UNIT 25072 ©

Demonstrate knowledge of electromagnetism theory

This workbook is intended for "SELF-PACED STUDY".

The assessment for this Unit is not included in this Workbook.

You will need:

Calculator – Casio fx-82

This unit was written by A. Kawana and amended by Phil Plunkett 2009

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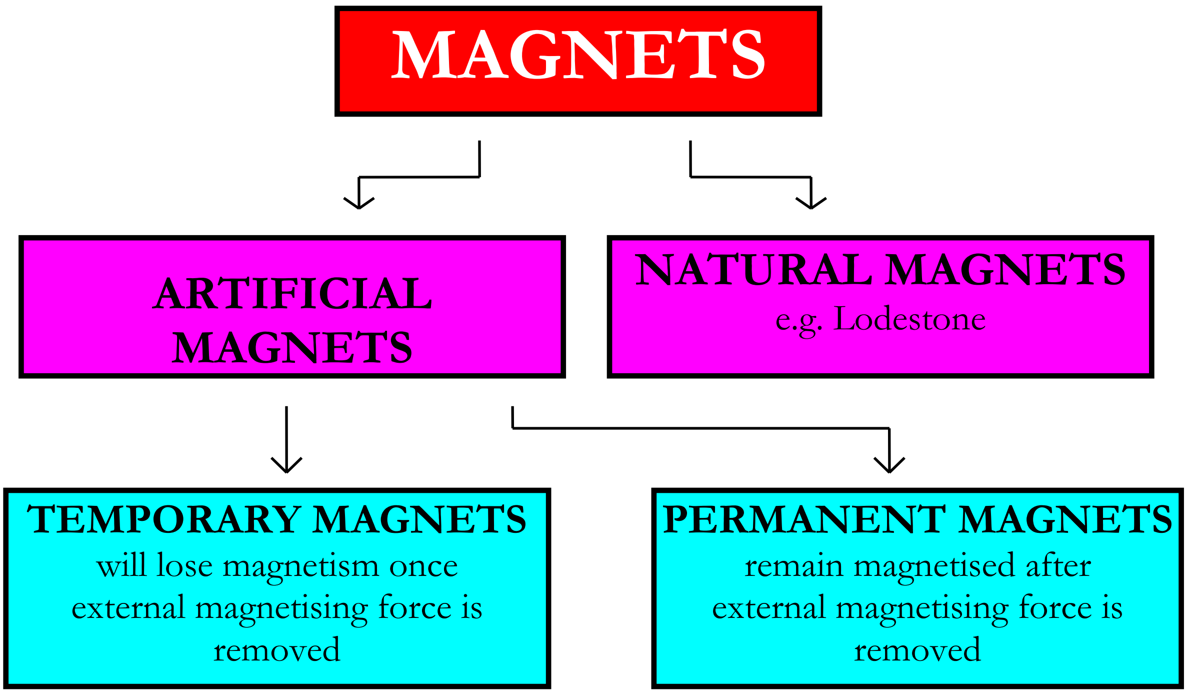
1 – Magnets & Magnetism

Magnets

It is believed that man's awareness of magnetism dates back 5 - 6000 years, when Asian shepherds discovered dark-coloured stones with mysterious properties.

These mysterious stones were later to be used for navigation, due to their property of aligning themselves so as to point in a North-South direction when suspended (one end always pointing North). This navigation by crude compass which first took place about 1200A.D. later gave rise to the name lodestone (=*way stone*). Lodestone is a natural magnet.

Naturally occurring lodestone is not among the world's most commonly used magnetic materials however due to its comparatively mild magnetic properties.



The chart above would suggest that the majority of commonly used magnets are artificial magnets - either temporary magnets or permanent magnets.

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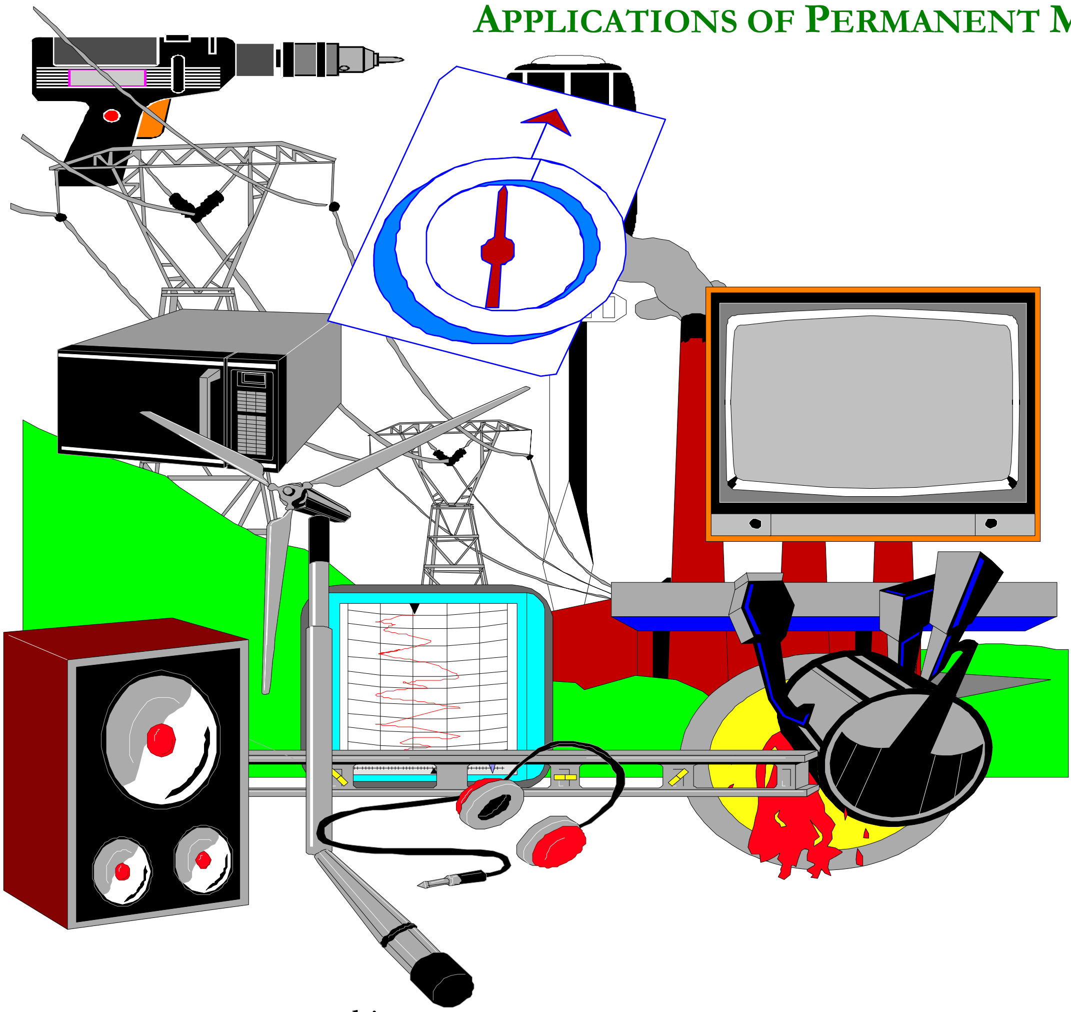
PERMANENT MAGNETS

Permanent magnets are really temporary magnets that require a great deal more energy to demagnetise them than their temporary counterparts. Permanent magnets are generally constructed from "magnetically hard" * material.

APPLICATIONS OF PERMANENT MAGNETS



Permanent magnets are used in:

Compasses, motors, generators, tachometers, door latches, magnetic tools, separators, control devices, magnetic bearings, sheet floaters, speakers, moving-coil instruments, water treatment, magnetrons, televisions, metallurgy, lifting hot steel and probably quite a few other applications.

*hard to magnetise but retain strong magnetic properties once magnetising force is removed.

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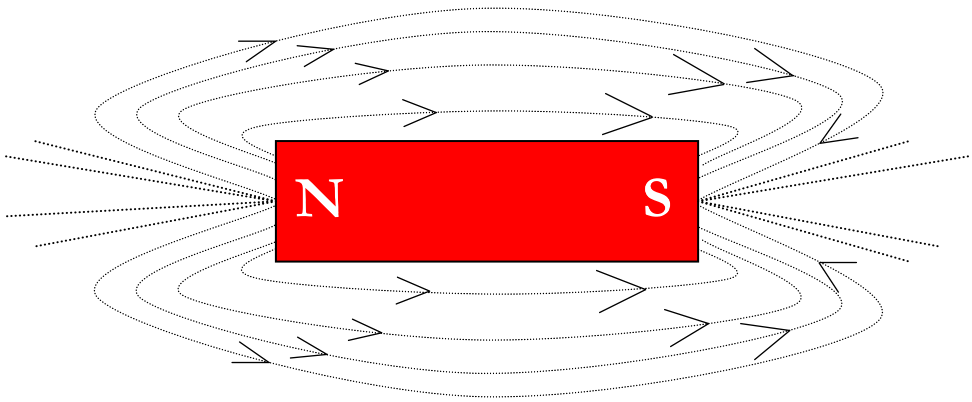
The following illustration represents the magnetic field that exists around a bar magnet:

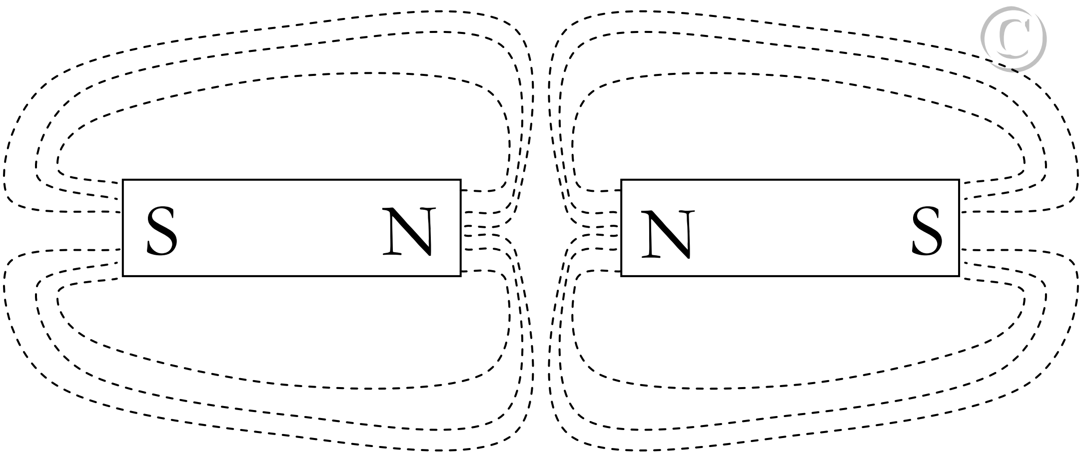


Lines of "**magnetic flux**" is the collective name given to the lines of magnetic force illustrated in the picture above, and by the iron filings in Fig. 2.1 on Page 12 of "Electrotechnology..".

Lines of flux have several properties:

- They never cross;
- Elastic in quality;
- Cannot be broken, but can be diverted (Shielding);
- They always take the path of least reluctance;
- They always try to shorten;
- From concentric circles;
- They exit from the North pole and re-enter through the South pole; and
- Travel from South to North inside the magnet.

The Fundamental Law of Magnetism:
Like Poles Repel
Unlike Poles Attract

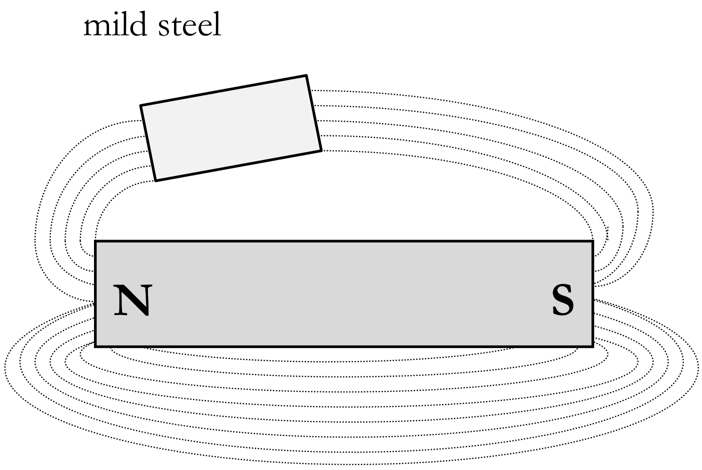


Like Poles Repel

INDUCED MAGNETS

An "induced magnet" is the name given to a temporary magnet which has magnetism induced in it by its proximity to a magnetic field, even though no physical contact takes place.

A piece of mild steel for example, in the field of a magnet will have magnetism induced in it, this magnetism will only be temporary as the strength of the induced magnetism will be much less once the magnet is removed.



1. Indicate the polarity of the mild steel in the diagram above:

TEMPORARY MAGNETS

Temporary magnets are constructed from "magnetically soft" materials - they are easily magnetised but retain very little magnetism once the magnetising force is removed.

Useful temporary magnets are usually in the form of electromagnets, and in many cases this ready loss of magnetic properties is desirable.

ELECTROMAGNETS

2 ***Illustrate and explain Fig.s 2.18 and 2.22 on Pages 23/25 of "Electrotechnology – Principles and Practice"***

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Magnetic field plotted by a compass around a current carrying conductor	Hans Oersted's discovery and the "Right Hand Grasp Rule"

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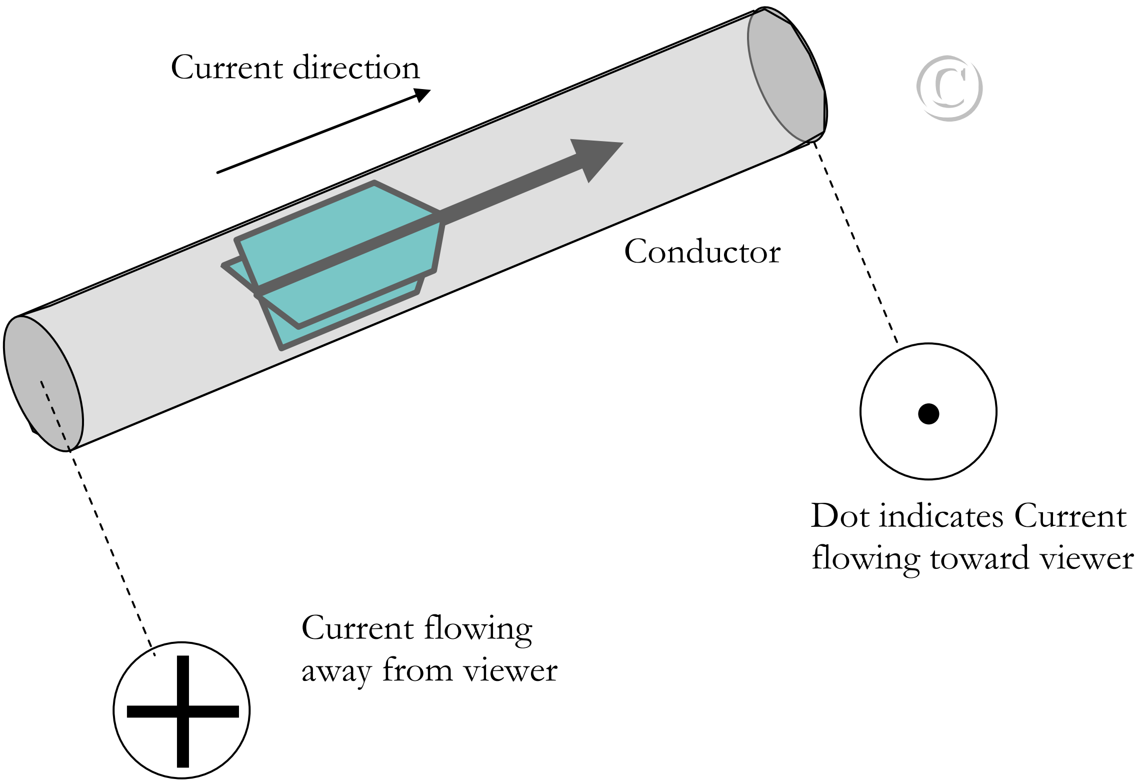
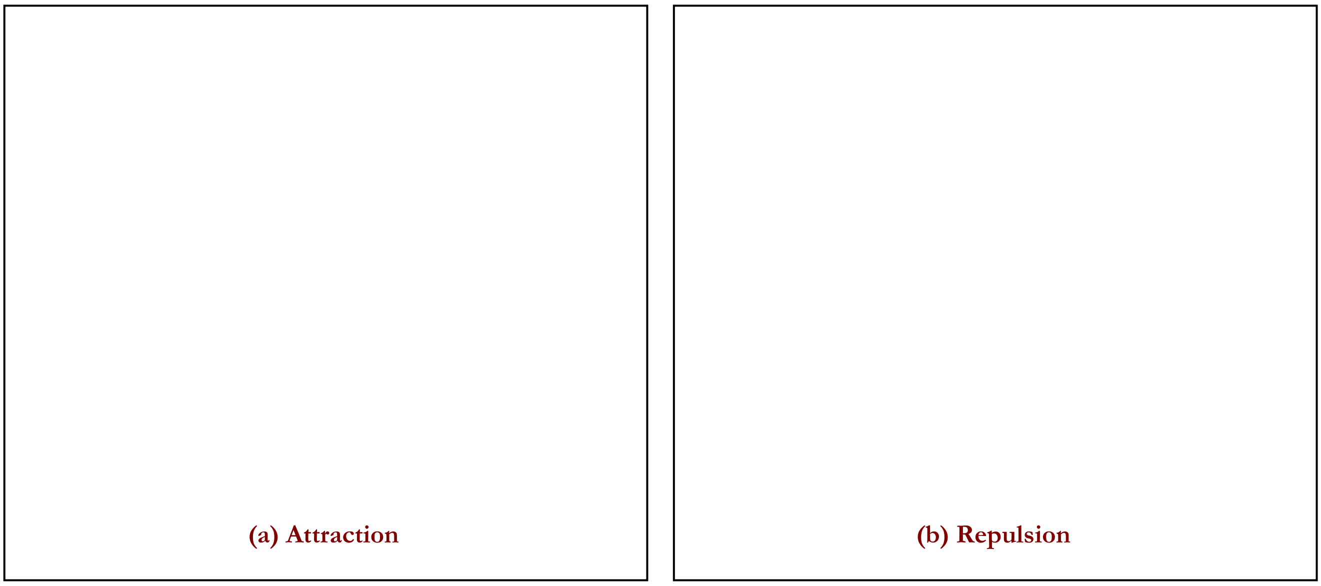


