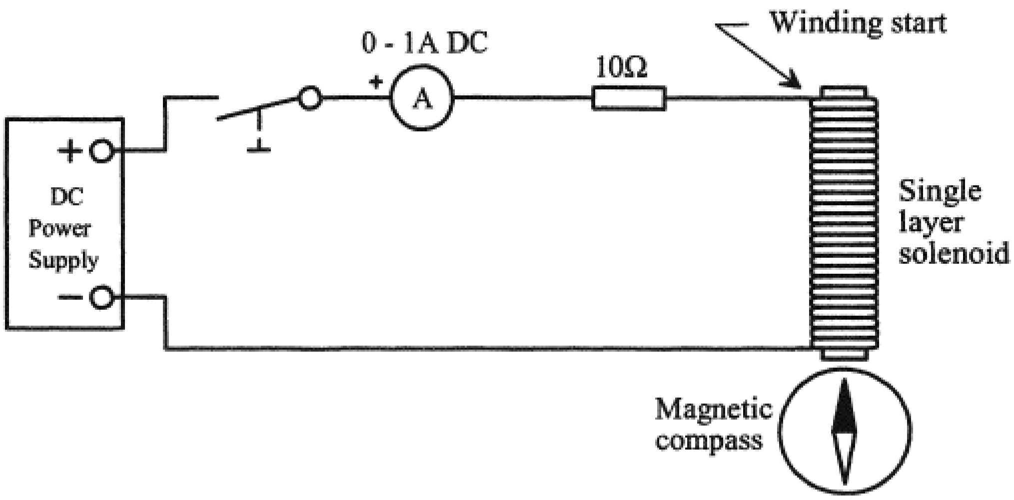

Figure 4

3. Adjust the power supply to deliver a circuit current of 1A.

4. Using the magnetic compass identify the north pole of the solenoid.

5. Does the north pole as identified with the compass match the north pole predicted using the right hand solenoid rule?

YES or NO ______________

6. Move the compass around the solenoid and note the direction taken by the compass needle.

7. Based on your results sketch the solenoid's field pattern. Use the layout shown in Figure 5.

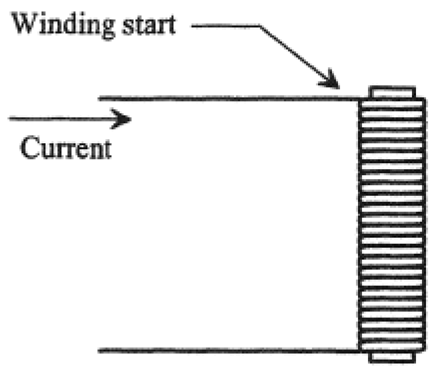

Figure 5

8. Please return all equipment to its proper place, safely and carefully.

4. OBSERVATIONS:

1 Does the number of turns on a solenoid effect the strength of the magnetic field produced by the solenoid?

____

____

2. Does the magnitude of the current flowing in a solenoid effect the strength of the magnetic field produced by the solenoid?

____

____

3. What effect did the brass rod have on the strength of the magnetic field produced by the solenoid?

____

____

4. What effect does the reversal of current flow through a solenoid have on the polarity of the solenoid's magnetic field?

____

____

5. What effect did the introduction of the mild steel core have on the strength of the magnetic field produced by the solenoid?

____

____

6. Why did the mild steel rod effect the solenoid's magnetic field strength, yet the brass rod did not?

____

____

7.

Does the right hand solenoid rule work when applied in practice?

____

____

Tutorial 2 Multiple Choice - Chapter

ELECTROMAGNETISM

SECTION A In the following statements one of the suggested answers is best.

1. The magnetic field surrounding a single current carrying conductor is:

    (a) circular and independent of the direction of current flow
    (b) circular and dependent of the direction of current flow
    (c) axial and independent of the direction of current flow
    (d) axial and dependent of the direction of current flow

2. The direction of the magnetic field around a single current carrying conductor can be determined by:

    (a) Fleming's right hand rule
    (b) Fleming's left hand rule
    (c) the right hand conductor rule
    (d) the right hand solenoid rule

3. In a single current carrying conductor, current flowing towards the viewer can be shown by a _________, whilst current flowing away from the viewer can be shown by a ___________.

    (a) cross, dot
    (b) cross, asterisk
    (c) dot, asterisk
    (d) dot, cross

4. If two single current carrying conductors adjacent to each other have currents flowing through them in opposite directions, then a/an ___________ force exists between the two coils.

    (a) Attraction
    (b) Repulsion
    (c) Magnetomotive
    (d) Inductive

5. The magnetic field around a copper coil can be increased by:

    (a) Increasing the number of turns on the coil
    (b) increasing the current through the coil
    (c) inserting an iron bar into the air gap of the coil
    (d) all of the above

Tutorial 2 Short Answer & Diagrams Chapter 11

For the following questions, complete the statements with the word or phrase you think fits best.

1. What effect does winding a conductor into a coil have on its magnetic field?

   ____

2. The two effects that current creates when flowing through a conductor are;

   (a) ______________________________

   (b) ______________________________

3. What is the force that exists between two adjacent conductors that have currents flowing in:

   (a) opposite directions?____

   (b) the same direction? ____

4. State the rule used to determine the direction of a magnetic field around a single conductor, and briefly describe how you would apply that rule.

   ____

   ____

   ____

5. State the rule used to determine the magnetic field around a coil, and briefly describe how you would apply that rule.

   ____

   ____

   ____

6. Describe electrical methods you would use to:

   (a) magnetise a piece of ferrous material

   ____

   ____

   (b) de-magnetise a piece of magnetic material

   ____

   ____

7. State three advantages of using an electromagnet over a permanent bar magnet.

   ____

   ____

   ____

8. Draw a cross sectional view of a conductor. On your diagram, clearly mark how you would show current was flowing towards the viewer through the conductor.

9. Draw a cross sectional view of a conductor. On your diagram, clearly mark how you would show current is flowing away from the viewer through the conductor.

10. For the circuit of Figure 1, determine which end of the electromagnet will be the north pole.

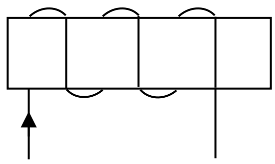

Figure 1

11. For the circuit of Figure 2, draw the windings and mark the current direction required to reverse the coils magnetic polarity in Fig 1.

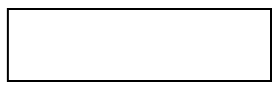

Figure 2

12. Two parallel conductors have currents flowing through them in opposite directions. Draw a sectional view of the two conductors, and show the following:

(a) the relative current directions in each conductor
(b) the correct magnetic field around each conductor
(c) the resultant magnetic field of the two conductors together
(d) the direction of the force exerted between the conductors

…………………Cont

Tutorial 2 Calculations - Chapter 11

The following problems are to be solved with the aid of a calculator. Any working for a problem is to be fully shown.

1. A coil of 120 turns has a current of 250mA flowing through it. Determine the magnetomotive force produced by the coil. (30At)

2. If the power supply for question1 has a current limitation of 120mA, how many additional turns are required to maintain the same magnetomotive force? (130)

3. How much current must flow in a coil of 1000 turns to produce a magnetomotive force of 125At? (125mA)

4. Determine the force acting between two copper conductors spaced 8mm apart when a fault current of 6KA flows in each conductor. (900N)

5. A coil of 800 turns wound on a 35mm long iron core has a current of 300mA passing through it. Calculate the magnetising force in the core. (6857At/m)

Practical 3 (approx 45min)

THE RELAY

PURPOSE:

This practical assignment will be used to examine the operation of the electric relay.

TO ACHIEVE THE PURPOSE OF THIS SECTION:

At the end of this practical assignment the student will be able to:

- Connect an electric relay using a circuit diagram as a guide
- Describe the operation of the electric relay
- Experimentally determine the pick-up and drop-out voltages and currents of a relay

EQUIPMENT:

- ☐ 1 x DC power supply
- ☐ 1 x 0 – 2V DC voltmeter
- ☐ 1 x 0 – 50mA DC ammeter
- ☐ 1 x relay panel
- ☐ 4mm connecting leads

NOTE:
This practical segment is to be completed by students on an individual basis.
The time given per student is to be no longer than 40 minutes at the bench.

