FORM 5 SPM PHYSICS SHORTHAND NOTES

Chapter 4 Electromagnetism

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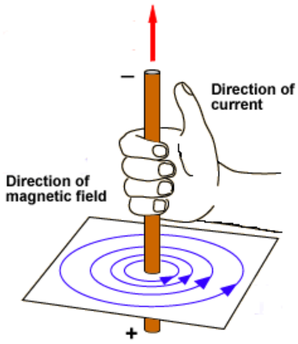
4.1 Force on current carrying conductor in a magnetic field

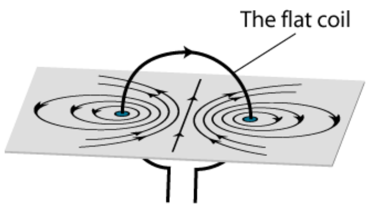
An electromagnet is a *temporary magnet* made by winding an insulated wire around a soft iron core, forming a coil known as a *solenoid*. When current passes through the solenoid it produces a magnetic field. The solenoid is said to magnetised and becomes and electromagnet.

Magnetic field patterns:

Straight wire

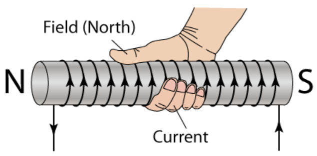


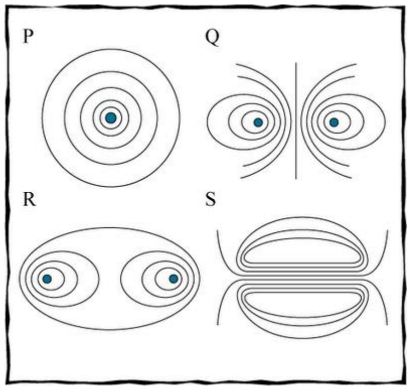
Use your Right Hand when you want to determine the magnetic field patterns! Your thumb is the direction of your current while your four fingers are the direction of the magnetic field.



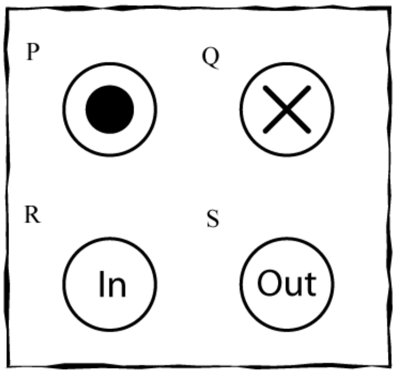
Magnetic field pattern generated by a flat coil

Magnetic field in solenoid



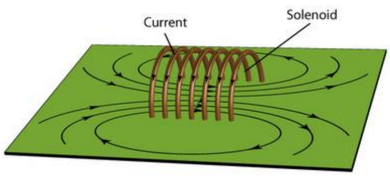


Which one shows the magnetic field lines generated by a) a coil and b) a straight wire?



Which one shows current a) coming out of the paper and b) going in to the paper?

Find the North Pole?



Magnetic field generated by a solenoid. The field pattern is resemble a long bar magnet.

The strength of a magnetic field is can be increased by:

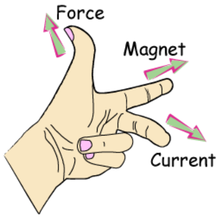
1) Increasing the current
2) Increasing the number of turns per unit length
3) Using a soft-iron core within the solenoid

Applications of electromagnets:

1) Electric bell
2) Circuit breaker
3) Electromagnetic relay
4) Electromagnetic lift
5) Telephone earpiece
6) Dot matrix printer

When a current-carrying conductor is placed a magnetic field, the interaction between two magnetic fields produces a force on the conductor.

Use your left hand when you want to determine the direction of the force! This rule is called Fleming's left-hand rule.

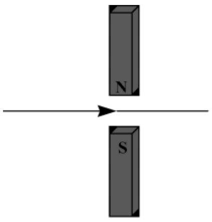


The forefinger, middle finger and thumb are perpendicular (90^{o} degrees) to each other. The forefinger points along the direction to the magnetic field, middle finger points in the current direction and the thumb points along the direction of the force.