Current Direction Symbols

3. Reproduce Fig. 2.23 on Page 26 of "Electrotechnology…" in the spaces below:



Forces exerted by current carrying conductors

4. Reproduce and explain Fig.2.28 on Page28 of "Electrotechnology…" into the space provided below and explain:

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The "Right Hand Grasp Rule for Solenoids"

Commonly used electromagnets are constructed from a core of steel alloy (**Stalloy**) for electric motors, transformers and contactors or a nickel-iron alloy such as "Mumetal", and a solenoid (coil of wire – typically copper) through which the current flows in order to set up a magnetic field that is greatly aided by the steel core.

STEEL ELECTROMAGNETS

Steel electromagnets are a major part of the electrical industry. They are employed in contactors and relays (for switching), are the major components of electrical motors, and find widespread use in transformers, which typically convert electricity from one voltage to another.

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MAGNETIC PROPERTIES

HYSTERESIS LOOP

hysteresis - Lagging of magnetic induction behind the magnetising force.

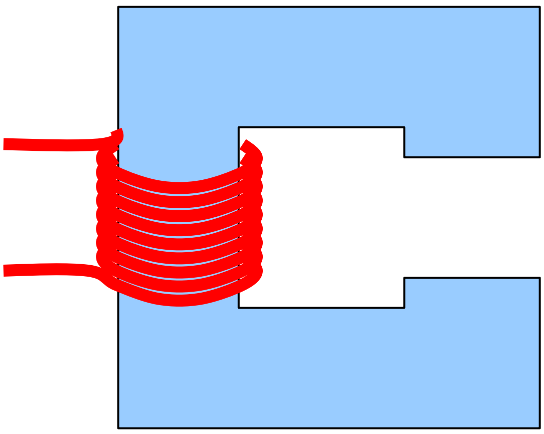
Two things that separate magnetically soft material from magnetically hard material are :

1. the amount of magnetising force required to magnetise the material; and
2. the amount of magnetism remaining in the material once the magnetising force has been removed.

As all magnetic materials (hard and soft) require/exhibit varying degrees of these two properties it makes sense for us to describe all magnetic materials in terms of their "hysteresis".

We will only consider electromagnets in our discussion, although induced magnets could be included.

The strength of an electromagnetic field is, among other things, proportional to the number of turns on the coil (which is usually a fixed number), and the amount of current flowing through that coil. This would suggest that an increase in current through a coil around a piece of magnetic material would increase the magnetism of that material (the magnetic flux density).



A materials ability to be magnetised is its "**permeability**".
The opposition to being magnetised displayed by a material is known as its "**reluctance**". The flux density of the material will increase until any large increase in the magnetising force has little or no effect on the flux density, at this point the material is said to be "**saturated**".

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A. When no current flows through the coil of an electromagnet it has no "**flux density**" (ie. it is demagnetised).

B. When we turn the d.c. current supplied to an electromagnet "ON", a current will flow through the conductor and set up a magnetic field around that conductor. If we increase the current value the flux density (the number of lines of flux in a given area) will increase also.

C. The more we increase the current value however the less noticeable the change in flux density, until any large increase in "**magnetising force**" has little or no corresponding increase in flux density. At this point the electromagnet is said to be "**saturated**".

D. If we now decrease the supplied current the flux density will reduce.

E. If we now turn the current "OFF" the material will still retain a certain amount of **"residual magnetism"**, this is also known as **"remanence"**.

F. The ability of a metal to retain magnetism after the magnetising force has been removed is known as its **"retentivity"**. Magnetically soft materials have a low retentivity, while magnetically hard materials have a high retentivity.

G. The simplest method of reducing the residual magnetism to zero is by applying a magnetising force in the opposite direction. This is known as a "**coercive force**".

H. If we continue to increase the magnetising force in this "opposite" direction the material will reach saturation again -polarised in the opposite direction.

I. A decrease in the current supplied to the electromagnet will cause the magnetic flux density to decrease again until only the residual magnetism remains.

J. A coercive force applied in the original and opposite direction will return the magnetic flux of the material to "zero" again.

K. Again if we continue to supply current after we have supplied enough to coerce the magnetic flux density back to "zero", the piece of material will become magnetised with the original polarity.

L. If we continue to increase the magnetising force in this direction the material will reach saturation again -polarised in the opposite direction.

This entire process above can be illustrated in a curve is known as a "hysteresis loop" but may also sometimes called a "B/H curve". Different magnetic materials have different shaped hysteresis loops. See the following Page:

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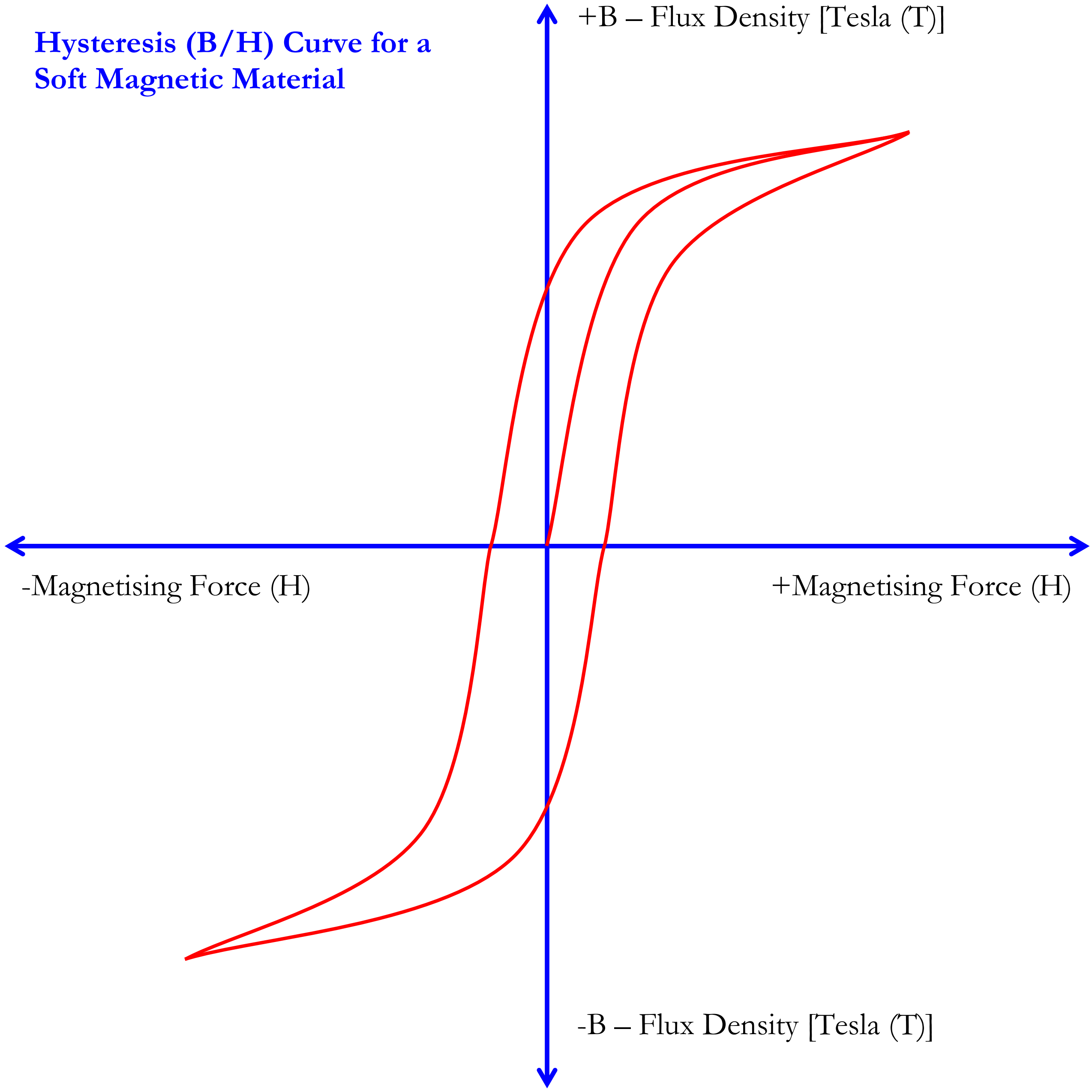
5. Indicate the areas defined by the letters on the previous page: - A, C, E, G, H, I, J, and L



An ideal electromagnet will be required to be magnetised very easily as soon as the power supply is switched on - it will then be required to lose its magnetism as soon as the power supply is removed.

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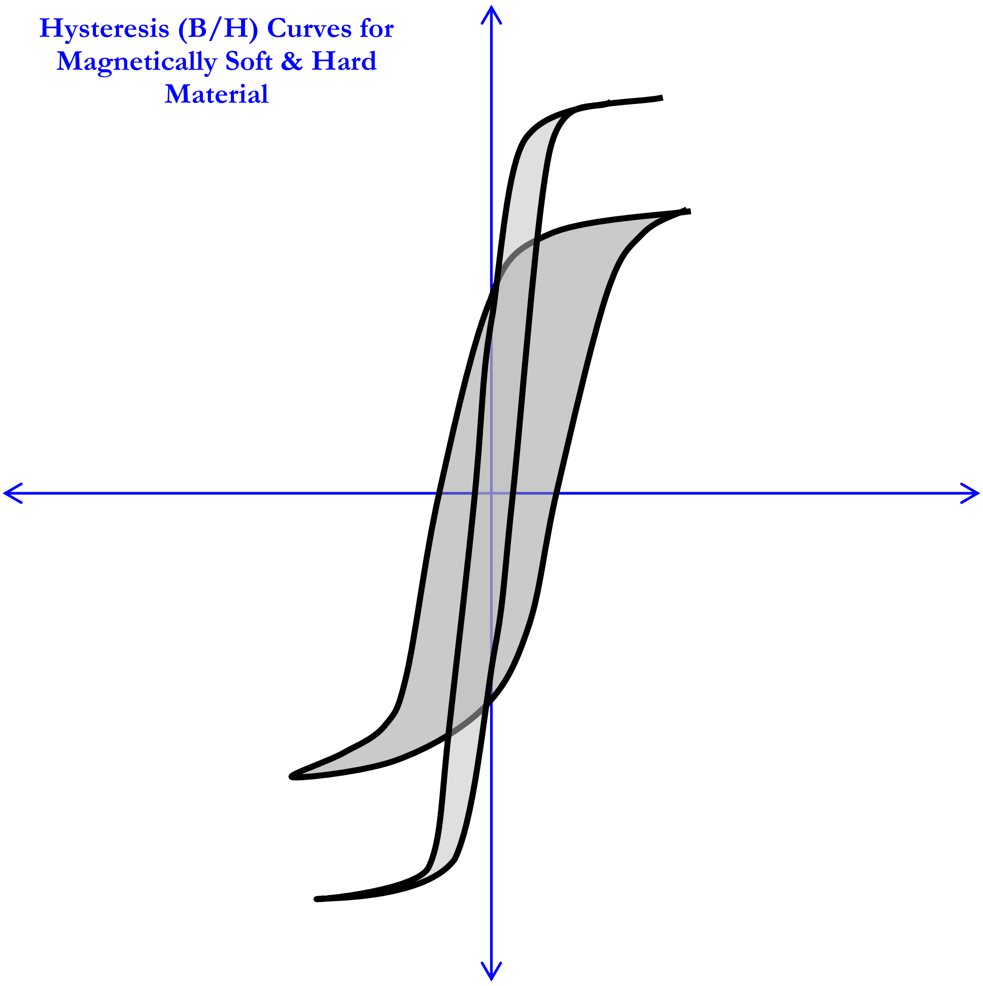
Any electromagnets supplied with alternating current (a.c.) are magnetised first in one direction and then almost instantly in the other direction. In New Zealand the electromagnet is probably required to switch polarity (N-S) 100 times every second.

The greater the coercive force required to achieve this rapid polarity changing, the higher the hysteresis losses, which will be given off as heat.

6 ***Label the axes and identify the typical hysteresis loops for magnetically soft and hard materials in the space provided below:***



HYSTERESIS EXPERIMENT

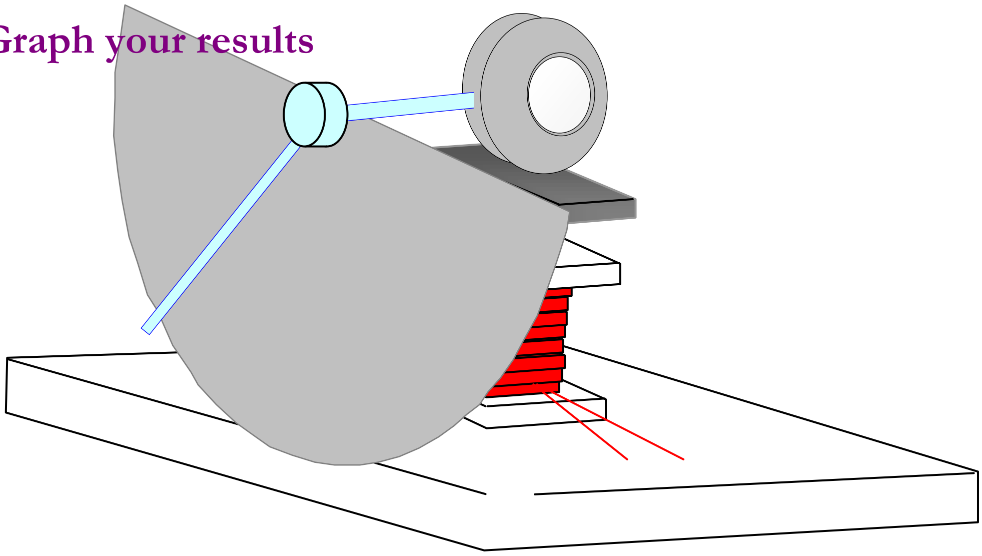
THIS CAN BE CARRIED OUT AT THE POLYTECHNIC

Aim: To observe hysteresis including saturation, remanence and coercive force as applied to magnetically hard and soft materials.

Equipment: Hysteresis Machine d.c. Power Supply

Method 1: **Carry out the experiment as outlined.**

Method 2: **Graph your results**



Method 1:

BE CAREFUL the permanent magnet used in this machine is fragile – DO NOT ALLOW STEEL TO COME IN CONTACT WITH THE PERMANENT MAGNET.

1. Carefully insert either the steel or the cast iron core into the coil.
2. Connect the d.c. power supply to the coil and increase the current values taking readings of both current and flux density at many regular intervals.
3. Continue increasing the current value until the core reaches saturation.
4. Reduce the current (take readings)until the current = 0.
5. Change the supply polarity and repeat steps 2,3 and 4. You must indicate the current is now in the opposite direction in your readings.
6. Change the supply polarity and repeat steps 2and 3. You must indicate the current is now in the original direction in your readings.