REMEMBER
WORK SAFELY AT ALL TIMES
Observe correct isolation procedures

PROCEDURE:

1. RELAY OPERATION

1. Arrange the equipment on the bench in a neat and logical manner.

2. Using the relay panel connect the circuit as shown in Figure 1.

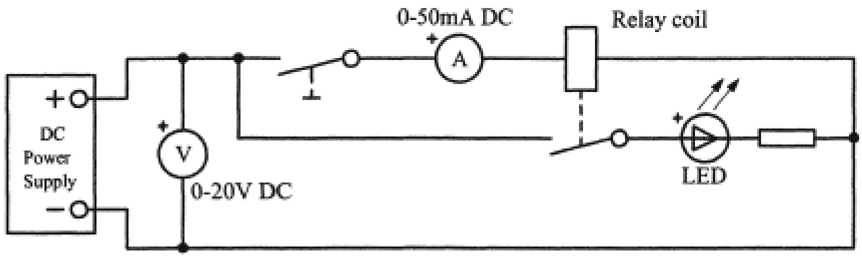

Figure 1

3. **<u>Do not proceed</u>** until the teacher checks your results and completes the progress table.

Progress Table 1		
Attempt 1	Attempt 2	Attempt 3
A	B	C

4. Turn on the power supply and adjust for an output voltage of 12V.

5. Watching the relay closely, close the circuit switch and note what happens to the relay, its normally open contact and the light emitting diode (LED).

   - When the switch was closed the relay ___________________________________
   - The normally open contacts of the relay _________________________________
   - The LED ____

6. Watching the relay closely, open the circuit switch and note what happens to the relay.

   - When the switch was opened the relay _________________________________
   - The normally open contacts of the relay _________________________________
   - The LED ____

2. RELAY PIC-UP and DROP-OUT VALUES

1. Adjust the power supply to give minimum output.

2. Turn on the power supply, close the circuit switch and adjust the power supply such that the voltmeter indicates 2 volts. Record the current taken by the coil and the condition of the LED (lit or not lit) in Table 1.

Table 1

Supply Voltage	Coil Current	LED Condition
2V		

3. Slowly increase the supply voltage whilst observing the LED. Record the voltage at which the LED just turns on in Table 2. Record the coil current at this voltage.

Table 2

Supply Voltage	Coil Current	LED Condition
		ON

4. Increase the supply voltage to 12V. Record the coil current and the LED condition.

Table 3

Supply Voltage	Coil Current	LED Condition
12V		

5. Slowly decrease the voltage observing the LED. Record, in Table 3, the voltage at which the LED turns off completely. Record the current at this voltage.

Table 4

Supply Voltage	Coil Current	LED Condition
		OFF

Repeat to check accuracy

6. **Do not proceed** until the teacher checks your results and completes the progress table.

Progress Table 3		
Attempt 1	Attempt 2	Attempt 3
A	B	C

7. Please return all equipment to its proper place, safely and carefully.

3. OBSERVATIONS:

1. By applying Ohm's Law, calculate the resistance of the relay coil using the results obtained from each table. Use the equation $R = \frac{V}{I}$

From Table 1: ____

From Table 2: ____

From Table 3: ____

From Table 4: ____

2. Answer true or false to each of the following statements.
Allowing for experimental error, the resistance of the relay coil:

(a) increases in proportion to the applied voltage ____________________
(b) decreases as the magnetic field strength increases ____________________
(c) remains unchanged regardless of change in voltage ____________________
(d) Changes when the relay 'picks-up' ____________________

3. Answer true or false to each of the following statements.
When electric current flows through the coil of a relay:

(a) the coil will usually overheat ____________
(b) a magnetic field is produced ____________
(c) the magnetic field strength is proportional to the current ____________
(d) the magnetic field strength is proportional to the applied voltage ____________

4. If the voltage applied to a relay coil is gradually increased, a voltage value is reached (called the 'pick-up' voltage') where the magnetic field is strong enough to overcome the spring tension and pull the armature towards the coil, thus operating the relay contacts. The relay is now said to be energised.

(a) The pick-up voltage of the relay used in this experiment was ____________
(b) The relay will energise provided that coil current is at least ____________
(c) The rated coil voltage for the relay used in this experiment was ____________
(d) The relay pick-up voltage was (greater than/less than/same as) the rated coil voltage.
____

5. If the voltage applied to the coil of a relay is gradually reduced, a voltage value is reached (called the drop-out voltage) where the spring tension on the armature will overcome the weakened magnetic field of the coil, and the relay will de-energise causing the relay contacts to revert to their normal state.

   (a) The drop out value of the relay used in this experiment was ______________
   (b) The relay will de-energise if the coil current is decreased to less than ______________

6. Answer true or false to the following statements.
   The pick-up voltage of the relay was:

   (a) approximately the same value as the drop-out voltage _________________________
   (b) much higher than the drop-out voltage _________________________
   (c) about one quarter of the rated coil voltage _________________________

7. Answer true or false to the following statements.
   In this practical assignment, when the LED was lit, it indicated that:

   (a) The relay was energised _________________________
   (b) The relay was de-energised _________________________

8. Using a red pen, neatly draw a dotted line onto the diagram of Figure 2 to indicate the path of the magnetic flux when the coil is energised.

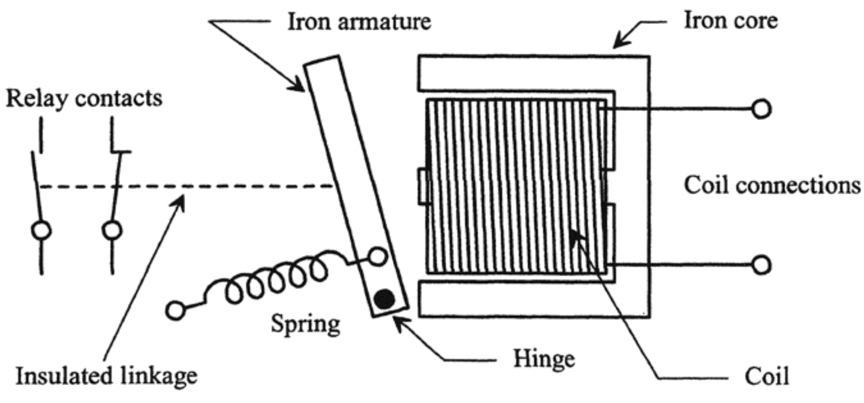

Figure 2

Tutorial 3 Multiple Choice – Chapter

THE MAGNETIC CIRCUIT

SECTION A

1. The magnetomotive force produced by a coil depends on:
   (a) the number of coil turns and the length of the magnetic circuit
   (b) the coil current and the C.S.A. of the magnetic core
   (c) the length of the magnetic circuit and the core reluctance
   (d) the number of coil turns and the coil current

2. The flux set up by a coil depends on the __________ produced by the coil and ____________ of the iron core:
   (a) Fm, reluctance
   (b) magnetising force, C.S.A.
   (c) Fm, magnetising force
   (d) Fm, flux density

3. The flux surrounding a coil is __________ to the coil current and ____________ to the reluctance of the core:
   (a) proportional, proportional
   (b) inversely proportional, inversely proportional
   (c) inversely proportional, proportional
   (d) proportional, inversely proportional

4. A material with a high permeability will easily _____________ magnetic flux
   (a) Concentrate
   (b) Oppose
   (c) Generate
   (d) Produce

5. A material with a high reluctance will ____________ the establishment of magnetic flux
   (a) Concentrate
   (b) Generate
   (c) Control
   (d) Oppose

6. In a magnetic circuit, reluctance is ___________ to the length of the core and ____________ to the cross sectional area of the core
   (a) proportional, proportional
   (b) inversely proportional, inversely proportional
   (c) inversely proportional, proportional
   (d) proportional, inversely proportional

Tutorial 3 Short Answer & Diagrams Chapter 11

For the following questions, complete the statements with the word or phrase you think fits best.

1. State three factors that affect the value of flux produced by a coil;
   (a)____
   (b)____
   (c) ____

2. Materials with a relative permeability of 1 are classified as;
   ____

3. Identify the permeability symbols below;
   μo ______________________________
   μr ______________________________
   μ ______________________________

4. If a material has a high ________________________ it is difficult to magnetise.

Tutorial 3 Calculations - Chapter 11

The following problems are to be solved with the aid of a calculator. Any working for a problem is to be fully shown.