The strength of the force can be increased by:

1) Increasing the current
2) Using a stronger magnet
3) Using a longer wire
4) Arranging the wire perpendicular to the direction of the magnetic field

Using the Left Hand Rule, state which direction the wire will move:



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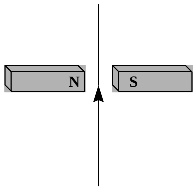

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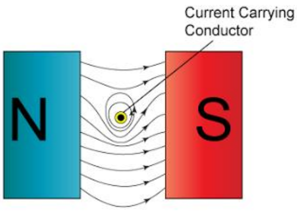
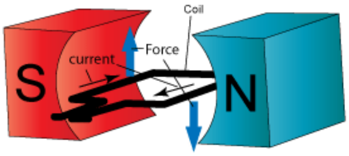
When current flows through a conductor, a magnetic field is generated. What happens when we place this conductor in a magnetic field? In which direction is the force pointing?

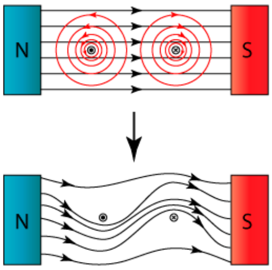


Catapult Field

If a current carrying a coil is placed in a magnetic field, pair of forces will be produced in the coil. This is due to the interaction of the magnetic field of the permanent magnet and the magnetic field of the current carrying coil.



Turning Effect of a Coil in a Magnetic Field

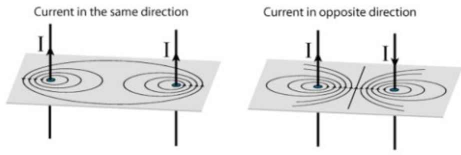


Interaction of the magnetic fields produces a catapult field

The direction of the force can be determined by Fleming's left hand rule. Since the current in both sides of the coil flow in opposite direction the forces produced are also in opposite direction. The 2 forces in opposite direction constitute a couple which produces a turning effect to make the coil rotate. Examples of electric equipment whose operation is based on this turning effect are

1) The direct current motor
2) The moving coil meter

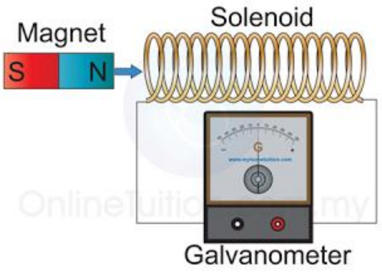
When 2 current carrying conductors are placed close to each other, a force will be generated between them. If the current in both conductors flow in the same direction, they will ______________, whereas if the current are in opposite direction, they will ______________ each other. *Hint: Use Flemming's left hand rule and the right hand rule.*



Catapult field produced by 2 straight curretn carrying conductors

4.2 Electromagnetic induction

When a magnet (a permanent one) is moved in and out of a solenoid, the magnetic field flux of the magnet is being cut by the coil. This in turn induces an e.m.f in the wire. If the solenoid is connected to a closed circuit as seen below, the induced current will flow through the circuit. The production of electric current by changing magnetic field is called electromagnetic induction. Current is only induced when the magnet or solenoid is moving relative to one another. The direction of induced current can be determined from Lenz's Law and Faraday's Law.

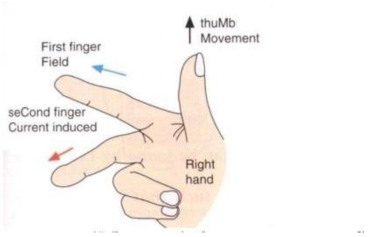


Faraday's Law: The *magnitude* of the induced e.m.f. is directly proportional to the rate of change of magnetic flux through a solenoid or the rate of the magnetic flux being cut. In a nutshell what he was trying to say was move the magnet faster or use a stronger magnet or increase the number of coils in the solenoid.

Lenz's Law: The induced current always flows in the direction that *opposes the change in magnetic flux*. This law obeys the conservation of energy principle. Work is done to move the magnet against the repulsive force. This work done is converted to electric energy (current).