RESULTS: - STEEL

©

	B	I		B	I
1			26		
2			27		
3			28		
4			29		
5			30		
6			31		
7			32		
8			33		
9			34		
10			35		
11			36		
12			37		
13			38		
14			39		
15			40		
16			41		
17			42		
18			43		
19			44		
20			45		
21			46		
22			47		
23			48		
24			49		
25			50		

Unitec NEW ZEALAND Te Whare Wānanga o Wairaka

RESULTS: - CAST IRON

	B	I		B	I
1			26		
2			27		
3			28		
4			29		
5			30		
6			31		
7			32		
8			33		
9			34		
10			35		
11			36		
12			37		
13			38		
14			39		
15			40		
16			41		
17			42		
18			43		
19			44		
20			45		
21			46		
22			47		
23			48		
24			49		
25			50		

GRAPH:

Graph your hysteresis results here – try to use the whole page. Label the axes, indicate saturation, remanence and the coercive force.

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MAGNETIC SCREENING (SHIELDING)

Electromagnetic shielding - If a cable is run through one of the ferrite sleeves above, the sleeve will absorb electromagnetic energy emitted by the cable, and reduce the effect that the magnetic field set up by that cable has on the other electrical/electronic components in the immediate area.

Magnetic shielding - In areas where magnetic fields may adversely affect the operation of equipment containing magnetic materials, magnetic shielding/screening may be used to decrease the magnetic field strength in that immediate area. The theory is that a piece of equipment in a magnetic field surrounded by a magnetically soft material will be exposed to only a portion of this magnetic fields strength.

The soft magnetic material in the diagram above forms a "magnetic shunt" around the compass - this technique is employed in cathode ray tube shielding to reduce the effect of external magnetic fields on the electron beam.

ELECTROMAGNETIC DEVICES

©

7. Use the space on the following 4 pages to illustrate and explain the workings of FOUR electromagnetic devices – you must include any TWO of the following:

Loudspeaker, relay, electric bell, moving coil meter, lifting magnet and electric door lock.

8. Draw a diagram illustrating the construction of a transformer, and explain its operation:

Complete the following questions:

9. What is the difference between an induced magnet and an electromagnet?

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10. How would you describe the hysteresis loop of a magnetically hard material compared to that of a magnetically soft material?

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11. List FIVE practical applications of an electromagnet:

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12. Name TWO commonly used magnetic materials (Cast Iron is not one of them):

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13. What are "hysteresis"losses and why are they a problem?

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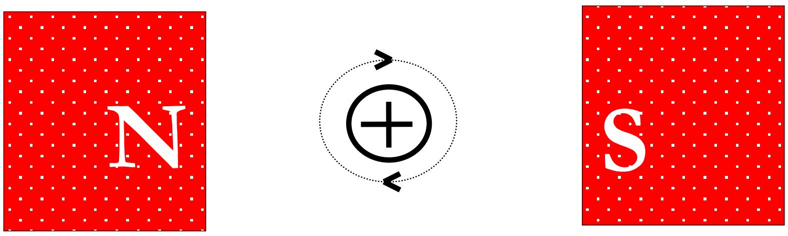
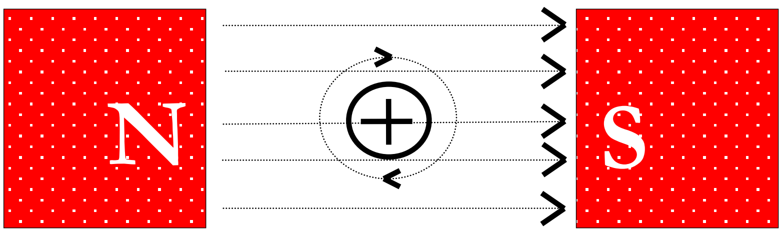
FLEMING'S LEFT HAND RULE FOR MOTORS ©

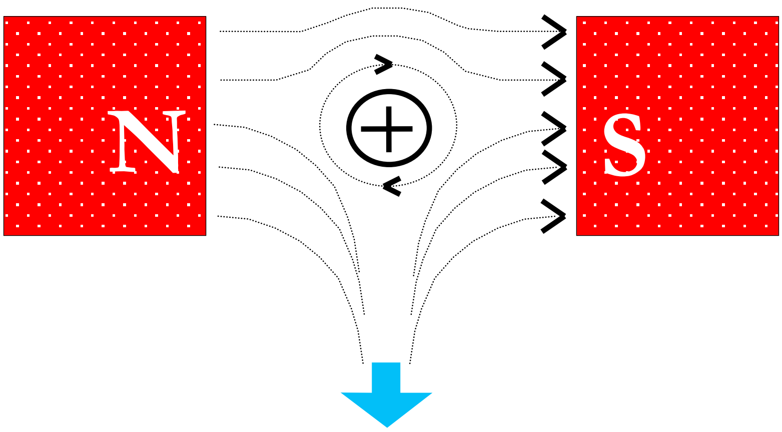
When a current carrying conductor is placed in a magnetic field, the electromagnetic field set up around that conductor reacts with the main magnetic field and will tend to move that conductor.



Circular electromagnetic field set up around conductor



Electromagnetic field and main magnetic field



The magnetic lines of force above the conductor are in the same direction and will combine and strengthen, the magnetic lines of force below this conductor are opposing and will tend to weaken - the conductor will move downwards in this case.

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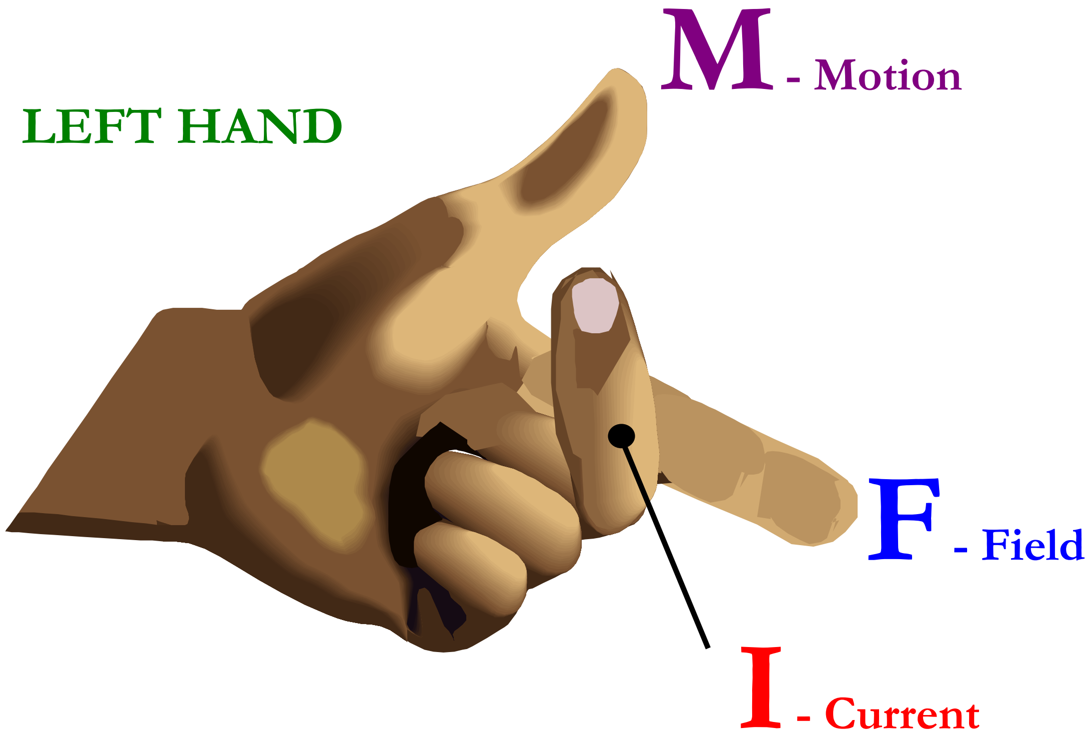
An easy method of determining the direction of the movement of a current carrying conductor in a magnetic field is the use of **"Fleming's Left Hand Rule© for Motors"**.



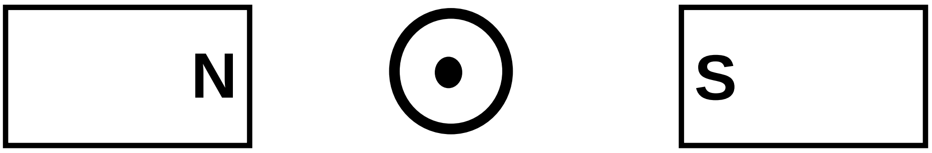
M- Motion -
this is the direction the conductor will move

F- Field - (magnetic)
this finger points from North to South

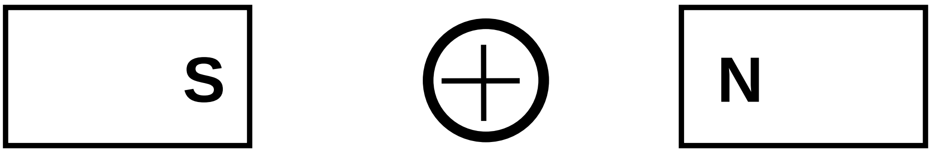
I - Current -
this finger points in the direction the applied current is flowing

14. ***Indicate the direction of movement in the following diagrams:*** ©

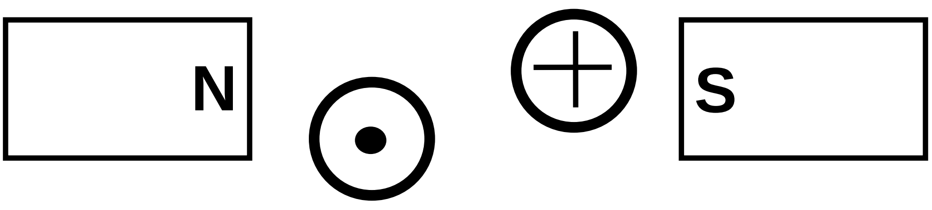
(a)



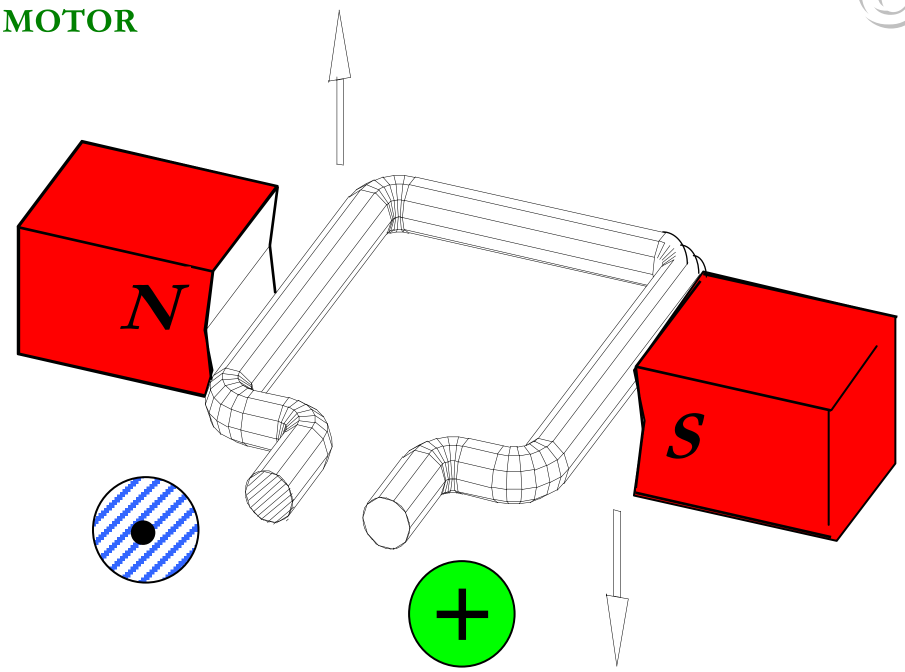
(b)



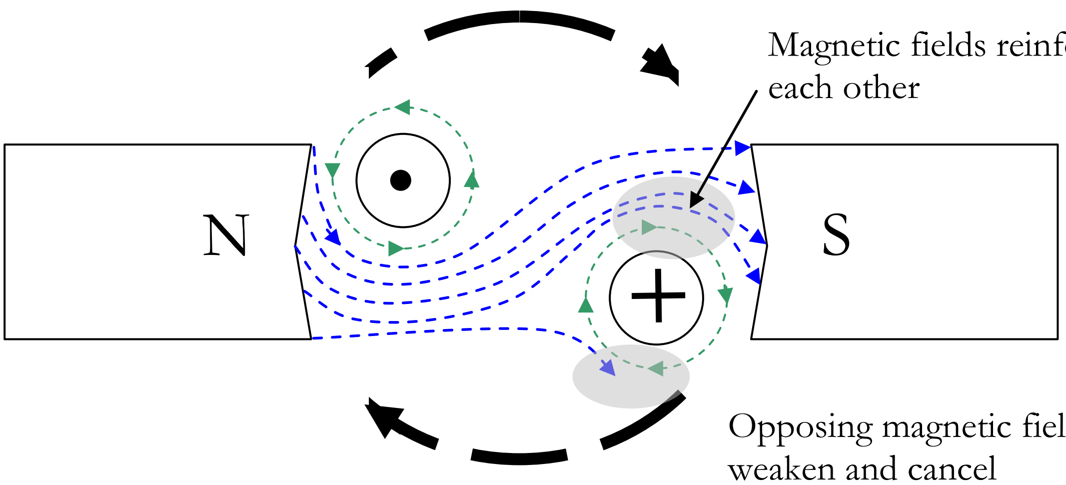
(c)



A SIMPLE MOTOR



When a current flows in the conductor above, a magnetic field is set up around that conductor that interacts with the main magnetic field. Rotational torque is produced as a result of this reaction.



How Torque is produced in a single loop coil motor

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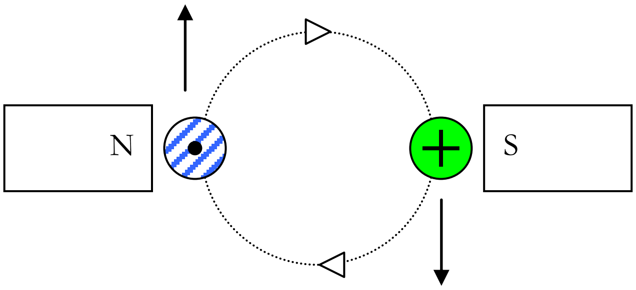
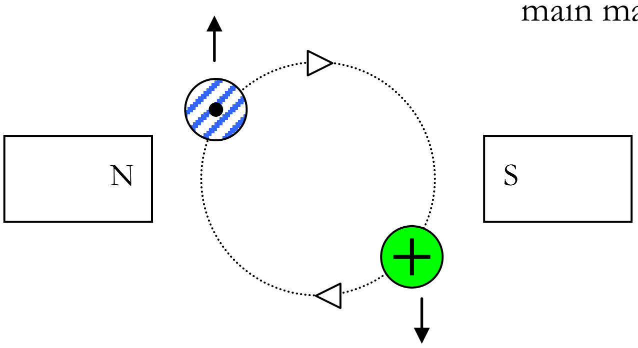
Look at what happens when the armature rotates in the magnetic field:

A.

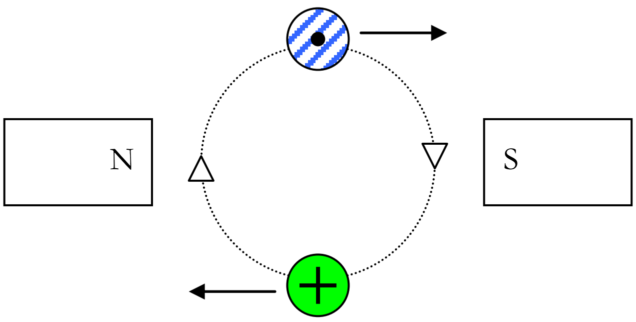


In **A.** and **B.** the magnetic field set up around the conductor will react with the main magnetic field and produce torque.

B.

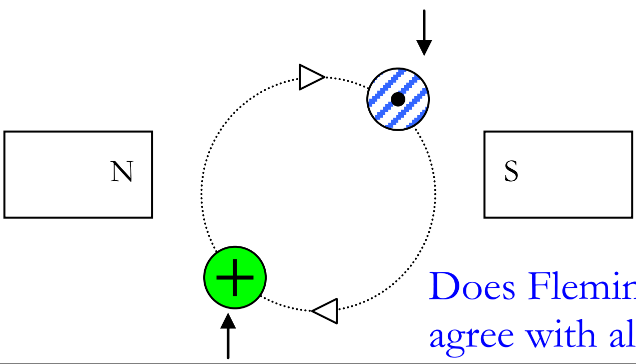


C.