1. A coil of 150 turns has a current of 3.5A flowing through it. Determine the magnetomotive force produced by the coil. (525At)

2. Determine the flux produced by a coil of 1000 turns when 1.5 amperes flows through it. The reluctance of the magnetic circuit is determined to be 45,000 At/Wb. (33.3mWb)

3. Determine the current that must flow through a coil containing 1500 turns, to produce a flux of 15mWb. The reluctance of the magnetic circuit is determined to be 5000 At/Wb. (0.05A)

4. Determine the flux density at the poles of an electromagnet which produces a flux of 15mWb if the area of the poles is $200mm^2$. (75T)

5. A magnetic circuit has a core area of $250mm^2$ and a flux density of 2T. if the reluctance of the core is 60,000 At/Wb, determine the current flowing through the coil of 600 turns. (50mA)

6. An electromagnet has a core length of 400mm, is wound with 2000 turns and carries a coil current of 200ma. Determine the magnetising force of the magnetic circuit. (1000 At/m)

7. Determine the current flowing in a coil of 600 turns which produces a magnetising force of 2000 At/m in a core 150mm long. (500mA)

8. A magnetic core is 300mm long with a cross sectional area of $50mm^2$ and has an absolute permeability of 125.7×10^{-3}. Determine the reluctance of the core. (47,732 At/Wb)

Practical 4

THE MAGNETISATION CURVE

PURPOSE:

This practical assignment will be used to examine the magnetisation curve of a DC generator.

TO ACHIEVE THE PURPOSE OF THIS SECTION:

At the end of this practical assignment the student will be able to:

- Connect a DC generator using a circuit diagram as a guide
- Carry out a test to determine the magnetisation curve for a DC generator
- Plot the magnetisation curve for a DC generator

EQUIPMENT:

- ☐ 1 x variable DC power supply
- ☐ 1 x Betts DC compound machine
- ☐ 1 x Betts single or 3Ph phase prime mover
- ☐ 1 x Betts machine bed to accommodate two machines
- ☐ 1 x digital multimeter
- ☐ 1 x 0 – 2A analogue DC ammeter
- ☐ 4mm connecting leads

NOTE:
This practical segment is to be completed by students on an individual basis.
The time given per student is to be no longer than 40 minutes at the bench.

REMEMBER
WORK SAFELY AT ALL TIMES
Observe correct isolation procedures

PROCEDURE:

1. Arrange the equipment on the bench in a neat and logical manner.

2. Connect the circuit as shown in Figure 1.

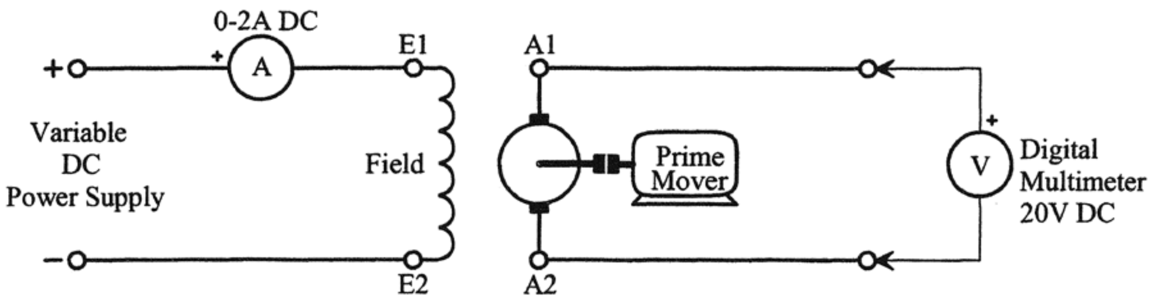

Figure 1

3. **Do not proceed** until the teacher checks your results and completes the progress table.

Progress Table 1		
Attempt 1	Attempt 2	Attempt 3
A	B	C

4. Ensure the DC power supply is switched off.

5. Start the prime mover.

6. Measure the generator output voltage using the digital multimeter and record in the space provided in Table 1.

Table 1

Field Current Amperes	0	0.1	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6
Output Voltage Field Current Increasing										
Output Voltage Field Current Decreasing										

7. Turn on the DC power supply, slowly adjust to give a field current of 0.1A, then measure the generator output voltage. Record the voltage value in Table 1.

8. Repeat the procedure for each of the values of field current shown in Table 1.

9. Reduce the field current to 1.4A, then measure the generator output voltage. Record the voltage value in Table 1.

10. Repeat the procedure for each of the values of field current shown in Table 1.

11. **<u>Do not proceed</u>** until the teacher checks your results and completes the progress table.

Progress Table 1		
Attempt 1	Attempt 2	Attempt 3
A	B	C

12. Turn the DC power supply and the prime mover off.

13. ***<u>Please return all equipment to its proper place</u>***, safely and carefully.

____END____

1. OBSERVATIONS:

1. What effect did increasing the magnetising force have on the output voltage of the generator?

____
____
____

2. What effect did decreasing the magnetising force have on the output voltage of the generator?

____
____
____

3. Were the generator output voltages the same when the field current was decreased as compared to when the field current was increased? If not, what caused the difference?

____
____
____

4. Using the results recorded in Table 1, draw the magnetisation curve for the generator.

26										
24										
22										
20										
18										
16										
14										
12										
10										
8										
6										
4										
2										
0										
	0	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	1.8

Figure 2

5.

In the graph drawing in Figure 2, what does the area between the two curves represent? What causes this loss?

____

____

____

____

Tutorial 4 Multiple Choice - Chapter

MAGNETISATION CURVES & MATERIALS

In the following statements one of the suggested answers is best.

1. Hysteresis loss is due to:

   (a) high reluctance
   (b) low permeability
   (c) high flux density
   (d) residual magnetism

2. A B-H curve shows how the ________ changes for changes in ____________.

   (a) material reluctance; Fm
   (b) flux density; magnetising force
   (c) magnetising force; flux density
   (d) flux; reluctance

3. The B-H curve which is shown as a straight line would be that for:

   (a) Air
   (b) cast iron
   (c) mild steel
   (d) silicon steel

4. The lagging of changes in magnetic flux density behind changes in magnetising force is known as:

   (a) eddy current loss
   (b) Permittivity
   (c) Hysteresis
   (d) Reluctance

5. __________ occurs when the flux density of a material cannot be increased further for increases in magnetising force.

   (a) Residual magnetism
   (b) Coercive force
   (c) Retentivity
   (d) Saturation

Tutorial 4 Short Answer & Diagrams Chapter 11

For the following questions, complete the statements with the word or phrase you think fits best.

1. A magnetisation curve shows the relationship between what to quantities?
   (a) _________ _________ ____
   (b)____ __________________

2. When the magnetising ________ __________ is reduced to zero, any magnetic flux remaining in the material is known as __________________ _________, and the force required to reduce this to zero is known as the ________________________ ________.

3. ______________________ steel is commonly used in transformers and electric motors due to its low ____________________________.

4. The following table represents the results of magnetising the field of a generator and the resulting field flux.

Magnetomotive Force (At)	0	500	1000	1500	2000	3000	4000	6000
Flux (mT)	5	17.5	32	45	57.5	72	75	78

   (a) On the 5mm grid, draw vertical and horizontal axes, and clearly label each axis and title the graph.
   (b) Using a scale of 10mm = 500At and 10mm = 5mT, plot and neatly draw the curve from the results of Table 1, using a curve of best fit.
   (c) On the graph, show the useful region of the curve, the knee of the curve and the point of saturation.
   (d) From the graph determine:
   - the flux density for Fm of 2500 At and 5000 At
   - the Fm for a flux density of 40mT and 65mT

5. On the graph paper supplied draw two hysteresis curves representing *Hard steel* and *Silicon steel*

   (a) identify and fully label the horizontal and vertical axes
   (b) show and label on the diagram the following:
   - the saturation points
   - the amounts of residual magnetism
   - the amounts of coercive force
   - from the text, draw the comparative hysteresis loop for silicon steel

Magnetising field of a generator

Hard Steel

Silicon Steel

Practical 5A (NOTE OPTION OF TWO PRACTICALS (A or B)

BALLAST INDUCTION & INDUCTANCE

PURPOSE:

This practical assignment will be used to examine inductance.

