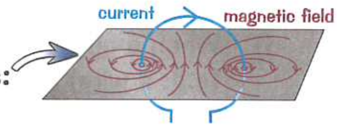
# Solenoids and Electromagnetic Induction

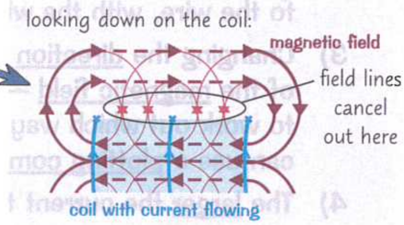
Solenoids and electromagnetic induction both sound pretty horrible — but don't panic, they're not as bad as they first seem. Just take this page slowly and you should be fine...

## A Solenoid is a Long Coil of Wire

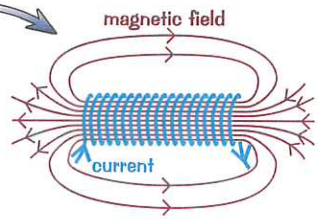
1) Around a single loop of current-carrying wire, the magnetic field looks like this:




2) You can increase the strength of the magnetic field produced by a length of wire by wrapping it into a long coil with lots of loops, called a solenoid.
3) The field lines around each separate loop of wire line up.
   - Inside the solenoid, you get lots of field lines pointing in the same direction. The magnetic field is strong and almost uniform.
   - Outside the coil, the overlapping field lines cancel each other out — so the field is weak apart from at the ends of the solenoid.




4) You end up with a field that looks like the one around a bar magnet. The direction of the field depends on the direction of the current (p.197).



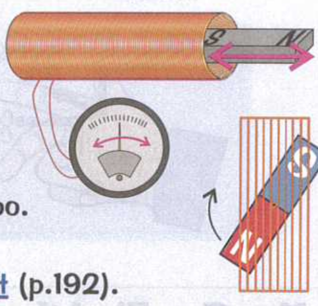

5) A solenoid is an example of an ELECTROMAGNET — a magnet with a magnetic field that can be turned on and off using an electric current.
6) You can increase the field strength of the solenoid even more by putting a block of iron in the centre of the coil. This iron core becomes an induced magnet (see p.196) whenever current is flowing.

## A Changing Magnetic Field Induces a Potential Difference in a Conductor

**Electromagnetic Induction:** The induction of a potential difference (and current if there's a complete circuit) in a wire which is experiencing a change in magnetic field.

Induces is a fancy word for creates.

1) There are two different situations where you get electromagnetic induction. The first is if an electrical conductor (e.g. a coil of wire) and a magnetic field move relative to each other.
   - You can do this by moving/rotating either a magnet in a coil of wire OR a conductor (wire) in a magnetic field (either way, you're "cutting" magnetic field lines and so inducing a p.d.).
   - If you move or rotate the magnet (or conductor) in the opposite direction, then the p.d./current will be reversed. Likewise if the polarity of the magnet is reversed, then the potential difference/current will be reversed too.
   - If you keep the magnet (or the coil) moving backwards and forwards, or keep it rotating in the same direction, you produce an alternating current (p.192).



2) You also get an induced p.d. when the magnetic field through an electrical conductor changes (gets bigger or smaller or reverses). This is what happens in a transformer.
3) You can increase the size of the induced p.d. by increasing the STRENGTH of the magnetic field, increasing the SPEED of movement/change of field or having MORE TURNS PER UNIT LENGTH on the coil of wire.
4) The induced p.d./current always opposes the change that made it:
   - When a current is induced in a wire, that current produces its own magnetic field (p.197).
   - The magnetic field created by an induced current always acts against the change that made it. Basically, it's trying to return things to the way they were.


### *Give me one good raisin why I should make the currant joke...*

Motors and solenoids are used in loads of everyday things from speakers to alarm clocks.

Q1 Sketch the magnetic field in and around a solenoid. [3 marks]

# Solenoids and Electromagnetic Induction

## Warm-Up

For each statement, circle whether it is true (T) or false (F).

| | |
|---|---|
| A single loop of current-carrying wire produces a magnetic field. | T / F |
| A solenoid is an example of a transformer. | T / F |
| An electromagnet can be turned on and off. | T / F |
| The magnetic field is weakest inside a solenoid. | T / F |

**1** This question is about statements 1 and 2, shown below. Grade 4-6

Statement 1: A potential difference is induced when an electrical conductor moves relative to a magnetic field.

Statement 2: A potential difference is induced when there is a change in the magnetic field around an electrical conductor.

Which of the following is correct?

☐ **A** Only statement 1 is true.

☐ **B** Only statement 2 is true.

☐ **C** Both statements 1 and 2 are true.

☐ **D** Neither statement 1 nor 2 is true.

*[Total 1 mark]*

**2** Solenoids are an example of an electromagnet. Grade 4-6

a) State what is meant by an electromagnet.

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*[1]*

b) i) Describe the magnetic field inside the centre of a solenoid.

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*[2]*

ii) Describe the magnetic field of a solenoid outside of the solenoid.

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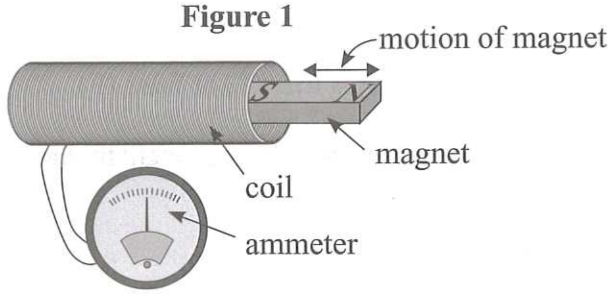
*[2]*

*[Total 5 marks]*

**3** A student sets up a simple circuit to measure the current generated when he moves a magnet in and out of a coil. The set-up of his apparatus is shown in **Figure 1**. Grade 6-7

**Figure 1**




a) State and explain whether the set-up in **Figure 1** generates alternating or direct current.

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*[3]*

b) State **three** ways to increase the potential difference induced by the set-up in **Figure 1**.

1. .........................................................................................................................
2. .........................................................................................................................
3. .........................................................................................................................

*[3]*

*[Total 6 marks]*

**4** A current-carrying solenoid has a magnetic field outside it similar to a bar magnet. Grade 7-9

a) State how iron can be used to increase the magnetic field of the solenoid.

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*[1]*

b) The north pole of a magnet is brought near to the current-carrying solenoid as shown in **Figure 2**. State whether the north pole is **attracted** or **repelled** by the solenoid. Explain your answer.

**Figure 2**


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*[3]*

*[Total 4 marks]*