Induced EMF and Current in a Straight Wire

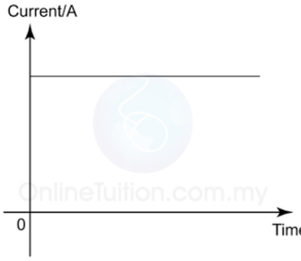
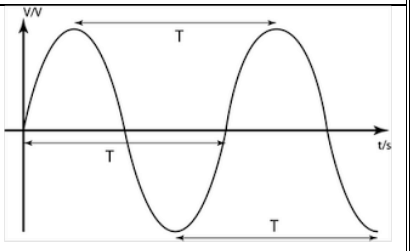
When a *straight conductor* (e.g. wire) moves and cut a magnetic field (example is on the right pane), e.m.f. will be induced across the conductor. If the conductor is a complete circuit, current will flow in the conductor. The direction of current can be determined by using Flemming's RHR.



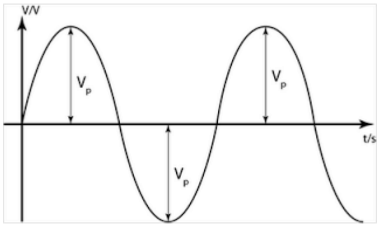
Induced EMF and Current in a Solenoid
When a bar magnet is moving into a solenoid, the solenoid will cut the magnetic flux of the bar magnet. This will induce a current and e.m.f. in the solenoid. The induced current will produce another magnetic field around it. The pole of the magnetic field and direction of the induced current can be determined by using Lenz's Law.

Some applications of electromagnetic induction are:

1) DC Generator
2) AC Generator

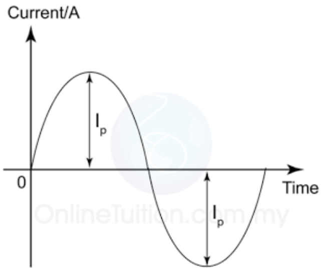
Type of Current	Direct Current	Alternating Current
Graph		
Magnitude and direction	Magnitude can be constant or change with time, but it flows in one direction only.	Its magnitude and direction change with time.
Properties	Lights up a bulb and causes heating effect on the bulb	Lights up a bulb and causes heating effect on the bulb
	Cannot flow through a capacitor	Can flow through a capacitor
	Cannot produce sound in loudspeaker	Can produce sound in a loudspeaker

5 Root Mean Square (RMS) Voltage/ Current



The effective potential difference for a.c. is knows as the r.m.s of the a.c. and is given by

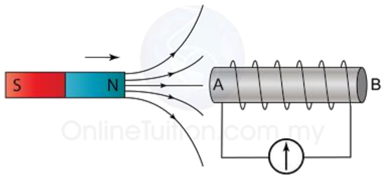
$$V_{rms} = \frac{V_P}{\sqrt{2}}$$

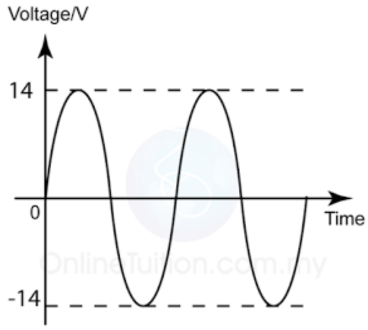


Likewise the r.m.s current can be calculated by using the following equation

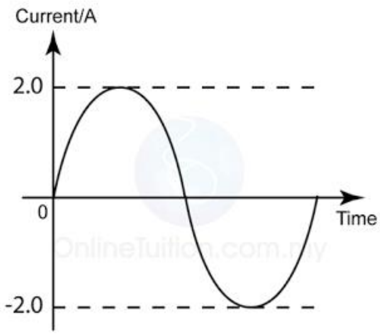
$$I_{rms} = \frac{I_P}{\sqrt{2}}$$

Current induced in a solenoid example. Find the direction of the induced current.





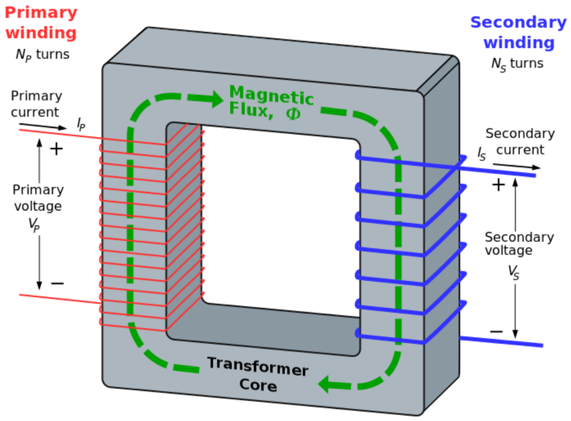
Find the r.m.s of the power supply.