TO ACHIEVE THE PURPOSE OF THIS SECTION:

At the end of this practical assignment the student will be able to:

- Describe the factors affecting the magnitude of an emf produced via electromagnetic induction
- Describe the factors affecting the inductance of a coil
- Use an LCR meter to measure inductance values
- Carry out a basic test to determine the presence of an emf of self induction

EQUIPMENT:

- ☐ 1 x DC power supply
- ☐ 1 x Fuse
- ☐ 1 x digital multimeter
- ☐ 1 x 40w ballast
- ☐ 1 x 500mA ammeter
- ☐ 2 x Rectangular bar magnets
- ☐ 1 x LCR meter
- ☐ 4mm Connecting leads
- ☐ Variac

NOTE:
This practical segment is to be completed by students on an individual basis.
The time given per student is to be no longer than 40 minutes at the bench.

REMEMBER
WORK SAFELY AT ALL TIMES
Observe correct isolation procedures

PROCEDURE:

1. ELECTROMAGNETIC INDUCTION *(NO POWER REQUIRED YET!)*

1. Arrange the equipment on the bench in a neat and logical manner.

2. Connect the circuit as shown in Figure 1 and measure the resistance.

Resistance______________

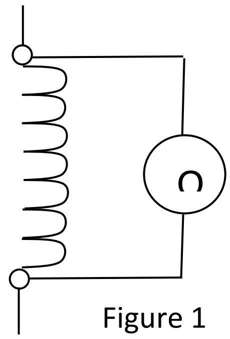

Figure 1

3. Connect the ballast to a **DC supply** as shown in the circuit diagram below in figure 2. Ensure the voltage of the **DC supply is set to Zero**.

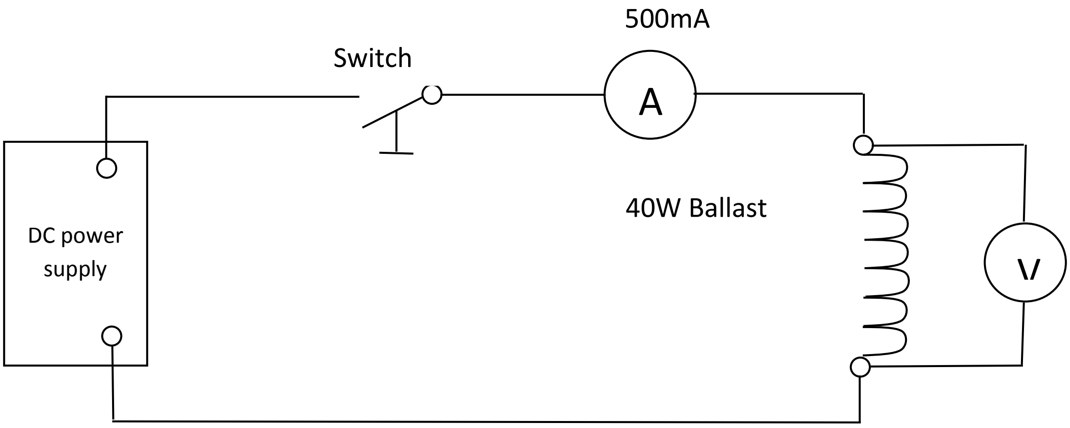

Figure 2

4. Slowly increase the voltage until **300mA** is showing on the ammeter. Record the voltage measured across the ballast. **Voltage ______________________**

5. Using the values above use Ohms Law to calculate the resistance of the ballast.

Resistance ___________________

6. Are the resistive readings in step 2 & 5 approximately the same?

____

____

7. Now reconnect the same circuit and connect to a variable **AC SUPPLY** as shown below in figure 3. Ensure the voltage is set to zero.

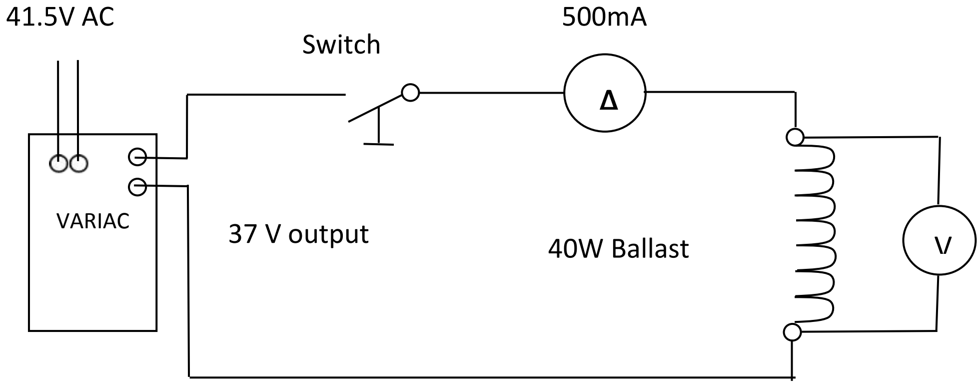

Figure 3

8. Slowly increase the output voltage of the Variac to 37 Volts. Record the current flowing in the circuit.

Current__________________________

9. Using the values recorded in step 8 use ohms law to calculate the value of the opposition to current flow.

Resistance ___________________

10. Was there a difference in ballast resistance when applying an AC or DC supply?

____

11. Was there a difference in ballast current when applying an AC or DC supply?

____

12. Explain any differences.

____
____
____

DISCONECT AND REPLACE ALL EQUIPMENT

Practical 5B

ELECTROMAGNETIC INDUCTION & INDUCTANCE

PURPOSE:

This practical assignment will be used to examine inductance.

TO ACHIEVE THE PURPOSE OF THIS SECTION:

At the end of this practical assignment the student will be able to:

- Describe the factors affecting the magnitude of an emf produced via electromagnetic induction
- Describe the factors affecting the inductance of a coil
- Use an LCR meter to measure inductance values
- Carry out a basic test to determine the presence of an emf of self induction

EQUIPMENT:

☐ 1 x DC power supply
☐ 1 x digital multimeter
☐ 1 x dual coil panel and 1 x soft iron core (or single copper coils)
☐ 1 x terminal panel
☐ 3 x neon lamps (no series resistor)
☐ 1 x 60-0-60μA centre zero microammeter
☐ 2 x rectangular bar magnets
☐ 1 x LCR meter
☐ 4mm connecting leads

NOTE:
This practical segment is to be completed by students on an individual basis.
The time given per student is to be no longer than 40 minutes at the bench.

REMEMBER
WORK SAFELY AT ALL TIMES
Observe correct isolation procedures

PROCEDURE:

1. ELECTROMAGNETIC INDUCTION

1. Arrange the equipment on the bench in a neat and logical manner.

2. Connect the circuit as shown in Figure 1. **Do not** insert the iron core.

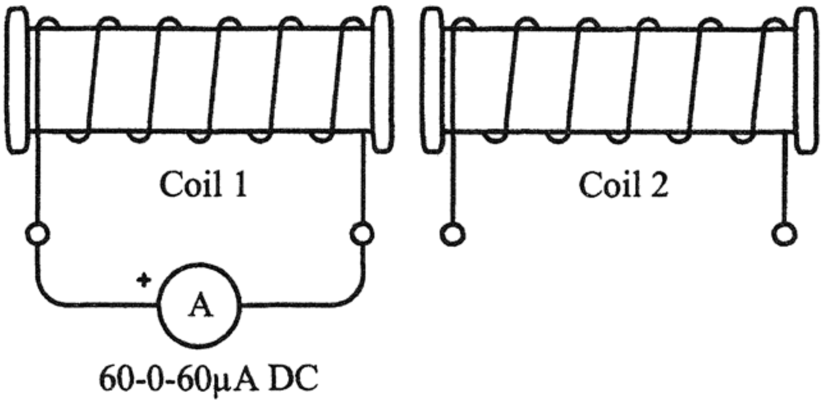

Figure 1

3. Hold the bar magnet at the side of the coil with the north pole pointing towards the centre line of the coil.

4. Slowly move the magnet in one direction (left to right) along the side of the coil, noting both magnitude and polarity of the induced voltage.
   NOTE: Try to remember the speed at which you move the magnet past the coil so that this speed can be doubled at a later stage in this experiment.

5. Repeat step 4, moving the magnet in the opposite direction.

Observation:

6. What effect does reversing the relative direction of the magnetic field cutting the conductor have on the polarity of the induced voltage?