The armature will continue to rotate due to inertia

D.



Does Fleming's Left Hand Rule for Motors agree with all of these diagrams.?

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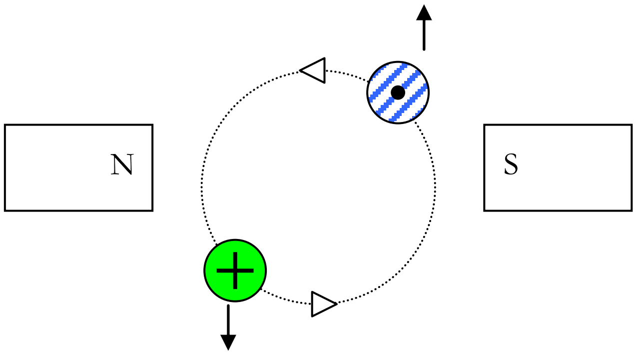
Careful inspection of Figure D. on the previous page would reveal a problem in the application of Fleming's Left Hand Rule for Motors to this diagram.

There is nothing wrong with the Rule however – the torque produced in Fig. D. would be in the opposite direction as shown below in Fig. D.2:

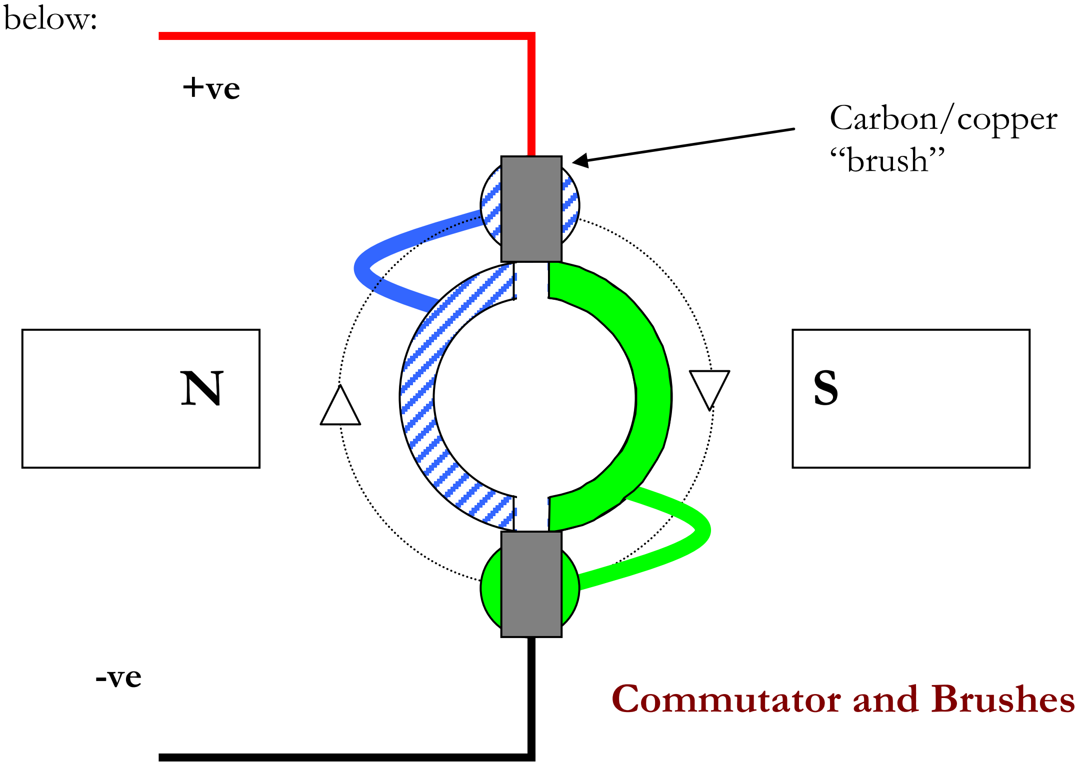
D.2



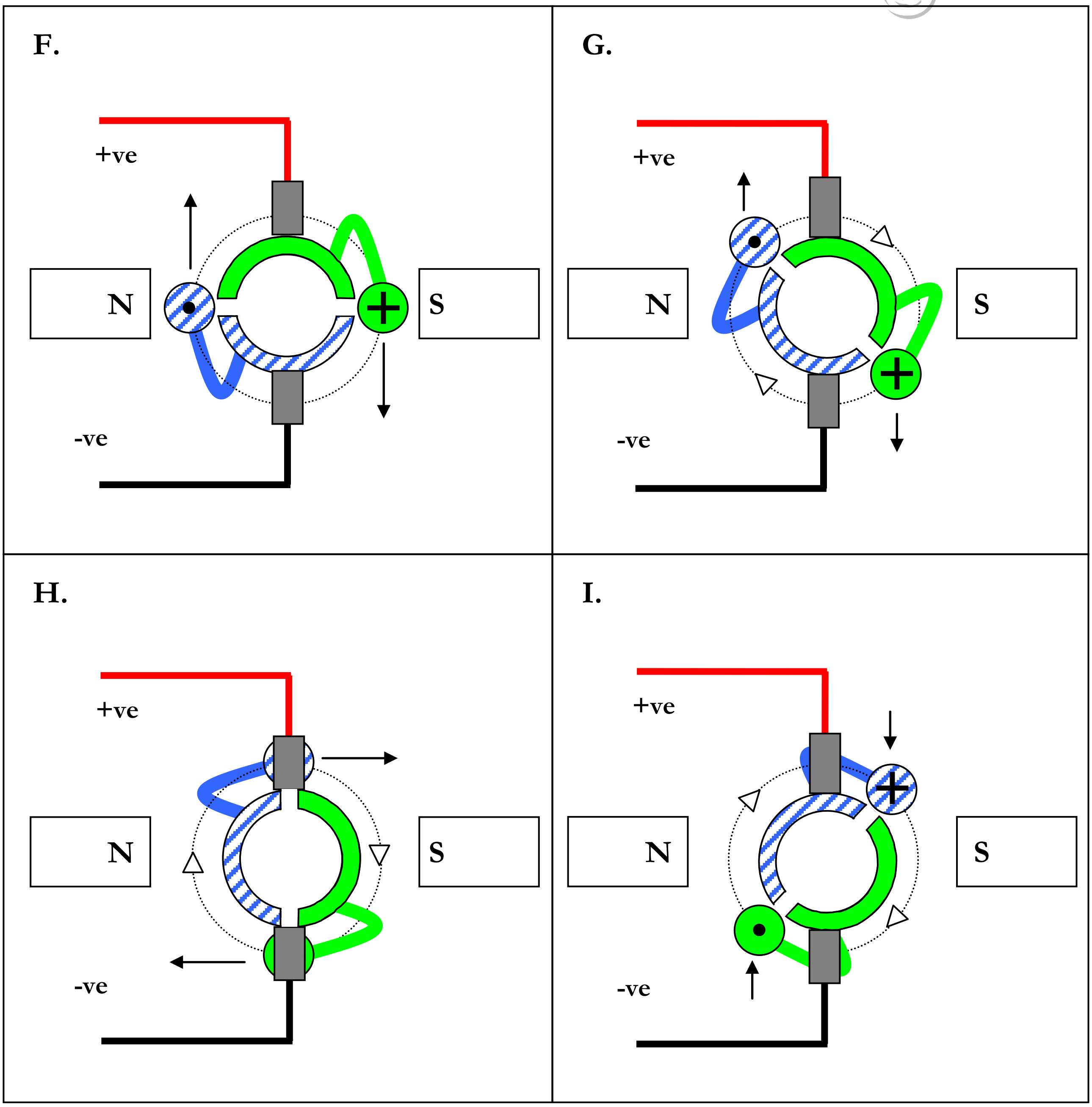
This motor would try to reverse direction every half turn – in fact it would just vibrate and heat up in position C. on the previous page.

The way to avoid this happening is to reverse the current through the armature when the armature passes position C. This is accomplished using a **"commutator"** as illustrated in Figure E. below:

E.



Figures F, G, H and I illustrate the action of a commutator.



Note how the current direction through the winding changes in Figure I. enabling the armature to continue rotating in its original direction.

The carbon brushes are soft compared to the copper "commutator segments", and will wear away eventually needing to be replaced.

The applied armature voltage controls the speed of this motor.

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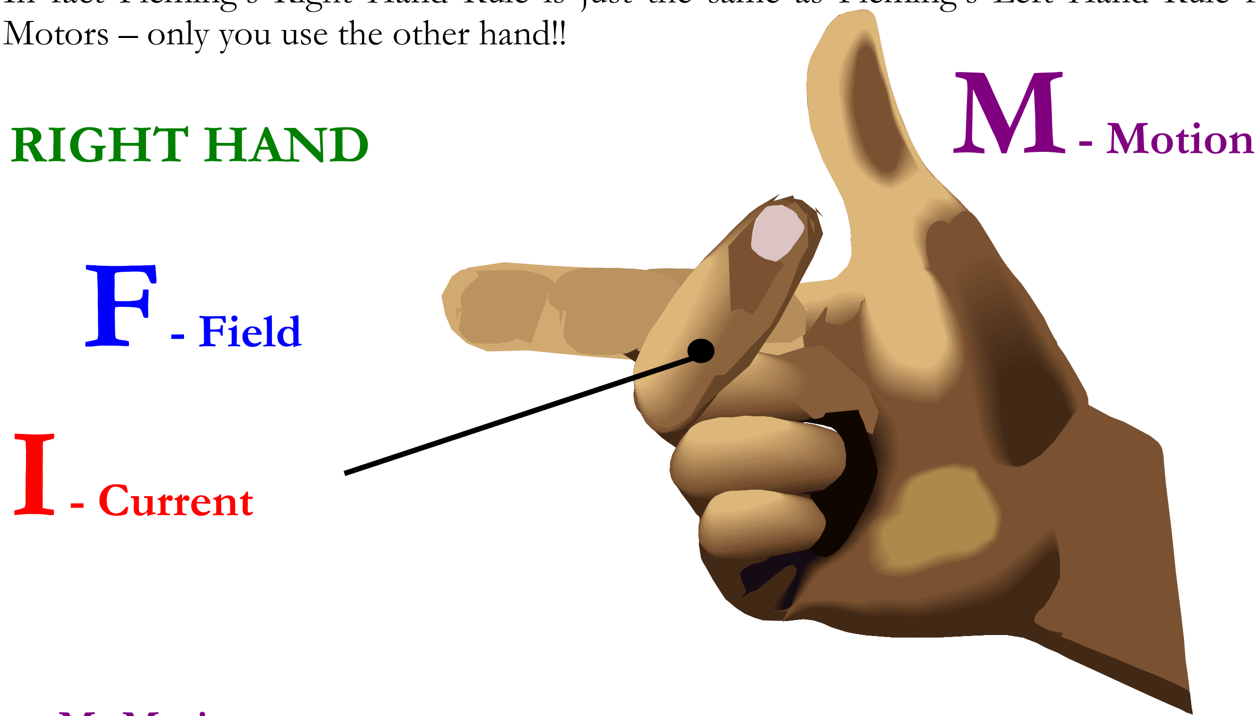
FLEMING'S RIGHT HAND RULE FOR GENERATORS

Obviously from the heading above Fleming has another Rule for Generators.

Just as current flow through a conductor sets up a magnetic field around that conductor; when a the magnetic field coupling a conductor changes in strength an EMF (electromotive force – measured in volts) is set up in that conductor, and, if that conductor forms a closed loop circuit – a current will flow.

This is how the majority of electricity for commercial use is produced (see Part 5 of this Manual). This process is known as "electromagnetic induction".

In fact Fleming's Right Hand Rule is just the same as Fleming's Left Hand Rule for Motors – only you use the other hand!!



M- Motion -
this is the direction the conductor is moved

F- Field - (magnetic)
this finger points from North to South

I - Current -
this finger points in the direction the induced current flows

This unit was written by A. Kawana and amended by Phil Plunkett 2009

ELECTROMAGNETIC INDUCTION EXPERIMENT ©

THIS CAN BE CARRIED OUT AT THE POLYTECHNIC

Aim: To draw conclusions relating to the movement of a conductor in a magnetic field similar to those drawn by Michael Faraday.

Equipment:

- Large Horseshoe Magnet
- Small Horseshoe Magnet
- 30 turn coil
- 80 turn coil
- Ammeter (large centreing)

Method 1: Select the "d.c amperes" and the "1mA" range on the ammeter.
Set the needle position so that it rests in the middle of the scale when there is no current flow.

Method 2: Determine what Faraday must have discovered by connecting the two different coils to the ammeter and carefully observing the reaction of the ammeter to different interaction between the coils and the magnet. Write it here:

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15. ***Devise a method of remembering which of Fleming's rules is for which application and write it here:***

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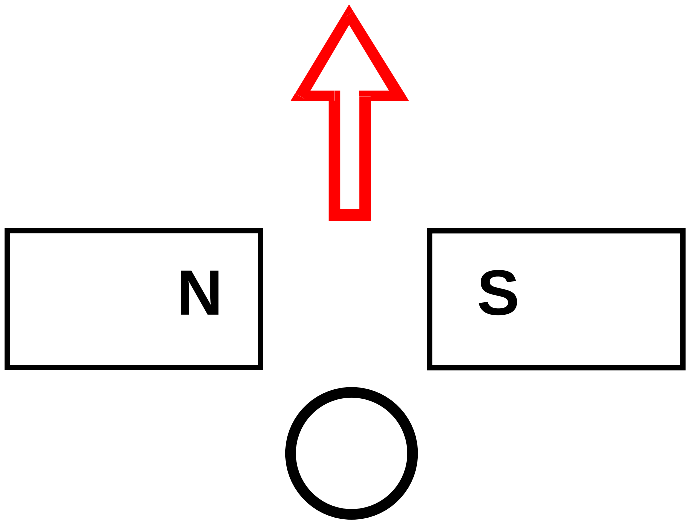
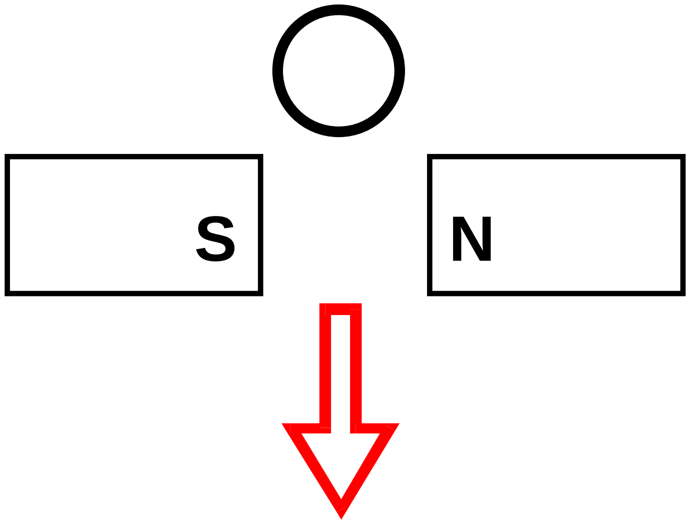
16. ***Indicate the direction that current will flow in the following diagrams:***

(a)



(b)

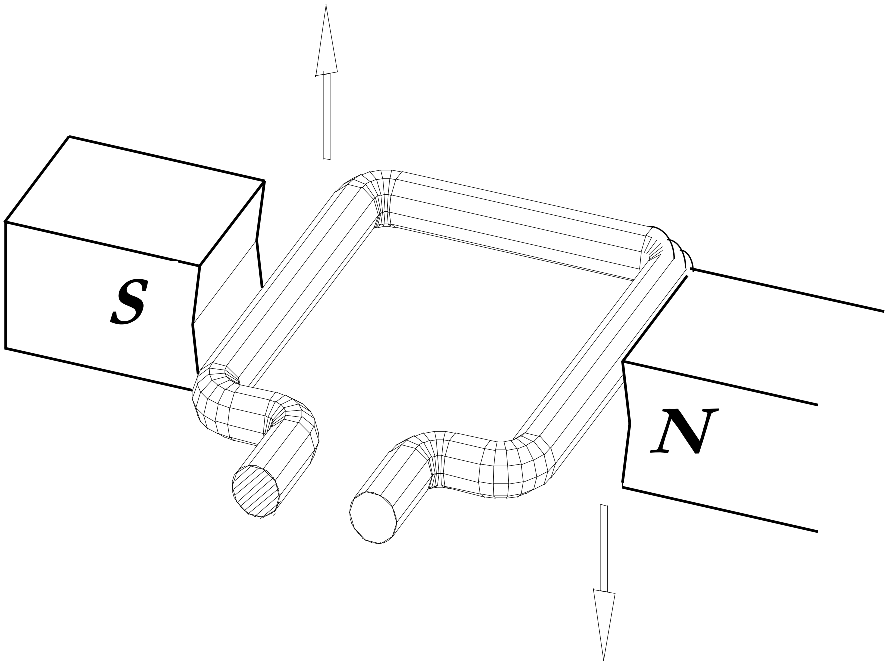


This unit was written by A. Kawana and amended by Phil Plunkett 2009

If two identical conductors moved at the same rate and angle through the same magnetic field, the same value of emf would be induced in each conductor. If those two conductors were connected in series the value of induced emf would be twice the value of the emf induced in one conductor.