Calculate the r.m.s for the current.

4.3 Transformer

A transformer is a device that is used to *raise or lower the potential difference of an alternating current*. Shown below is a typical transformer with all its components

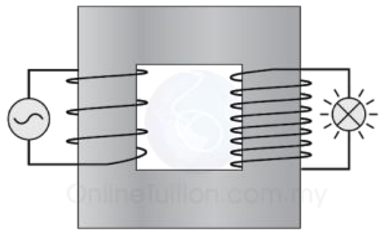
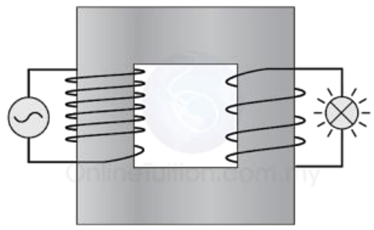


Important: The input current goes through the primary winding first before exiting through the secondary winding.

A transformer consists of a primary and secondary coil wound on a soft iron core. When an a.c current flows in the primary coil, a changing magnetic flux is generated around the primary coil. The changing flux is transferred to the secondary coil through the iron core. The flux is then cut by the secondary coil, hence inducing an e.m.f in the secondary coil. The magnitude of the output voltage can be controlled by the ratio of the number of primary and secondary coil.

Important: The current in the primary circuit must be a.c. because a.c. can produce changing magnetic flux. A changing magnetic flux is needed to induce e.m.f. in the secondary coil. The induced current is also a.c. and has the same frequency.

Step up vs step down transformer

Step-up transformer	Step-down transformer
	
$N_P < N_S$	$N_P > N_S$
$V_P < V_S$	$V_P > V_S$
$I_P > I_S$	$I_P < I_S$

In an ideal transformer the input power is equal to the output power. Recall from the previous chapter that for electricity

$$P = VI$$

A transformer is used to step down a mains voltage of 240 V a.c. to 24 V a.c. If this transformer has a primary coil of 20000 turns, how many turns are there in the secondary coil?

A transformer has 400 turns in its primary coil and 2000 turns in its secondary coil. An a.c. supply of 6V is connected to the primary coil and the secondary coil is connected to a 15W bulb, which lights up with normal brightness. If the transformer is ideal calculate,

a) the secondary voltage, V_s
b) the current in the secondary coil, I_s
c) the input power, P_{input}
d) and current in the primary coil, I_P

Therefore, input power,

$$P_{input} = V_P I_p$$

and output power

$$P_{output} = V_S I_S$$

For an ideal transformer,

$$V_P I_p = V_S I_S$$

Also,

$$\frac{V_P}{V_s} = \frac{N_P}{N_s}$$

However, in real life applications no transformer is ideal. This is due to heat loss which causes the output power to be less than the input. Therefore, the efficiency of a transformer is always less than 100%. Recall that efficiency is output over input.

$$Efficiency = \frac{P_{output}}{P_{input}} \times 100\%$$

There are 4 factors that cause energy loss in a transformer. In SPM you'll have to remember all of them.

1) Heating effect in the coils
2) Eddy currents in iron core
3) Magnetisation and demagnetisation of the core
4) Leakage of magnetic flux

The FAQ related to this topic are: what is renewable energy? the examples of Renewable and non-renewable energy and the advantages of using renewable energy

Renewable sources are energy sources which can be replaced. E.g.

1) Hydro
2) Solar
3) Wind
4) Geothermal
5) Biomass
6) Tidal

Its advantages are its clean and won't pollute the environment. It's easily obtained and can be replenished.

The primary coil of a transformer has 5000 turns whereas its secondary coil has 250 turns. When an a.c. voltage of 240 V is supplied to the primary coil, the current in the primary coil is 0.12 A and the current in the secondary coil is 2 A. Find the efficiency of the transformer.