   ____

   ____

7. Insert the soft iron core in the coil.

8. Repeat steps 4 and 5 noting any change in magnitude of the induced voltage.

9. What is the effect on the induced emf of inserting the soft iron core into the coil?

   ____

   ____

10. Hold the two bar magnets together with like poles adjacent to each other as shown in Figure 2. (This will double the strength of the magnetic field).

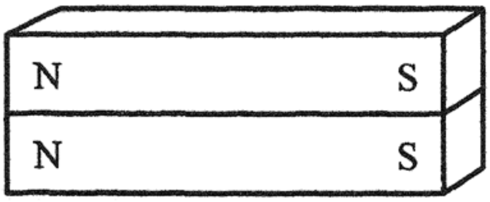

Figure 2

11. Repeat steps 4 and 5 nothing any change in the induced voltage.

12. **What is the effect** on induced emf of increasing the strength of the magnetic field that cuts the conductors?

____

____

13. Connect the two coils in series as shown in Figure 3. (This will double the number of turns cut by the magnetic field).

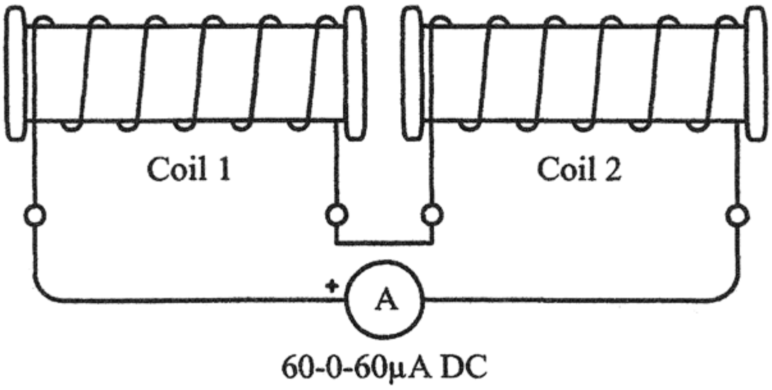

Figure 3

14. With the soft iron core inserted in the coils and the two magnets held together as in step 10, repeat steps 4 and 5 noting any change in the magnitude of the induced voltage.

15. **What is the effect** on induced emf of increasing the number of conductors being cut by the magnetic field?

____

____

16. With the equipment set up as in step 14, double the velocity of the magnet when it is moved past the coil nothing any change in induced voltage.

Observation:

17. What is the effect on the induced voltage of increasing the velocity of the magnetic field cutting the coil conductors?

____

____

18. Reconnect the circuit as shown in Figure 4, with the soft iron core removed.

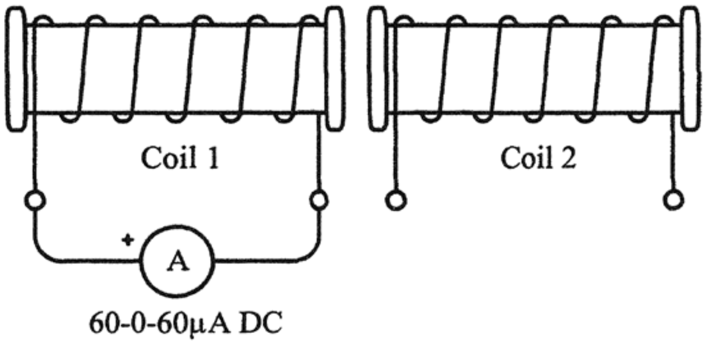

Figure 4

19. Place one magnet on the coil as shown in Figure 5.

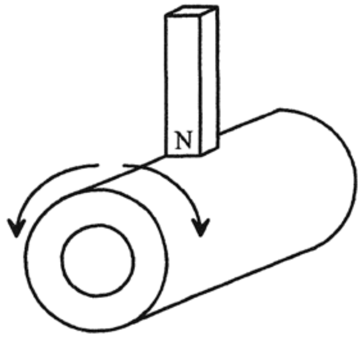

Figure 5

20. Slowly move the magnet around the outside of the coil, noting the value of the induced voltage.

21. **What is the value** of induced voltage when the motion of the magnetic field was parallel to the conductors in the coil?

____

____

22. Insert the soft iron core into the coil. Ensure that circuit is connected as shown in Figure 4.

23. Hold magnet stationary against one end of the iron core. Observe the meter

deflection.

24. Move the magnet to and from past iron core. Observe an record the meter deflection.
____
____

2. INDUCTANCE

1. Using the LCR meter measure the individual inductances of coil 1 and coil 2. Record your results in Table 1.

Table 1

	Inductance Coil 1	Inductance Coil 2
Air Core		
Iron Core		

2. Insert the soft iron core and measure the individual inductances of the two coils. Record your results in Table 1.

3. Remove the iron core.

4. Connect the two coils in series and measure the total inductance. Record your results in Table 2.

Table 2

	Inductance Coils 1 and 2 in Series
Air Core	
Iron Core	

5. Insert the iron core and measure the total inductance. Record in Table 2.

6. **<u>Do not proceed</u>** until the teacher checks your results and completes the progress table.

Progress Table 3		
Attempt 1	Attempt 2	Attempt 3
A	B	C

3. EMF OF SELF INDUCTION

1. Connect three neon lamps to the terminal board.

2. Connect one neon lamp across the power supply as shown in Figure 6.

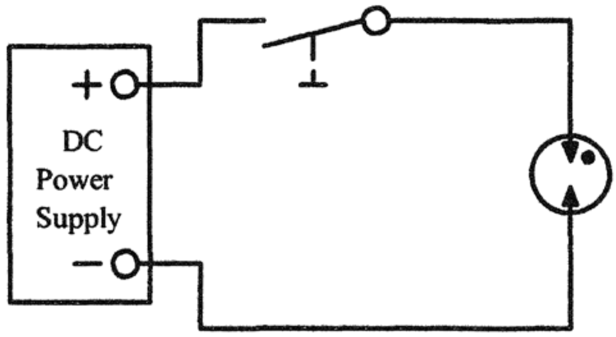

Figure 6

3. Close the circuit switch and adjust the power supply for maximum voltage.

4. Measure and record the lamp voltage and condition, that is, lit or not lit.

Lamp condition = _______________ Lamp voltage = ________________

5. Connect the circuit as shown in Figure 7, using one coil and a neon lamp.

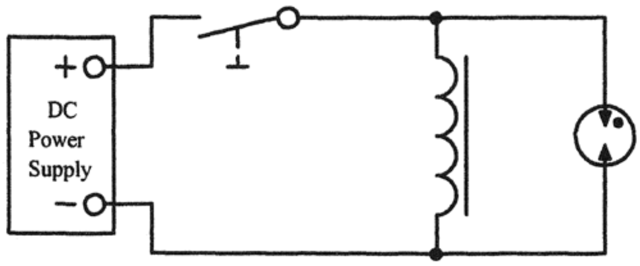

Figure 7

6. Insert the iron core into the centre of the coil.

7. With the circuit switch open, adjust the power supply for an applied voltage of 10V.

8. Close the circuit switch and note the effect on the lamp, that is, lit, not lit or flicked on.

____

9. Open the circuit switch and note the effect on the lamp.

____

16. **<u>Do not proceed</u>** until the teacher checks your results and completes the progress table.

Progress Table 3

Attempt 1	Attempt 2	Attempt 3
A	B	C

17. Switch off the power supply, then disconnect the circuit.

18. Please return all equipment to its proper place, safely and carefully.

4. OBSERVATIONS:

1. Answer true or false to each of the following statements. Base your answers on observations made during this practical assignment.

   An emf will be induced into a conductor:

   (a) when there is relative movement between the conductor and the magnetic field

   ____

   (b) when a conductor is placed within a magnetic field, whether there is movement or not

   ____

   (c) provided the conductor is moving, whether a magnetic field exists or not

   ____

2. Answer true or false to each of the following statements. Base your answers on observations made during this practical assignment.

   The emf induced into a coil is:

   (a) directly proportional to the number of turns in the coil

   ____

   (b) inversely proportional to the rate of cutting of the lines of force

   ____

   (c) increased by a factor of 4 if the flux density of the magnetic field is doubled

   ____

3. What factors determine the magnitude of the emf induced in a conductor?

   ____
   ____
   ____

4. Briefly explain the reason for the results when the magnet was moved around the coil as opposed to along the coil.

   ____
   ____

____

5. Based on your observations what factors affect the inductance of a coil?

____
____
____

6. Why did the inductance of the coils increase when the iron core was inserted?

____
____
____

7. Explain why the neon lamp would flick on only when the power was isolated?

____
____
____

8. What was the approximate self induced emf developed by the coil in the circuits of Figures 7, 8 and 9?

____
____
____

9. If the iron core in the circuits of Figures 7, 8 & 9 was removed, what would happen to the level of the self induced emf?