Single loop conductor in a constant 2-pole magnetic field:

The emf that will be induced in a single loop conductor moving in a constant magnetic field will be double that induced in a single conductor. This is because the effective length of the magnetic field has been doubled.



The emf induced in a single loop conductor rotating in a constant 2-pole magnetic field can be determined using the equation:

$E = B.\ell.\nu.\text{Sin}\ \theta$

where :

E = induced emf (volts)

B = magnetic flux density (Teslas)

ℓ = effective length of the magnetic field (metres)

ν = velocity of the conductor (metres/sec)

θ = angle at which the conductor is moving (perpendicular is 90°)

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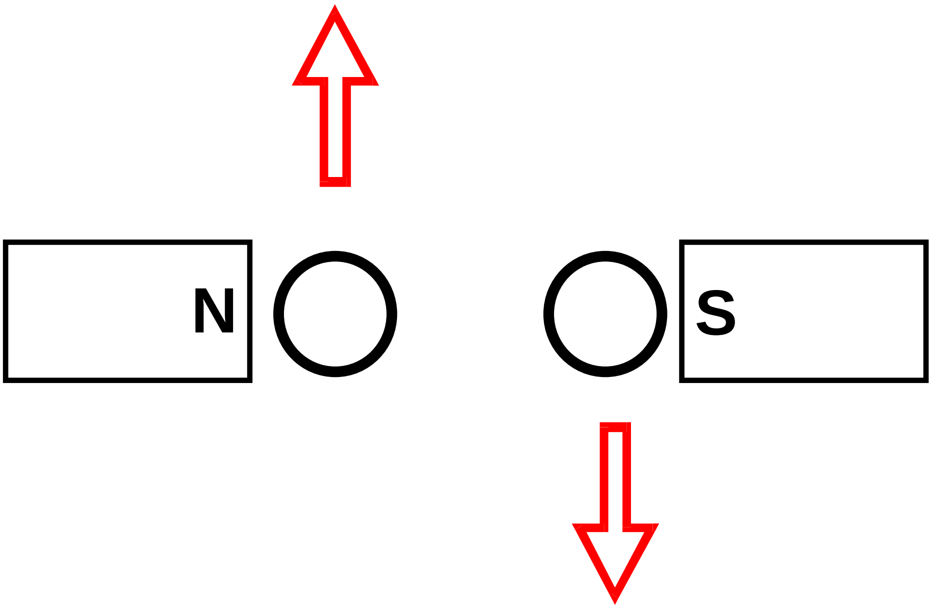
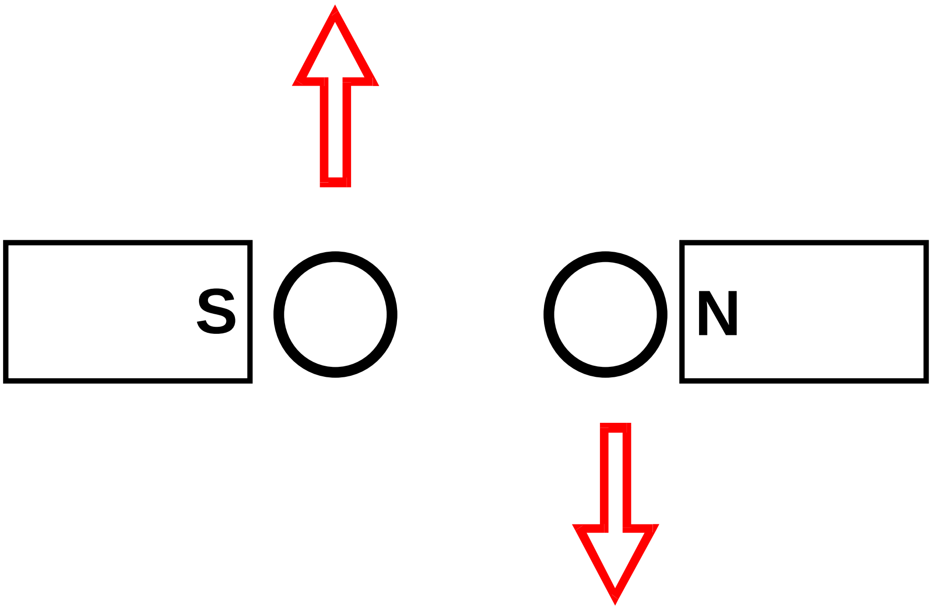
17. Indicate the direction of the induced current in the following diagrams:

(a)



(b)



18. What value of emf would be induced in this single loop coil at the instant it is shown at in this diagram, if the length of one of the magnetic pole faces is 5cm, the flux density is 0.8T and the conductor is moving at 12.5m/s? Indicate the direction of current flow on the diagram also.

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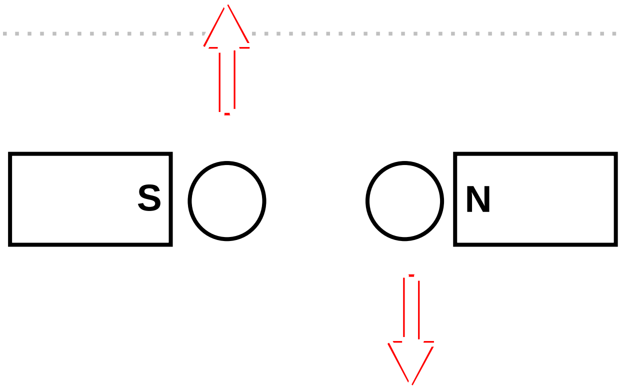

19. A loop coil will produce a sinusoidal (sinewave) output. What value of emf would be induced in this coil (the length of one of the magnetic pole faces is 8cm, the flux density is 0.6T and the conductor is moving at 10m/s) in the diagram below where the conductor is now moving at an angle 55° to the parallel?

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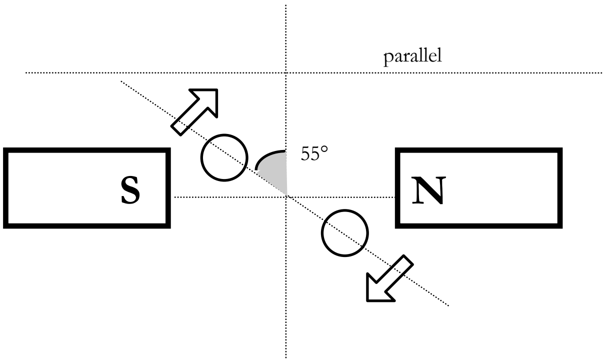
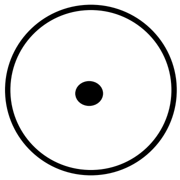
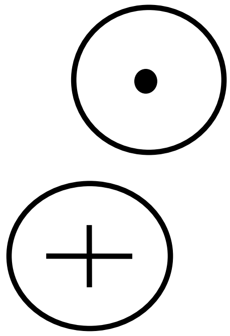


20. ***Indicate the direction of the magnetic field set up around these conductors:***

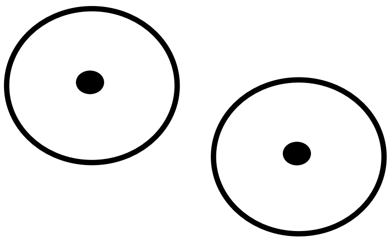
a.



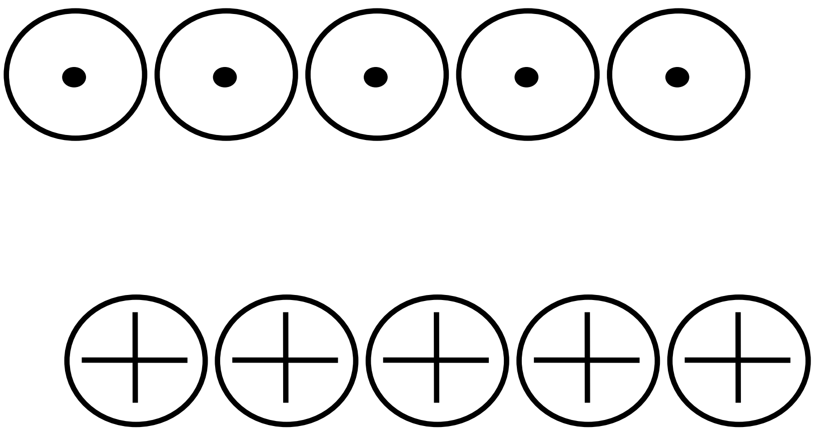
b.



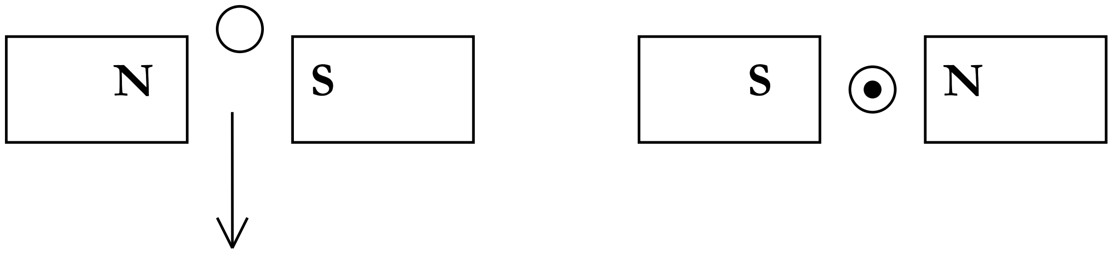
c.



21. ***Indicate the direction of the magnetic field set up around this air-cored solenoid:***



22. ***Which of the diagrams below is a motor and which is a generator?***



23. ***The flux density of an electromagnetic air gap between the two poles of an electromagnet is 1.2 Tesla. How fast would a single conductor have to move perpendicularly through that air gap to induce a voltage of 1 volt in that conductor? (The poles are 10cm long).***

Give your answer in kilometres per hour -

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24. ***How fast would a 120-turn coil have to move in the same airgap as in question 4. above to produce the same output voltage?***

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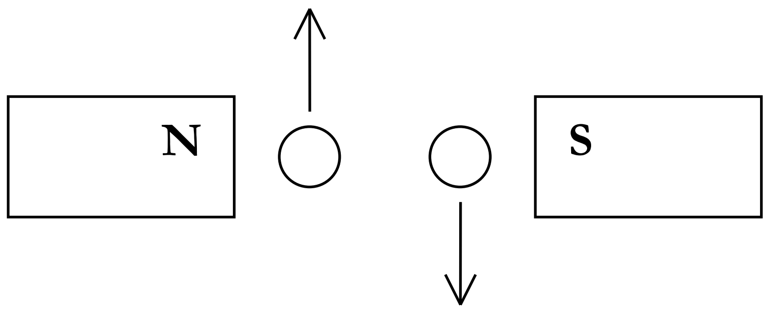
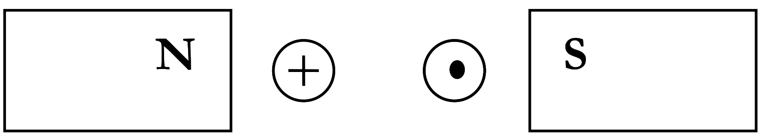
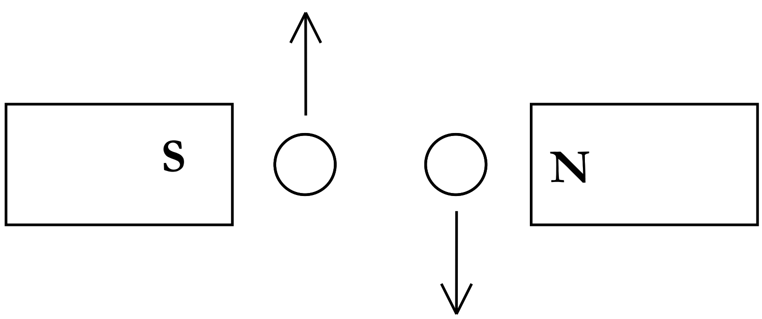
25. ***Which direction will current flow in the single turn loop coil in the diagram below - and which rule did you use?***



26. ***Which direction will the single turn loop coil in the diagram below rotate - and which rule did you use?***



27. ***Which direction will current flow in the single turn loop coil in the diagram below - and which rule did you use?***



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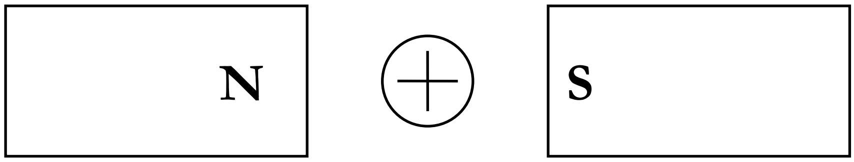
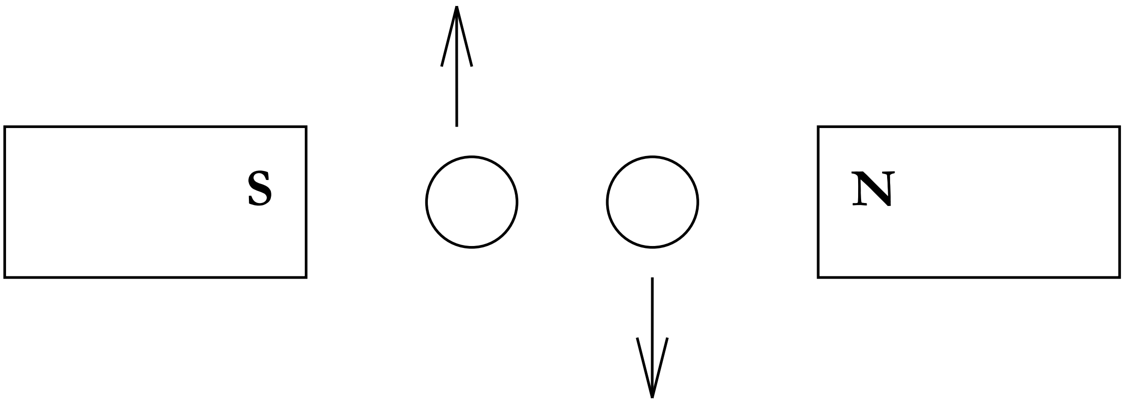
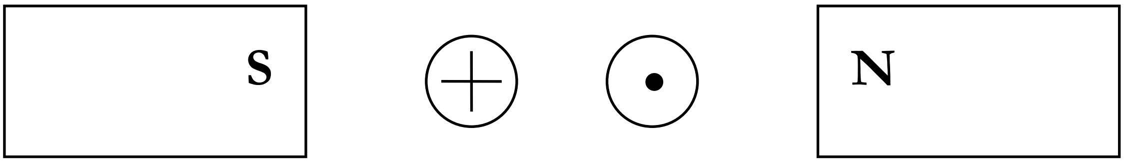
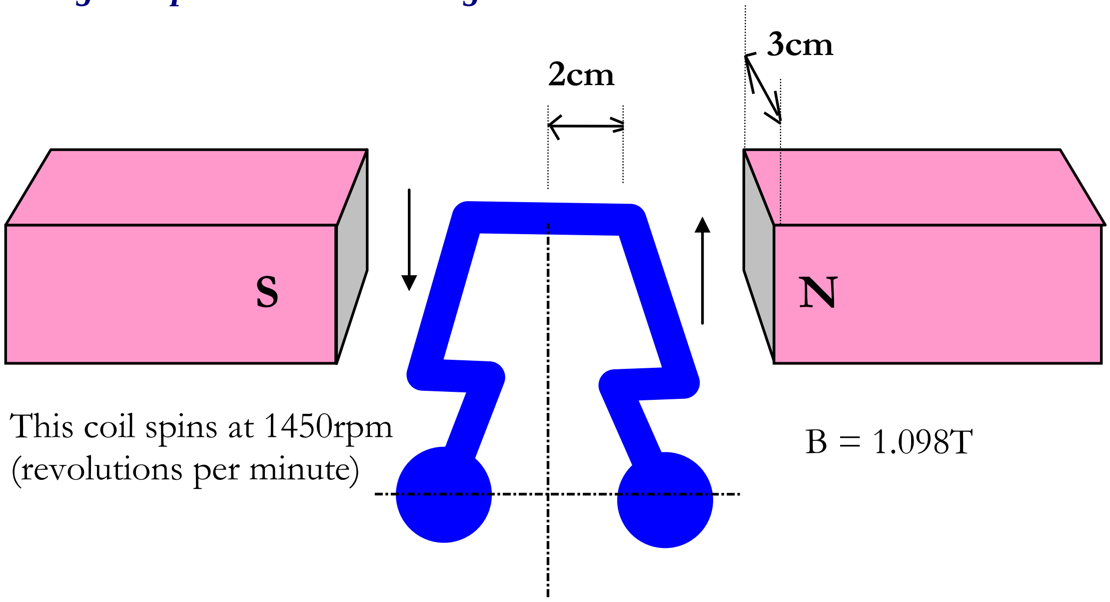
28. ***Indicate either the direction in which the conductor(s) will move or the direction of the induced current flow in each of the following diagrams:***