____
____
____

10. What is inductance and in what form does inductance provide opposition current?

____
____
____

Tutorial 5A Multiple Choice – Chapter (note Induction)

ELECTROMAGNETIC INDUCTION

In the following statements one of the suggested answers is best.

1. If a conductor in a magnetic field moves parallel to the magnetic field, the induced voltage will be __________ volts.

   (a) a maximum
   (b) Alternating
   (c) an average
   (d) Zero

2. Fleming's Right Hand Rule is used to determine the direction of the:

   (a) magnetic field around a solenoid
   (b) induced currents in a conductor
   (c) magnetic field around a single conductor
   (d) force exerted on a current carrying conductor

3. The value of emf induced into a conductor is dependent upon the ___________ density, _________ of conductor and __________ of the conductor.

   (a) conductor, length, velocity
   (b) flux, type, velocity
   (c) flux, length, velocity
   (d) flux, length, material

4. Maximum emf is induced in a conductor when it moves through a magnetic field at an angle of intersection of:

   (a) 0^o
   (b) 45^o
   (c) 90^o
   (d) 180^o

5. If the rate at which a conductor moves through a magnetic field is increased, the induced emf will:

   (a) Decrease
   (b) remain the same
   (c) Alternate
   (d) Increase

Tutorial 5A Short Answer & Diagrams Chapter 11

For the following questions, complete the statements with the word or phrase you think fits best.

1. In Flemings Right Hand Rule,
   the thumb indicates _______ _____________ _______________________________
   the first finger indicates _______ ____
   the middle finger indicates ______________________________________ _________

2. A cross shown in a cross sectional view of a conductor shows _______ _________________ _________, whilst a dot shows ____ ________

3. If the rate at which a conductor cuts across a magnetic field is increased, what effect will this have on the induced voltage?
   ____
   ____

4. Define the term Self Inductance
   ____
   ____

5. Explain why a coil will induce a high voltage in itself when the supply current is disconnected.
   ____
   ____

6. State Lenz's Law
   ____
   ____

Tutorial 5A Calculations - Chapter 11

The following problems are to be solved with the aid of a calculator. Any working for a problem is to be fully shown.

1. A conductor 250mm long moves at right angles with a velocity of 20m/s through a magnetic field with a flux density of 1.5 Tesla. Determine the emf induced in the conductor. (7.5V)

2. For the conductor in question1, determine the new flux density required to increase the induced voltage to 12V? (2.4T)

3. Determine the velocity of a conductor of 200mm length which is moving at a uniform speed through a magnetic field of 1.25 tesla flux density at right angles to produce a voltage of:

   (a) 1.5V (6m/s)
   (b) 10V (40m/s)
   (c) 500mV (2m/s)

4. Determine the flux density of a magnetic field if a conductor 25mm long cuts through the flux at right angles with a velocity of 15m/s to produce a voltage of 6V. (16T)

5. A coil of 150 turns is lined by a flux of 300mWb. If the flux is reduced to 100mWb in 100mS, determine the voltage induced in the coil. (300V)

Tutorial 5B Short Answer & Diagrams – (Note Inductance)

INDUCTANCE

For the following questions, complete the statements with the word or phrase you think fits best.

1. Most inductor cores are made from laminated ________________ _________ to reduce ____________________ and ____________________________________ losses.

2. A non-inductive coil (as used in some wire wound resistors) is produced by ____________ ______________________________________. Accompany your answer with a diagram.

3. To increase the inductance of a coil would you increase or decrease its core area.
   (a) _________________

   (b) State the inductance formula which you could refer to, too prove your answer.

4. To increase the self induced voltage of a coil, increase either the _________ _________ of the coil, or the _____________________________ of the flux linking the coil.

5. An inductor opposes __________________________________ in current.

6. If the flux change linking a coil is increased, the ____________________ voltage will be ___________________.

   (b) State the formula which proves this.

7. Draw the Australian Standard symbols for the following, and give an example of an application for each one:

   (a) an air cored inductor
   (b) an iron cored inductor
   (c) a fixed ferrite cored inductor
   (d) an adjustable ferrite cored inductor

Tutorial 5B Calculations - Chapter

The following problems are to be solved with the aid of a calculator. Any working for a problem is to be fully shown.

1. Determine the inductance of a 100m length of straight 2.5mm^2 single cored conductor. Assume that the number of turns equals 1, and the permeability of air is 12.57 x 10^{-7} H/m. (31.4 x 10^{-15} H)

2. If the conductor in question 1 is now wound to produce an air cored coil of 3000 turns with a cross sectional core area of 400mm^2 and an overall length of 50mm, determined the new inductance. (90.5mH)

3. An air cored coil of 400 turns has a cross sectional are of 1000mm^2 and a length of 125.7mm. If the permeability of free air is 12.57 x 10^{-7} H/m, determine the inductance of the coil. (1.6mH)

4. If an iron core with a relative permeability of 1400 is inserted into the centre of the coil in question 3 above, determine the new inductance of the coil. (2.24H)

5. A coil of 354 turns and a length of 350mm has a cross sectional area of $50mm^2$. Determine the inductance of the coil with:

   (a) an air core ($\mu = 12.57 \times 10^{-7}$ H/M) (22.5μH)
   (b) an iron core (μr = 180) (4.05mH)
   (c) a mu-metal core ($\mu r = 100 \times 10^{-3}$) (2.25μH)

6. An inductor with 600 turns has a flux linking it of 25mWb. If this flux is reduced to zero in 5 milliseconds, determine the voltage induced in the coil. (3kV)

7. Determine the flux change required to generate 240V in an inductor of 150 turns if the flux changes in 10 milliseconds. (16mWb)

8. Determine the inductance of a coil of 120 turns when a reduction of the coil current from 2.0A to 0.4A produces a reduction of the core flux from 25mWb to 9mWb. (1.2H)
   (Note: Formula $L = N (\Delta\Phi/\Delta I)$- Optional Question

Practical 6

MUTUAL INDUCTANCE

PURPOSE:

This practical assignment will be used to examine mutual inductance and the degree of coupling that exists between two mutually coupled coils.

TO ACHIEVE THE PURPOSE OF THIS SECTION:

At the end of this practical assignment the student will be able to:

- Describe the operation of mutual induction when one of two mutually coupled coils is supplied from a DC source
- Describe the operation of mutual induction when one of two mutually coupled coils is supplied from an AC source
- Explain the effects of varying the coupling between mutually coupled coils

EQUIPMENT:

☐ 1 x 24V, 50Hz AC power supply
☐ 1 x digital multimeter
☐ 1 x dual coil panel
☐ 3 x soft iron cores – 1 of each 6mm,
☐ 1 x 1.5V cell
☐ 1 x 60-0-60µA centre zero micro ammeter
☐ 4mm connecting leads

NOTE:
This practical segment is to be completed by students on an individual basis.
The time given per student is to be no longer than 40 minutes at the bench.

REMEMBER
WORK SAFELY AT ALL TIMES
Observe correct isolation procedures

PROCEDURE:

1. MUTUAL INDUCTION WITH A DC SUPPLY (Use DC Power Supply or 1.5V cell)

1. Arrange the equipment on the bench in a neat and logical manner.

2. Connect the circuit as shown in Figure 1. **Do not** insert an iron core.

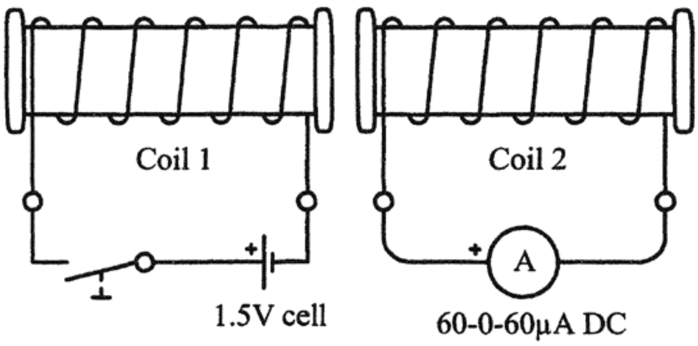

Figure 1

3. Close the circuit switch and note the polarity and magnitude of any deflection on the micro-ammeter.

4. Open the circuit switch and note the polarity and magnitude of any deflection on the micro-ammeter.

5. Insert the **6mm iron core** into the centre of the two coils.

6. Close the circuit switch and note the polarity and magnitude of any deflection on the micro-ammeter.

7. Open the circuit switch and note the polarity and magnitude of any deflection on the micro-ammeter.

8. Repeat each procedure, if necessary, to obtain your results.

9. **<u>Do not proceed</u>** until the teacher checks your results and completes the progress table.

Progress Table 2		
Attempt 1	Attempt 2	Attempt 3
A	B	C

2. MUTUAL INDUCTION WITH AN AC SUPPLY

1. Connect the circuit as shown in Figure 3. **Do not** insert a soft iron core.

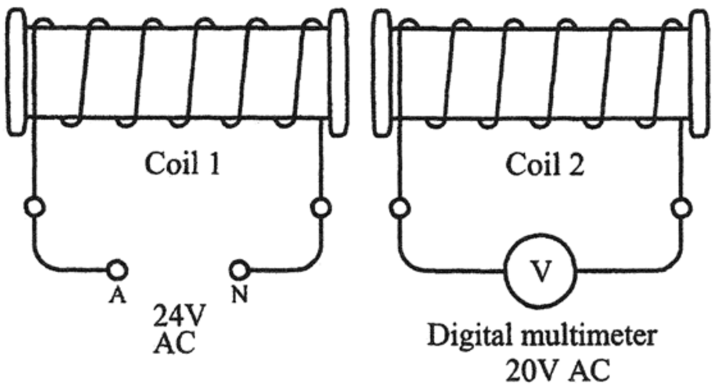

Figure 3

2. Switch on the 24V AC supply, then measure and record the value of voltage induced into coil 2. Record in Table 1.

Table 2

<table>
<tr><th></th><th>Voltage Applied to Coil 1</th><th>Voltage Induced in Coil 2</th></tr>
<tr><td>Air Core</td><td rowspan="2">24V</td><td></td></tr>
<tr><td>25mm Iron Core</td><td></td></tr>
</table>

3. Insert the 6mm soft iron core, then measure and record the value of voltage induced into coil 2. Record in Table 1.

4. <u>**Do not proceed**</u> until the teacher checks your results and completes the progress table.

Progress Table 4		
Attempt 1	Attempt 2	Attempt 3
A	B	C

5. Switch off the power supply, then disconnect the circuit. Please return all equipment to its proper place, safely and carefully.

3. OBSERVATIONS:

1. What is mutual inductance?

____
____

2. When is an emf of mutual inductance produced, when one of two mutually coupled coils is supplied from a DC source?

____
____

3. When is an emf of mutual inductance produced, when one of two mutually coupled coils is supplied from an AC source?

____
____

4. What is meant by the term coupling, as applied to two mutually coupled coils?

____
____

5. Of the four cores used in this assignment, which provided the tightest coupling between the coils?

____
____

6. How could the coupling between the two coils used in this assignment be improved?

____
____

7. Will two mutually coupled coils work either way round?

____
____

8. What factors affect the level of induced voltage produced in a coil as a result of mutual inductance?

____

Tutorial 6 Multiple Choice – Chapter

MUTUAL INDUCTANCE & LR CIRCUITS

In the following statements one of the suggested answers is best.

1. Mutual inductance is defined as the magnetic linkage between:

   (a) a single coil and its' flux
   (b) any number of adjacent coils
   (c) an inductor and a resistor
   (d) the flux and the magnetic core

2. A transformer operates on the principle of:

   (a) self inductance
   (b) core inductance
   (c) mutual inductance
   (d) coil inductance

3. If a current change occurs in a coil, an emf of self-induction is induced in the coil. This induced emf is commonly known as a ____________ and is explained by _____________

   (a) back emf, Lenze's Law
   (b) back emf, Ohm's Law
   (c) mutually induced emf; Faradays Law
   (d) mutually induced emf; Lenze's Law

4.. The unit of mutual inductance is the:

   (a) Farad
   (b) Henry
   (c) Ohm
   (d) Teslas

5. To increase the time constant of an LR circuit, either __________ the inductance value or ___________ the resistance value

   (a) increase, increase
   (b) decrease, increase
   (c) increase, decrease
   (d) decrease, decrease

Tutorial 6 Short Answer & Diagrams - Chapter

For the following questions, complete the statements with the word or phrase you think fits best.

1. Name two common machines which operate by mutual inductance;
   (a) ____.
   (b) ____

2. Explain what would happen if you installed a telecommunications cable directly beside a power cable within the same enclosure.
   ____
   ____

3. Sketch a simple LR circuit containing an inductor of 12mH and a Resistor of 4Ω, supplied by a 24Vdc supply

4. What does the resistor limit within the LR circuit
   ____

5. Determine the maximum current for the circuit in question 3

6. If an inductive circuit is open circuited, the rapidly ________ ____________ magnetic field can ______________ _______ dangerously high _____________ ________.

7 How many time constants would the circuit in question 3 take to reach its maximum current value?
   ____

Tutorial 6 Calculations - Chapter

1. Determine the voltage induced in two adjacent coils of 250 turns and 600 turns respectively if they are cut by a magnetic flux with a rate of change of flux of 10mWb/5mSec. (500V & 1200V)

2. Determine the change in flux of a coil with 1200 turns if 240V is induced into the coil in 10mSecs. (2mWb)

3. For the coil in question 2, determine the voltage that is induced if the flux of 2mWb collapses in 2mSec. (1.2kV)

4. A coil of 30mH is connected in series with a resistance of 120Ω. When connected to a 36V DC supply, determine:

   (a) the time constant of the circuit (250μSec)
   (b) the steady state circuit current (300mA)
   (c) the circuit current after one time constant (189.6mA)

5. Sketch an LR circuit connected to a 12V supply, where the inductor has a value of 1.5H, and contains 250 turns with a resistance of 220Ω :

   (a) the time constant of the circuit (6.81mSec)
   (b) the steady state current with the switch closed (54.5mA)
   (c) the circuit current after one time constant (34.5mA)
   (d) the current after one time constant when the switch opens (20mA)
   (e) the time taken for the current to fall to zero (34mSec)
   (f) If the flux in the coil at steady current is 140m Wb, determine the voltage induced in the coil as the current collapses to zero (1kV)

WORKSHEET

Summary Questions Chapters 11-12

Chapter 11 – Magnetism and Electromagnets

True/False

1. Lodestone is a naturally occurring magnetic material.

2. The pointer of a compass that points north is a north pole.

3. Lines of magnetic flux never cross each other.

4. When electricity flows a magnetic field is always created.

5. The right hand rule is used to determine the direction of magnetic flux based on the direction of current flow.

Multiple Choice

1. The smallest possible magnet is known as a magnetic:
A. domain
B. bead
C. flux line
D. ore

2. External magnetic flux is said to flow from:
A. south to north
B. north to south
C. either direction
D. top to bottom

3. The term given to the item place at the poles of magnets to preserve their strength is called a:
A. holder
B. retainer
C. keeper
D. shield

4. Flux density is measured in:
A. teslas
B. webers
C. farads
D. henries

5. Flux density is the number of lines of flux per square:
A. yard
B. foot
C. centimetre
D. metre

Completion

1. Air is said to have a very _________ value of permeability.

2. The term used to describe magnetic resistance is _________.

3. One of the advantages of a lifting electromagnet is that it can be _________ on and off.

4. The point at which an electromagnet begins to reach saturation on B-H curve is called the _________.

5. A common additive to steel to produce low hysteresis is _________.

Short Answer

1. What is the flux density if the flux is 5mWb and with an area of 100square millimetres?

2. What is the force acting on two conductors 50mm apart with 1000A flowing in them?

3. If 10A flows through a coil of 120 turns what is the Magnetomotive force?

4. What would be the absolute permeability of a material if it had a flux density of 0.1T and a magnetising force of 50 At/m?