29. ***Indicate the direction and the magnitude of the instantaneous voltage induced in the single loop turn coil in the diagram below:***



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30. ***What instantaneous voltage would be induced in the coil above if it was moving at:***

a) 0 ° to the main magnetic field; b) 30 ° to the main magnetic field; and c) 45 ° to the magnetic field

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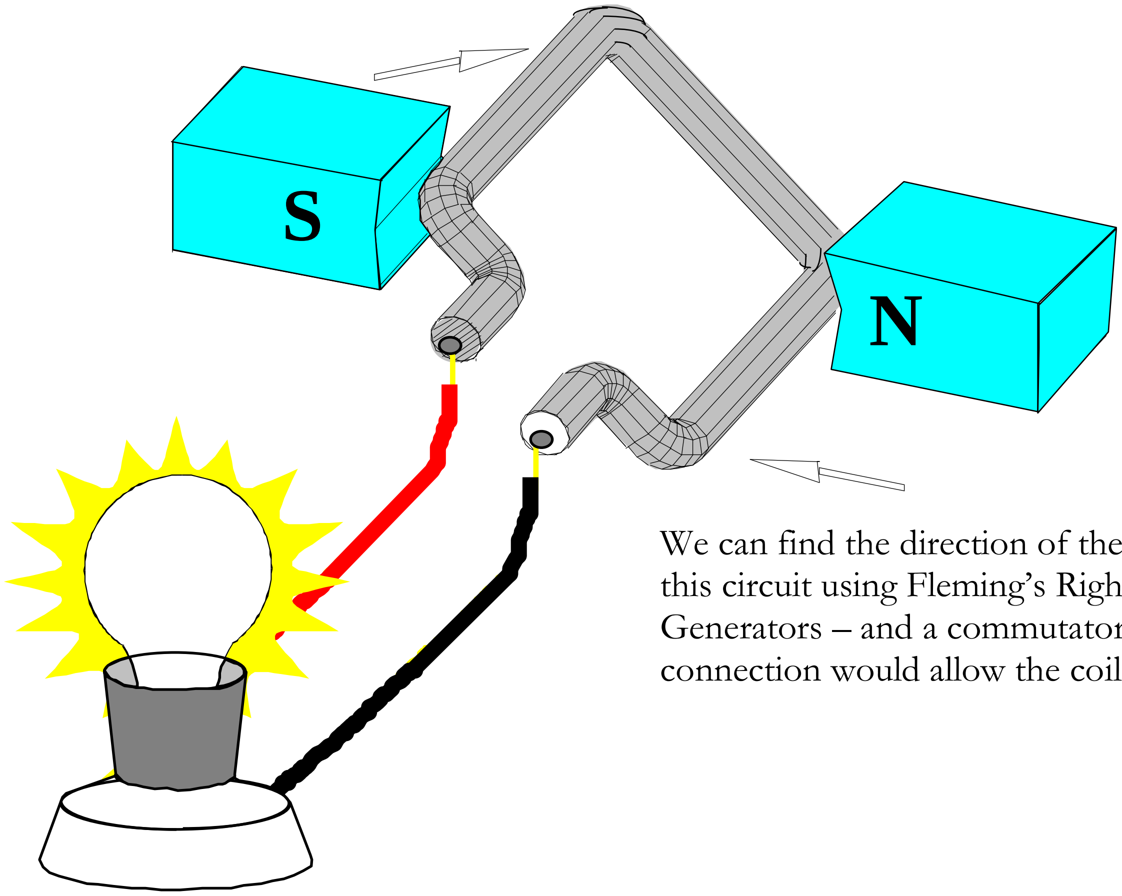
31. Answer the Questions from "Electrotechnology.." Chapter 2 on Page 35 here:

2 – Alternating Current (a.c.) Generation

A.C. GENERATION IN A SINGLE LOOP COIL

In Chapter 7 we introduced the theory of an emf being induced in a "single loop coil" as it rotates in a magnetic field. We also stated that current would flow through this coil so long as it formed a closed loop.



We can find the direction of the current flow in this circuit using Fleming's Right Hand Rule for Generators – and a commutator and brush connection would allow the coil to keep spinning.

A "slip-ring" type connection would also allow us to draw a current from the spinning coil of wire. There is an illustration of a simple slip-ring generator in "Electrotechnology…" Fig. 3.13 on Page 43.

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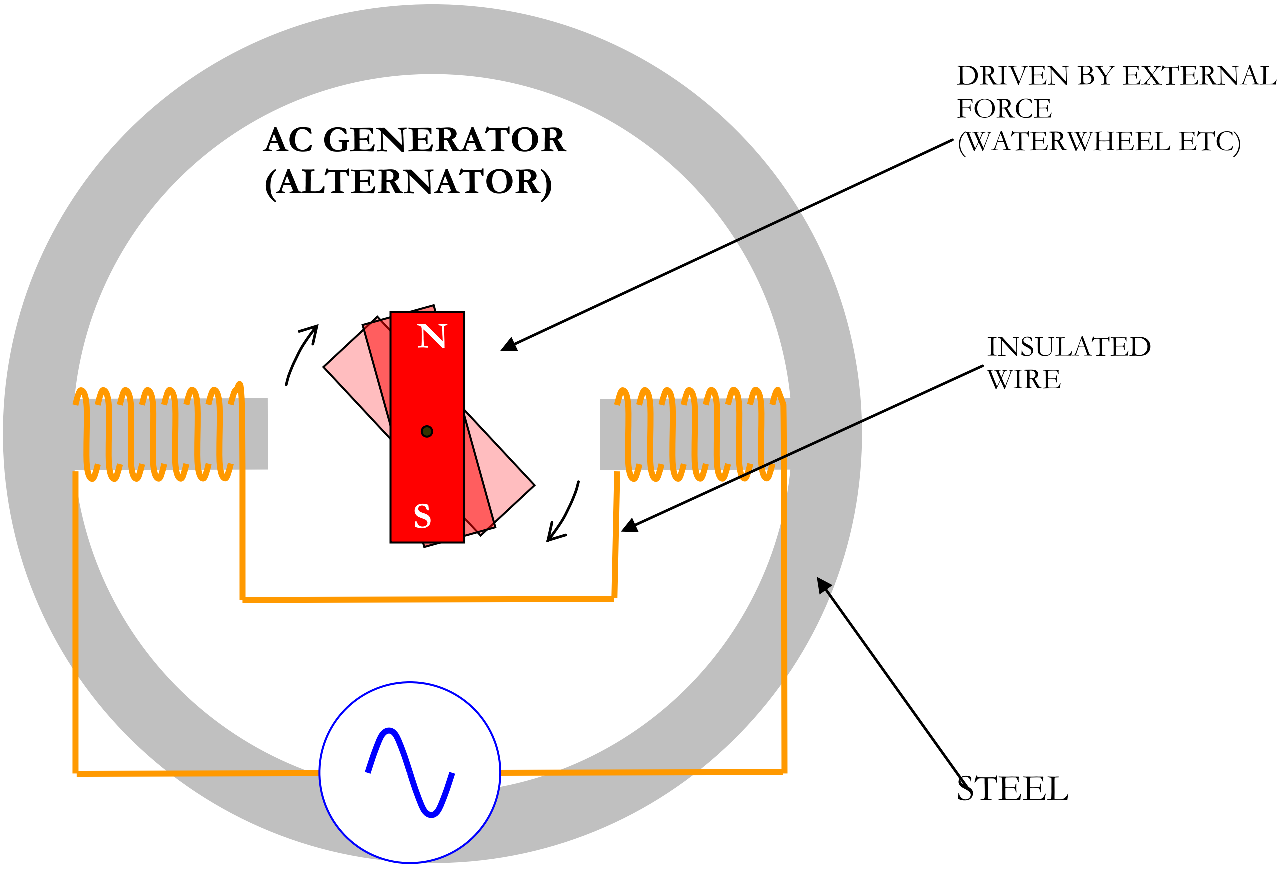
If we reverse the construction of our a.c. generator (alternator):

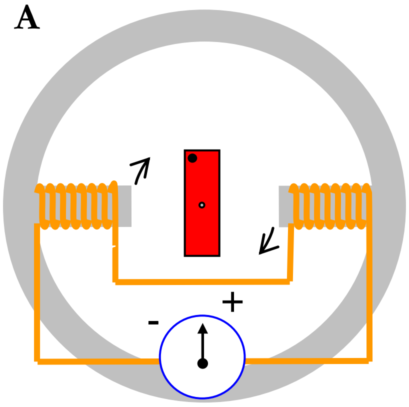
As the magnet moves away from the conductor the amount of induced EMF reduces. The direction the magnet moves, and the polarity (North-South) of the magnet determine the polarity and hence the direction of current flow induced.



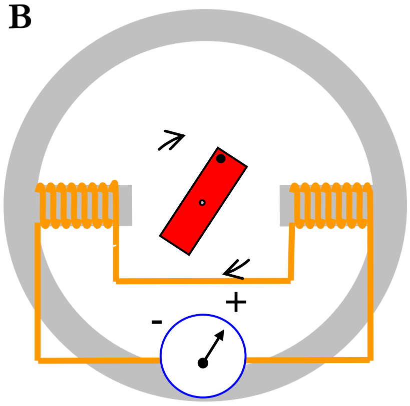
This results in the output from the generator being a sinusoidal (sinewave) voltage.

As the magnetic poles of the generator's rotor pass closest to the phase winding of the generator, the EMF and thereby the current induced in that phase will also be at a maximum (C & G), no EMF will be induced at A, E & I. See graph on following Page:

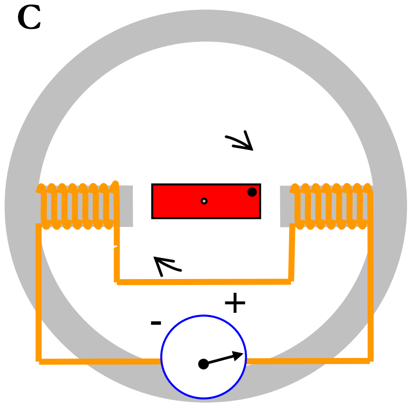
A



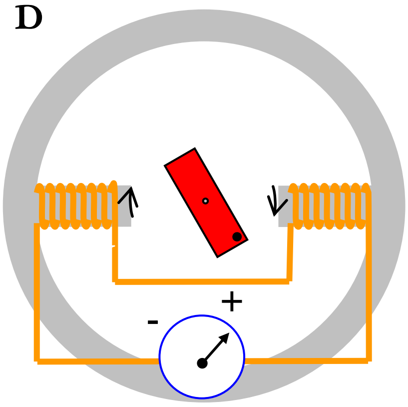
B



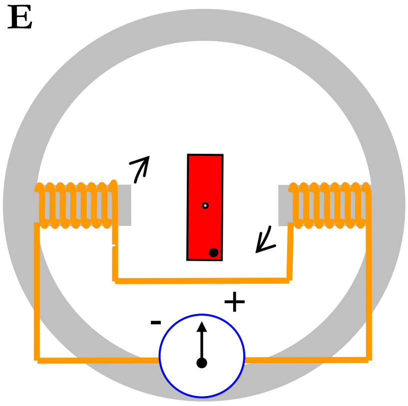
C



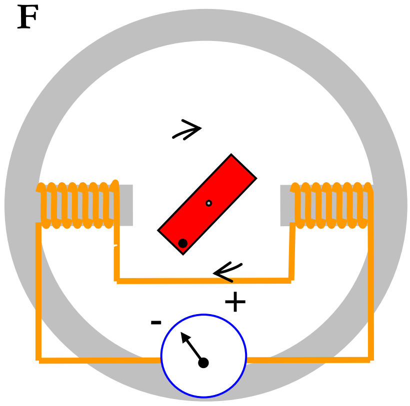
D



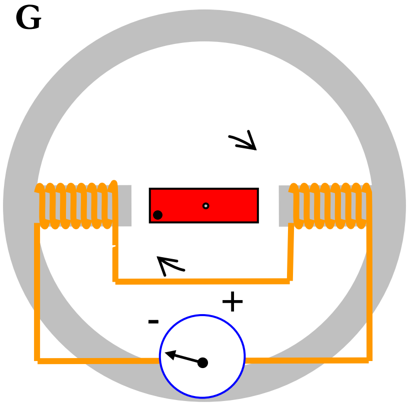
E



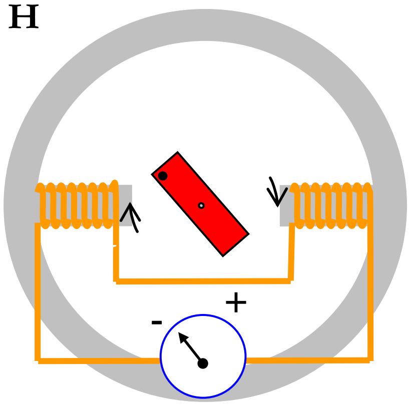
F



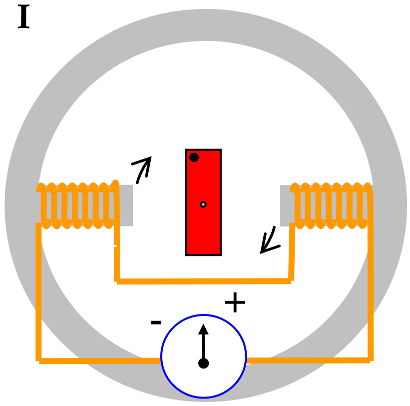
G



H



I



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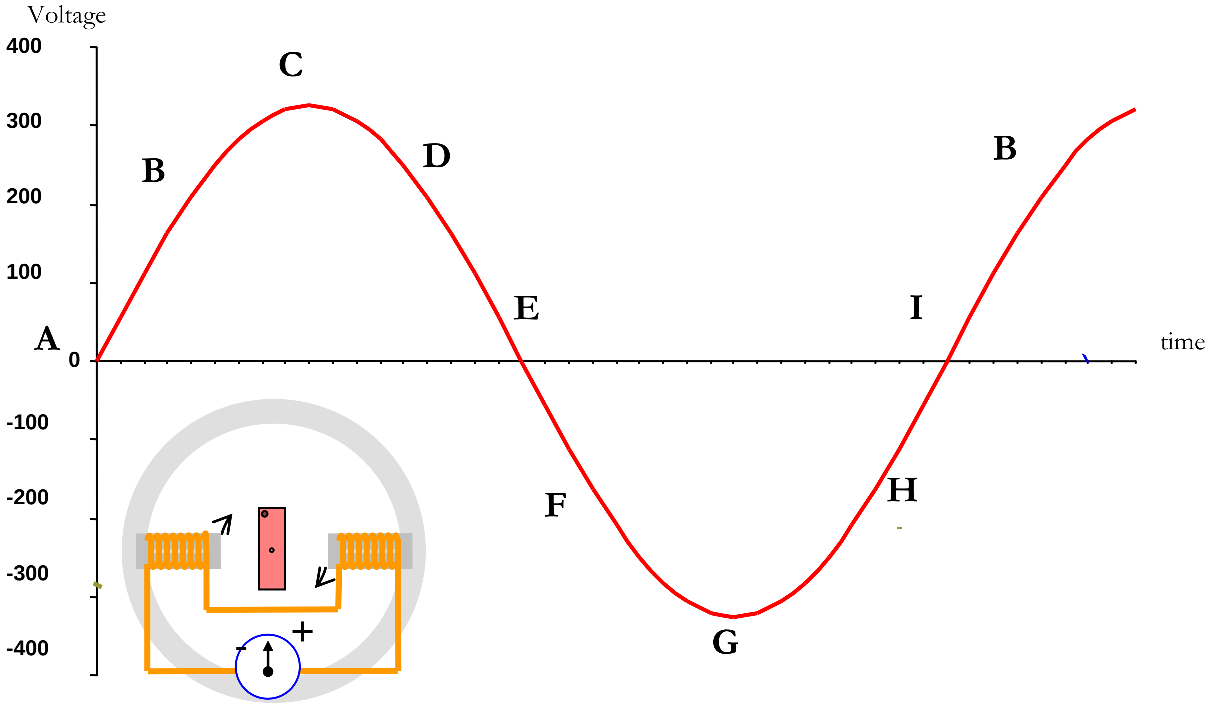
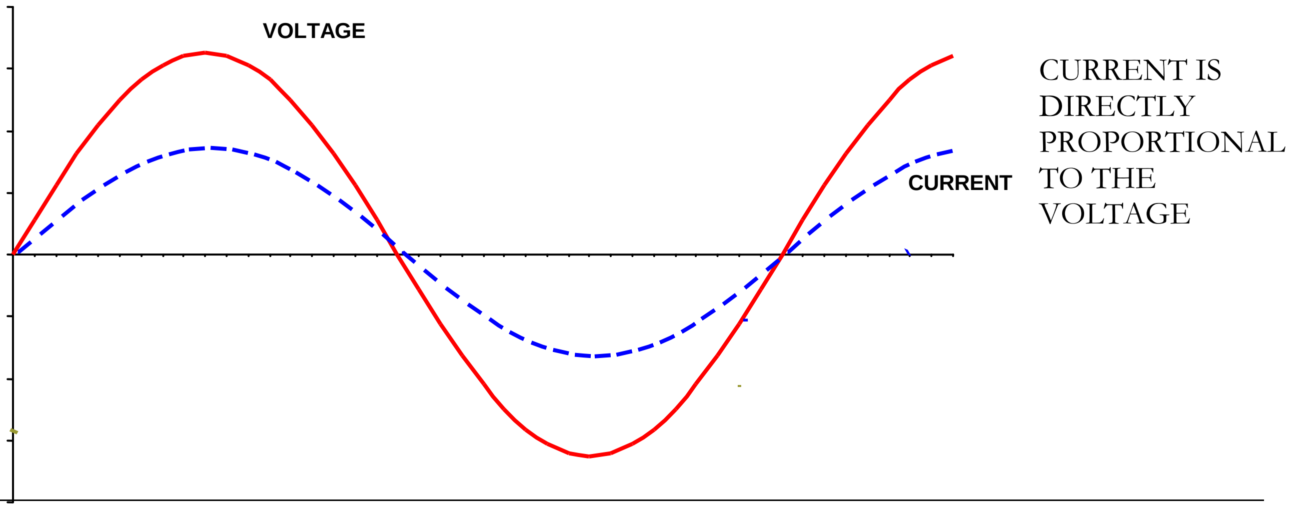
The output voltage from an a.c. generator (alternator) as illustrated on the previous Page is sinusoidal (a sinewave). The voltage produced depends on the Flux Density of the magnetic field produced by the magnet, the number of turns on the two coils and the speed at which the rotor is moving.



As you can see - half of the time the voltage produced is positive and the other half of the time the voltage is negative. Since Ohm's Law says that current is directly proportional to the voltage we must be able to safely assume that the current in an a.c. circuit flows from Phase-to-Neutral half of the time, and from Neutral-to-Phase for the other half, See below:



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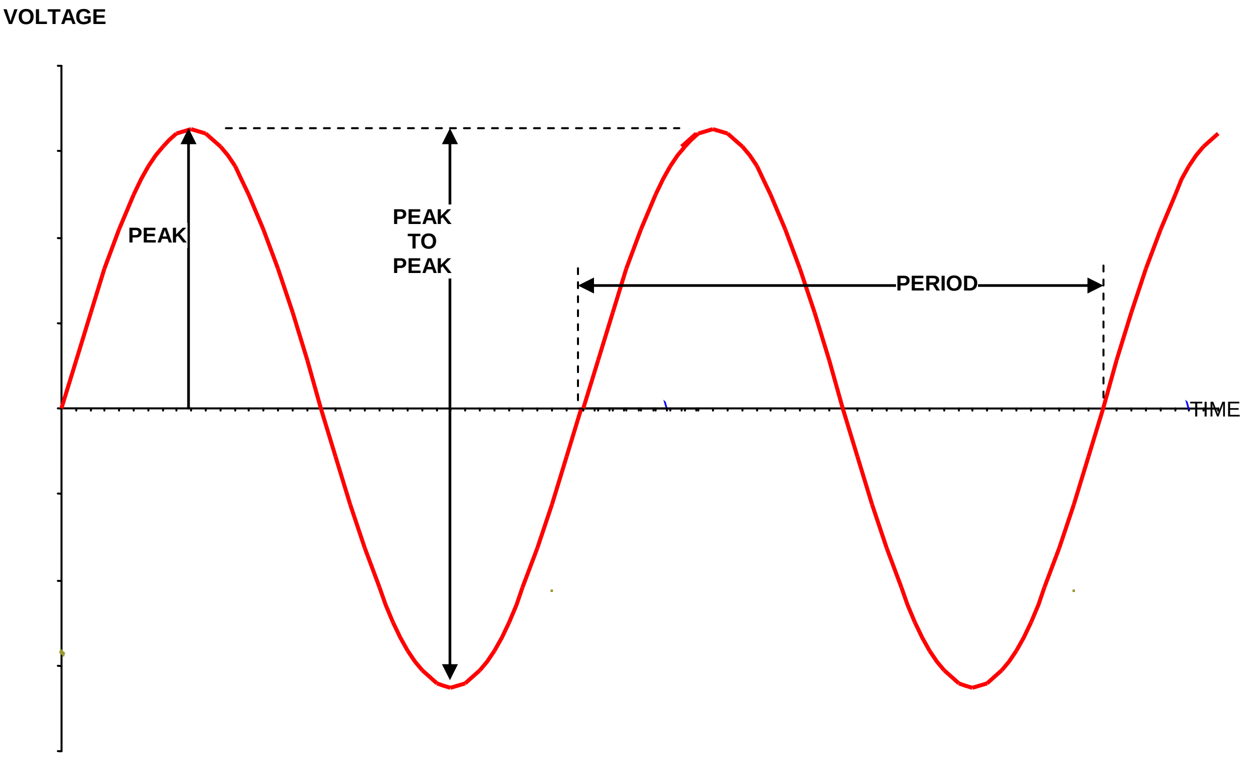
One **cycle** is the output of a process that happens before the process repeats itself.
One **period** is the time taken for one cycle, this is also the time taken for one complete revolution of the alternator. Period is measured in seconds (s).
The **frequency** of the output is the number of cycles completed in 1 second. Frequency is measured in Hertz (Hz).
Electricity in New Zealand is produced at 50 cycles per second, the frequency of (50Hz) and this means one complete revolution of the alternator every 20 milliseconds.



The RMS Value

The electricity supplied to New Zealand homes and most other electrical installations is **230V RMS** - this means that the supply voltage is equivalent to 230V d.c. (ie. it has the same heating effect as would a constant 230V d.c.) and is therefore considered to be the **effective value** or the **equivalent d.c. heating value** . AC voltages and currents are always given in RMS unless stated otherwise, and the peak value of our 230V RMS supply voltage is 325V.

The RMS (root-mean-squared) or effective value of an ac sinewave can be calculated:

$$V_{RMS} = \frac{1}{\sqrt{2}} V_{pk}$$

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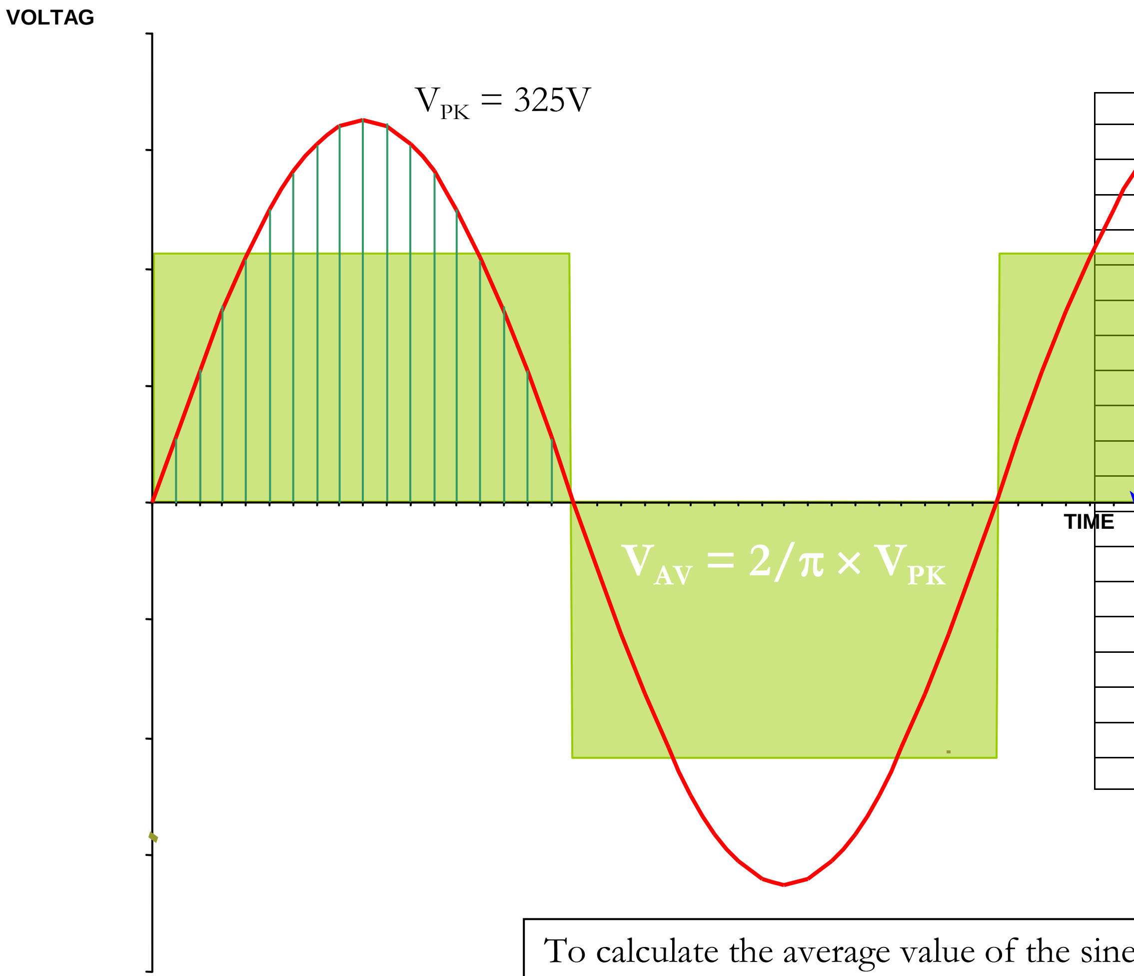
The Average Value

Since the Average value of a sinewave is "zero" (the positive area under the graph equals the negative area under the graph) it makes little sense to discuss the average value of a sinewave. It makes more sense to discuss the average value of half a sinewave:



Degrees	Magnitude
0°	0.00V
10°	56.44V
20°	111.16V
30°	162.50V
40°	208.91V
50°	248.96V
60°	281.46V
70°	305.40V
80°	320.06V
90°	325.00V
100°	320.06V
110°	305.40V
120°	281.46V
130°	248.96V
140°	208.91V
150°	162.5V
160°	111.16V
170°	56.44V
TOTAL	3714.78V

To calculate the average value of the sinewave above we could take samples every 10° and divide by the number of samples to get the average:

$$v_{INSTANTANEOUS} = \sin\phi \times V_{PEAK}$$

$$e.g. v_{10^\circ} = \sin 10^\circ \times 325V = 56.44V$$

$$V_{AV} \approx \frac{3714.78V}{18 samples} = \underline{\underline{206.38V}}$$

Our answer was close to the actual answer (206.9V) calculated using:

$$\mathbf{V_{av} = 2/\pi \times V_{PEAK}}$$

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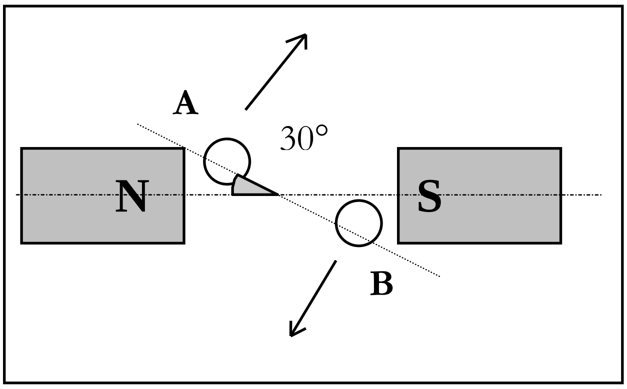
Determining the Magnitude of the Induced EMF

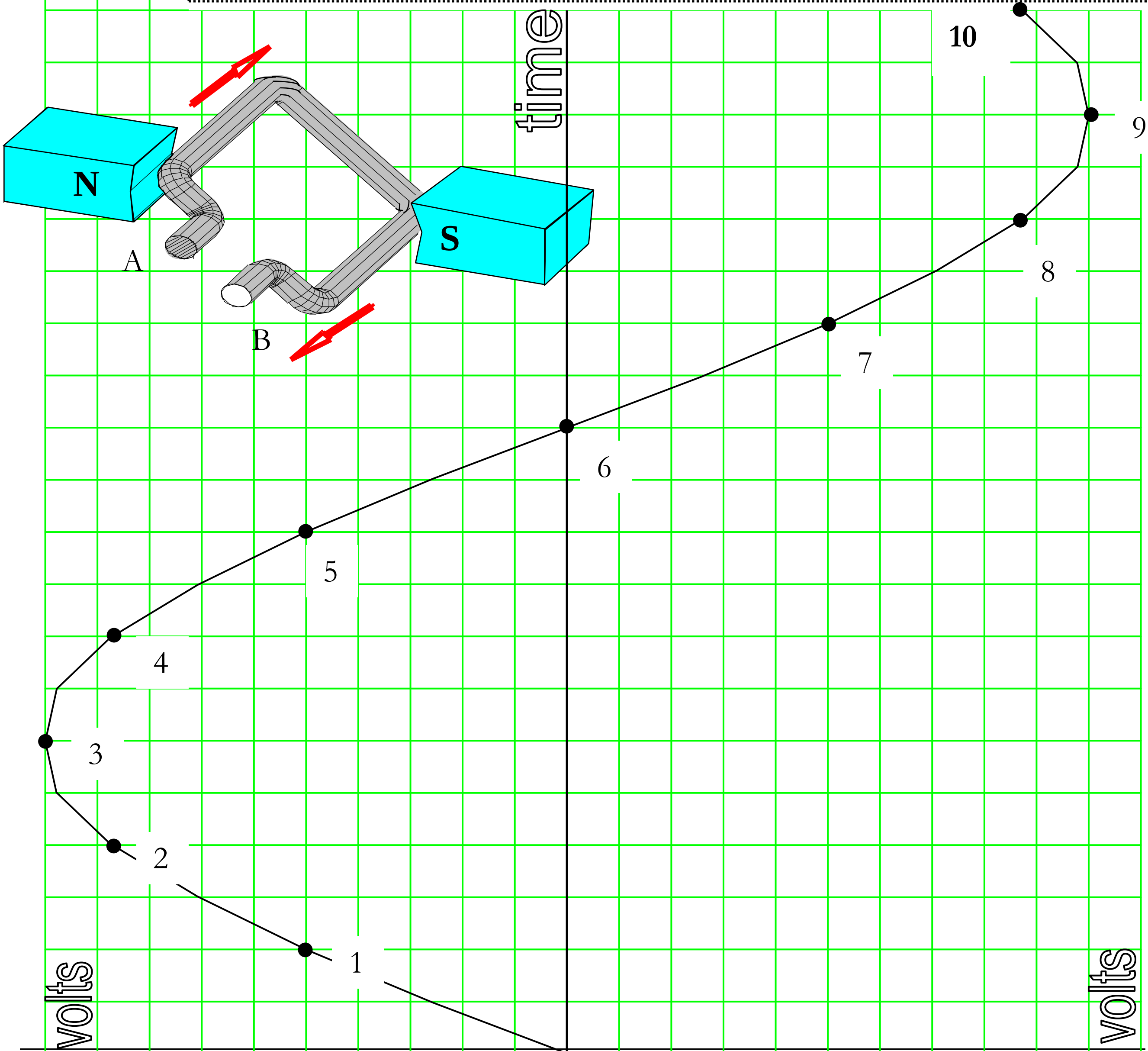
Although it is impossible to determine the output voltage from the information given, we can calculate the emf induced at any one instant in time in relation to the maximum emf that would be induced:

$$V_{inst} = Sin(90^{\circ} - 30^{\circ}) \times V_{\max.}$$

$$V_{inst.} = 0.866 \times V_{\max.}$$

this is for step “10.” on this graph.





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You should have noticed over the last 3 pages that a single-loop coil rotating in a uniform magnetic field will produce an emf, that when graphed has the shape of a sinewave. The fact that this output voltage alternates between a positive value and a negative value gives rise to the name **alternator**, which is the name given to a machine that produces an alternating current.

For us to measure the sinewave output from the rotating coil we would have to connect the meter to the coil by a sliding connection that would ensure that the same end of the coil would remain connected to the same meter terminal at all times.

32. Illustrate the type of connection that would supply a sinewave output voltage from a single loop coil rotating in a uniform magnetic field below, and label that sliding connection nice and clearly:

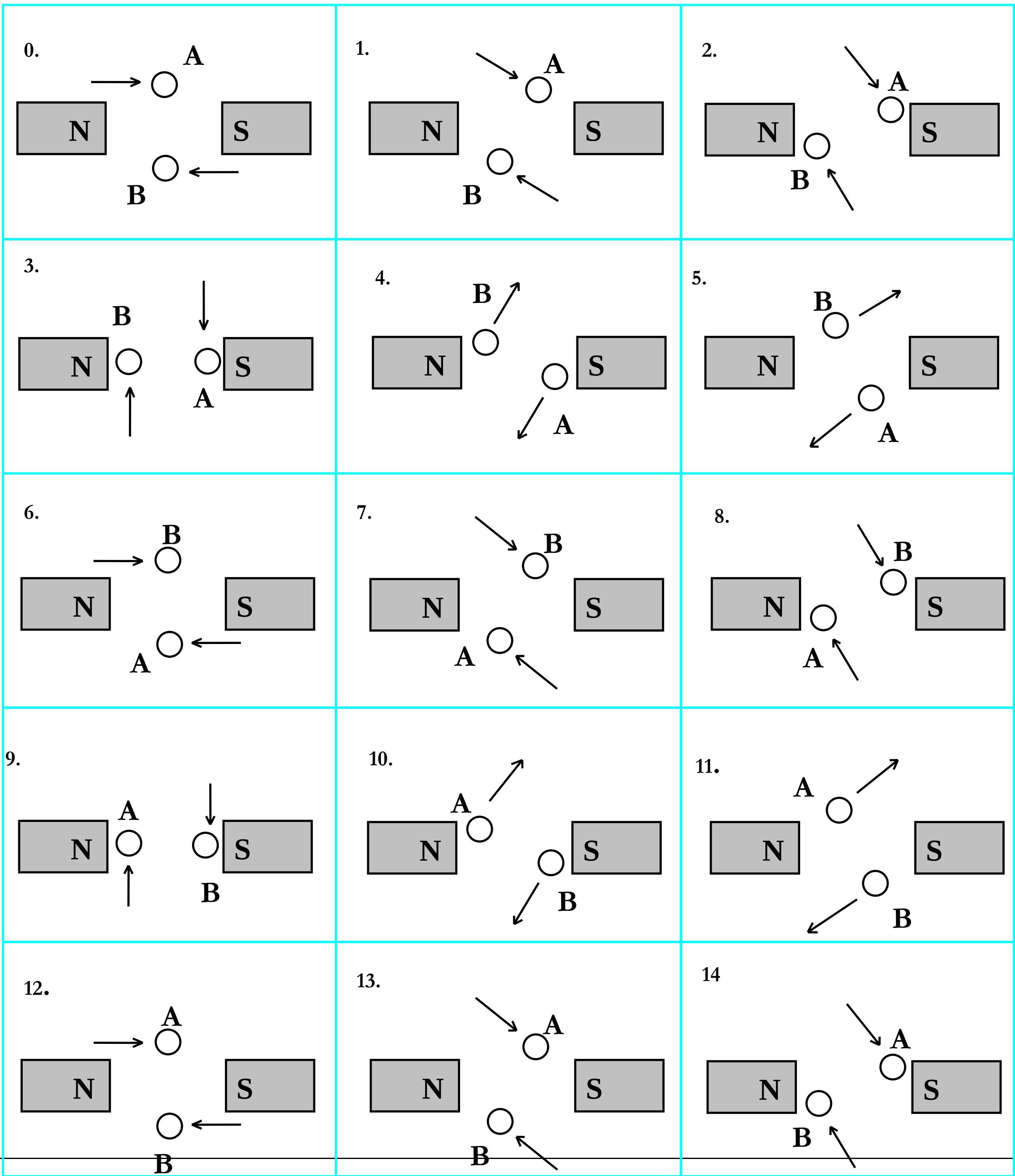
Direct Current Generation in a Single Loop Coil

So far we have discussed the production of an alternating current using a "slip-ring" connected single-loop coil being rotated in a uniform magnetic field by an external force. If we were to swap the slip-ring connection for a "commutator" we would get a differently shaped output waveform.

33. ***Illustrate the type of connection that would supply a pulsating d.c. output voltage from a single loop coil rotating in a uniform magnetic field below, and label that sliding connection nice and clearly:***

THE COMMUTATOR OUTPUT WAVEFORM

34. ***Plot the resultant output voltage waveform from a Commutator connection of this single-loop coil rotating in a uniform magnetic field, on the following page. USE "B" AS THE REFERENCE (ie. "B" is the x-axis)***



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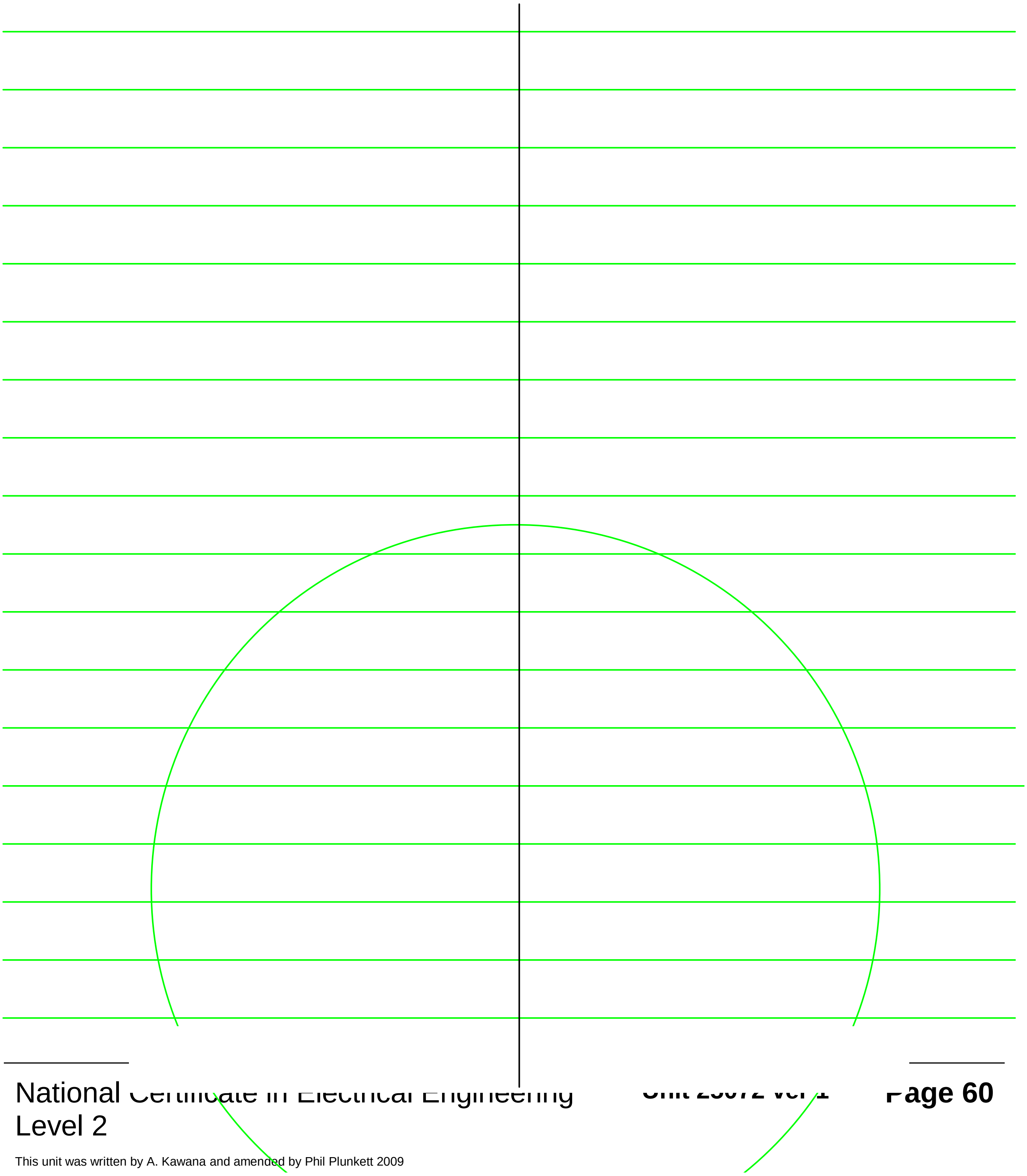
CONSTRUCTING A SINEWAVE

35. ***Use a compass and a protractor to construct a 230V(rms) 50Hz sinusoidal waveform in the space provided below with a minimum of 30 ° intervals. Indicate: the peak voltage; the peak to peak voltage; the period; and label the graph and axes appropriately. See "Electrotechnology.." Fig. 7.1 Page 133.***



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CALCULATIONS

Answer the following questions:

ex. ***The method of calculating the instantaneous value of a sinewave was given on Page 143 of this manual.***

What would the instantaneous voltage be of a 110V a.c. (this would normally be considered an rms value unless otherwise stated) 60Hz supply, 12ms after switch-on?

$$t_{period} = \frac{1\sec}{60cycles} = 16.667ms$$

$$V_{peak} = \left(\frac{110V}{0.707}\right) = 155.56V$$

$$V_{inst} = 155.56V \times \sin\left(\frac{12ms}{16.667ms} \times 360^\circ\right) = -152.8V$$

36. ***What is the period of a 10kHz sinewave?***

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37. ***If one complete cycle was considered 360°, how many degrees would be included in 18.65 complete cycles? If a sinewave repeats every cycle, how many degrees of the last (uncompleted) cycle would have been completed?***

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38. ***The "RMS" value is 1/√2 times the peak value of a sinewave. What is meant by the "RMS" value?***

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39. ***What is the instantaneous value of the voltage from a 230V (rms) alternating supply after 15.37ms if the supply frequency is 50Hz?***

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40. ***What is the instantaneous value of the voltage of a sinusoidal output from a 100Vpk-pk supply 7.235μs if the supply frequency is 23kHz?***

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41. ***What is the instantaneous value of the current through a 57Ω resistor supplied with a sinusoidal voltage of 24Va.c. at 60Hz at 57ms?***

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42. ***What is the average value of the current through a lamp with a working resistance of 13.95Ω when supplied by pulsating d.c. power supply which has a peak voltage of 18.84V?***

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43. ***What is the equation used to calculate the magnitude of the emf induced in a conductor as it cuts through a magnetic field?***

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44. ***What value of emf would be induced in a conductor that was moving at 90° to the main magnetic field, if the field strength was 0.6T and the effective length of the magnetic field was 30mm? The conductor is moving at 10m/s.***

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45. ***How fast would a conductor have to be moving in a 40mm long magnetic field with a flux density of 0.8 Tesla, if that conductor was to have an emf of 2 volts induced in it while that conductor was moving at 60° to that magnetic field?***

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46. Explain each of the following terms in regard to an a.c. waveform:

Periodic Function-	....
Periodic time-	....
Frequency-	....
Crest Factor-	....
Form Factor-	....
V_{pk-pk} and I_{pk-pk} -	....
Average value-	....
RMS value (effective value)-	....
Instantaneous values-	....

REVIEW

This Unit of learning is larger than most other units (15 credits).

It is the basis for all further study – and subsequently requires your complete understanding.

This unit included:

Electrical conductors, insulators & semiconductors;

Resistance, resistivity & resistors;

Resistive circuits;

Power, Energy & EMF production;

Electrochemistry;

Magnets & Electromagnetism; and

a.c. & d.c. generation.

You will be required to complete the practical part of this course and the assessment at UNITEC

NOTES

NOTES

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ANSWERS

9. An induced magnet has a temporary magnetic field set up due to the proximity of a permanent magnet

11. Contactor coil, Motor pole, Transformer core, Speaker driver, Lifting magnet

13. Coercive force required particularly in a.c. circuits to reduce residual magnetism to zero creates a loss of power in the form of heat.

15. Rig**h**t for **g**enerators, Left for motors

19. E = 0.6 × (2 × 0.08m) × 10 × Sin55°= 0.786V

23. E=Blv 1V = 1.2T × 0.1m × *v* ***v*** = 1/ (1.2 × 0.1) = 8.333m/s (30kph)

25. None

29. One conductor moves about π × 0.04m × 1450rpm/60sec = 3.037m/s

    E = Blv E = 1.098T × (2 × 0.03m) × 3.037m/s = 200mV

31. See Answers Electrotechnology Page 540

37. 6714°, 234°

39. -323.1V

41. 287.2mA

43. E = B.l.v

45. 72.17m/s

47. E=0.6×(2×0.08m)×10 ×Sin55°=0.786V

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$$X_L = 2\pi fL \qquad MMF = S.\phi$$

FORMULAE

$$U_m = I.N$$

$$X_L = 2\pi fL$$

$$\mu = \mu_0 \mu_r$$

$$P = V.I.\cos\vartheta$$

$$P = \sqrt{3}.V_{Line}.I_{Line}.\cos\vartheta$$

$$X_C = \frac{1}{2\pi fC}$$

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$$

$$L = \frac{\mu_0 \mu_r N^2 a}{l}$$

$$\Phi = B.a$$

$$SHC_{H^2O} = 4180$$

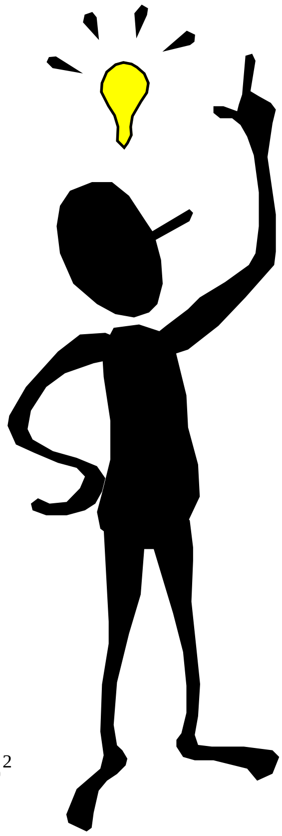
$$\varepsilon_0 = 8.854 \times 10^{-12} F/m$$

$$C = \frac{\varepsilon_0 \varepsilon_r A(n-1)}{d}$$

$$E = B.l.v.\sin\vartheta$$

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

$$\frac{R_1}{R_2} = \frac{1+\alpha.t_1}{1+\alpha.t_2}$$



$$S = \frac{l}{\mu_0 \mu_r a}$$

$$\rho_{Cu} = 1.72 \times 10^{-8}\Omega m$$

$$f = \frac{B^2 a}{2\mu_0}$$

$$S = {}^{O}\!/_{H} \quad C = {}^{A}\!/_{H} \quad T = {}^{O}\!/_{A}$$

$$R = \frac{\rho.l}{a}$$

$$W = {}^{1}\!/_{2} C.V^2$$

$$H = \frac{I.N.l}{a}$$

$$v = V(1 - e^{\frac{-t}{TC}})$$

$$Q = CV$$

$$R = R_0(1 + \alpha_0.t)$$

$$Z^2 = R^2 + (X_L - X_C)^2$$

$$accl_{Gravity} = 9.81 m/s/s$$