5. What sort of material has an almost square hysteresis curve?

Chapter 12 – Electromagnetic Induction

True/False

1. A voltage is induced in a conductor when it moves through a magnetic.

2. If the polarity of the magnet is changed by swapping the north and south poles, the polarity of the induced voltage will also change.

3. Inductors with an air core have a higher value that those with an iron core.

4. Inductors are use to limit inrush current to capacitors.

5. All inductors possess some form of resistance.

Multiple Choice

1. The scientist who discovered that a moving magnetic field causes a current to flow in a conductor was:
A. Henry
B. Watt
C. Oersted
D. Faraday

2. Fleming's right-hand rule determines the direction of the _________ when a conductor is moving in a magnetic field.
A. current
B. magnetic north
C. size of conductor
D. polarity

3. If you increase the speed of a conductor passing through a magnetic field the induced voltage will:
A. halve
B. reduce
C. increase
D. remain the same

4. Inductor cores used with an alternating current require:
A. laminations
B. longer sizes
C. copper rings
D. being removed

5. The letter shapes that are often used to make laminations are:

A. A & B
B. D & F
C. E & I
D. Z & T

Completion

1. If you triple the effective length of a conductor passing through a magnetic field you will _________ the voltage produced.

2. When an inductor is first energised current flow will be _________ until the coil is fully magnetised

3. The three main types of inductor cores are air, soft iron and _________.

4. When a coil produces a voltage in an adjacent coil this is called _________ inductance.

5. A device that relies on mutual inductance is the _________.

Short Answer

1. What voltage will be induced when a 5 metre conductor passes through a 0.002 T field at 20 metre per second?

2. Name the four factors that determine inductance?

3. What would be the value of one time constant in an LR circuit with a resistance of 50Ω and an inductance of 3H?

4. Calculate the value of the induced EMF in a coil that has 1000 turns and the flux increasing 0.02Wb every five seconds?

5. Once a coil has become magnetised by a DC current what is the only factor limiting current flow

Practical 7

INDUCTANCE

PURPOSE:

This practical assignment will be used to examine inductance and the turns within a coil

TO ACHIEVE THE PURPOSE OF THIS SECTION:

At the end of this practical assignment the student will be able to:

- Determine the turns in a coil from factors relating to inductance.
- Correct use of an LCR meter

EQUIPMENT:

☐ 1 x Ruler
☐ 1 x LCR Meter
☐ 1 x dual coil panel
☐ 1 x Digital Multimeter
☐ 1 x Ruler
☐ 4mm connecting leads

NOTE:
This practical segment is to be completed by students on an individual basis.
The time given per student is to be no longer than 40 minutes at the bench.

REMEMBER
WORK SAFELY AT ALL TIMES
Observe correct isolation procedures

PROCEDURE

1. Determine the following details from the coil provided. Use the correct units when writing your anaswer

Resistance of coil	Ω
Inductance of coil	
Length of air core	
Internal width of air core	
Internal height of air core	

2. Calculate the CSA of the air core.

Ans. ___________________________________

3. Transpose the inductance formula and calculate the number of turns of the coil.

   Given that;
   Permeability of free space = 1.26^{x10-6} H/m,
   Permeability of air = 1

Ans. ___________________________________

4. Calculate the magnetising force of a coil if it was connected to a 24DC supply.

Ans. ______________________________

Note: The symbols used on this sheet follow AS1046 pt 1. There are alternate recognised symbols in use. The list does not contain every equation used in the course. Transposition of equations will be necessary to solve problems

$Q = It$	$v = \frac{s}{t}$	$a = \frac{\Delta v}{t}$
$F = ma$	$W = Fs$	$W = mgh$
$W = Pt$	$\eta\% = \frac{output}{input} \times \frac{100}{1}$	$I = \frac{V}{R}$
$P = VI$	$P = I^2 R$	$P = \frac{V^2}{R}$
$R_2 = \frac{R_1 A_1 l_2}{A_2 l_1}$	$R_h = R_c(1 + \alpha \Delta t)$	$R = \frac{\rho l}{A}$
$R_T = R_1 + R_2 + R_3$	$V_T = V_1 + V_2 + V_3$	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
$I_T = I_1 + I_2 + I_3$	$V_2 = V_T \frac{R_2}{R_1 + R_2}$	$I_2 = I_T \frac{R_1}{R_1 + R_2}$
$R_x = \frac{R_A R}{R_B}$	$C = \frac{Q}{V}$	$\tau = RC$
$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$	$C_T = C_1 + C_2 + C_3$	$C = \frac{A \varepsilon_o \varepsilon_r}{d}$
$F_m = IN$	$H = \frac{F_m}{l}$	$B = \frac{\Phi}{A}$
$\Phi = \frac{F_m}{S}$	$S = \frac{l}{\mu_o \mu_r A}$	$V = N \frac{\Delta \Phi}{\Delta t}$
$e = Blv$	$L = \frac{\mu_o \mu_r A N^2}{l}$	$L = N \frac{\Delta \Phi}{\Delta I}$
$V = L \frac{\Delta I}{\Delta t}$	$\tau = \frac{L}{R}$	$F = Bil$
$T = Fr$	$E_g = \frac{\Phi Z n P}{60a}$	$P = \frac{2\pi n T}{60}$
$t = \frac{1}{f}$	$f = \frac{np}{120}$	$V = 0.707 V_{\max}$
$I = 0.707 I_{\max}$	$V_{ave} = 0.637 V_{\max}$	$I_{ave} = 0.637 I_{\max}$
$v = V_{\max} \sin \phi$	$i = I_{\max} \sin \phi$	$I = \frac{V}{Z}$
$Z = \sqrt{R^2 + (X_L - X_C)^2}$	$X_L = 2\pi f L$	$X_C = \frac{1}{2\pi f C}$

$$\cos\phi = \frac{P}{S} \qquad \cos\phi = \frac{R}{Z} \qquad S = \sqrt{P^2 + Q^2}$$

$$S = VI \qquad P = VI\cos\phi \qquad Q = VI\sin\phi$$

$$f_o = \frac{1}{2\pi\sqrt{LC}} \qquad V_L = \sqrt{3}V_P \qquad I_L = \sqrt{3}I_P$$

$$S = \sqrt{3}V_L I_L \qquad P = \sqrt{3}V_L I_L \cos\phi \qquad Q = \sqrt{3}V_L I_L \sin\phi$$

$$\tan\phi = \sqrt{3}\left(\frac{W_2 - W_1}{W_2 + W_1}\right) \qquad Q = mC\Delta t$$

$$V' = 4.44\Phi fN \qquad \frac{V_1}{V_2} = \frac{N_1}{N_2} \qquad \frac{I_2}{I_1} = \frac{N_1}{N_2}$$

$$N_{syn} = \frac{120f}{p} \qquad s\% = \frac{(n_{syn} - n)}{n_{syn}} \times \frac{100}{1} \qquad f_r = \frac{s\% \times f}{100}$$

$$V_{reg}\% = \frac{(V_{NL} - V_{FL})}{V_{FL}} \times \frac{100}{1} \qquad V_{reg}\% = \frac{(V_{NL} - V_{FL})}{V_{NL}} \times \frac{100}{1} \qquad T = \frac{\Phi ZIP}{2\pi a}$$

$$I_{ST} = \frac{1}{3} \times I_{DOL} \qquad T_{ST} = \frac{1}{3} \times T_{DOL} \qquad I_{ST} = \frac{V_{ST}}{V} \times I_{DOL}$$

$$T_{ST} = \left(\frac{V_{ST}}{V}\right)^2 \times T_{DOL} \qquad I_{motor\,st} = \frac{\%TAP}{100} \times I_{DOL} \qquad I_{line\,st} = \left(\frac{\%TAP}{100}\right)^2 \times I_{DOL}$$

$$E = \frac{\Phi_v}{A} \qquad E = \frac{I}{d^2} \qquad \eta_v = \frac{\Phi_v}{P}$$

$$V_L = 0.45V_{ac} \qquad V_L = 0.9V_{ac} \qquad V_L = 1.17V_{phase}$$

$$V_L = 1.35V_{line} \qquad PRV = \sqrt{2}V_{ac} \qquad PRV = 2\sqrt{2}V_{ac}$$

$$PRV = 2.45V_{ac} \qquad V_{ripple} = \sqrt{2}V_{ac} \qquad V_{ripple} = 0.707V_{phase}$$

$$V_{ripple} = 0.1895V_{line}$$