202: Principles of electrical science  
**Handout 9: Electro-magnetism**

**Learning outcome**

The learner will:

1. Understand the fundamental principles which underpin the relationship between magnetism and electricity.

**Assessment criteria**

The learner can:

5.1 describe the effects of magnetism in terms of attraction and repulsion

5.2 state the difference between magnetic flux and flux density

**Electro‑magnetism**

**Magnetic field**

This is the area around a magnet or electromagnet where the effects of the magnetic force produced can be felt. Magnetism is represented by unseen **lines of flux** that form closed loops, as shown in the following diagrams. Some conventions must be remembered:

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| --- |
| * **Lines of flux cannot cross** * **Lines of flux flow externally from the North Pole to the South Pole.** |

Flux patterns for various arrangements of permanent magnets are shown below:

|  |
| --- |
| 01 permanent magnetic fields.png |

**Two permanent magnets – North Pole to North Pole**

|  |  |
| --- | --- |
| 02 permanent magnetic fields.png | |
| **Like poles repel** |

**Two permanent magnets – North Pole to South Pole**

|  |
| --- |
| 03 permanent magnetic fields.png |
| **Unlike poles attract** | |

**Electro-magnetism**

Electricity and magnetism are closely related.

An electrical current flowing through a conductor produces a magnetic field in the form shown below, around the conductor.

In order to help us to establish the direction of the magnetic fields around conductors, we must have a current direction convention, as shown below.

|  |  |
| --- | --- |
| 04 electro-magnetic fields.png | Current flowing into the conductor (ie away from the observer) |
| Current flowing out of the conductor (ie towards the observer) |

The direction of magnetic fields around cables can be found by using:

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| --- |
| **Maxwell’s screw rule** |

Maxwell’s screw rule shows the relationship between the direction of the current flowing and the magnetic field produced by that current.

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| --- |
| 05 electro-magnetic fields.png |

Imagine that you are driving a screw into the conductor in the direction of the current flow. The magnetic field produced by the current will form circular lines around the conductor, in the direction in which you have to drive the screw to advance it.

**Magnetic fields due to electric current**

**In straight conductors**

|  |
| --- |
| 06 electro-magnetic fields.png |

**In a flat coil**

|  |
| --- |
| 07 electro-magnetic fields.png |

**In a solenoid**

|  |
| --- |
| 08 electro-magnetic fields.png |

Winding the conductors into a coil/solenoid increases the magnetic effect and produces a magnetic field similar to a bar magnet with North and South Poles.

A **solenoid** is a coil wound into a tightly packed helix. In physics, the term solenoid refers to a long, thin loop of wire, often wrapped around a metallic core, which produces a magnetic field when an electric current is passed through it. Solenoids are important because they can create controlled magnetic fields and can be used as electromagnets. The term solenoid refers specifically to a coil designed to produce a uniform magnetic field in a volume of space.

A common use for a solenoid is in a **relay** (or contactor): an electrically operated switch. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits) or where several circuits must be controlled by one signal. The first relays were used in long-distance telegraph circuits, repeating the signal coming in from one circuit and re-transmitting it to another.

A type of relay that can handle the high power required to directly control an electric motor or other loads is called a **contactor**.

There are two quantities relating to magnetism that we need to be familiar with when considering electrical science. These are detailed below:

**Magnetic flux**

The number of magnetic lines of forces set up in a magnetic circuit is called magnetic flux. It is comparable to electric current in an electric circuit.

The unit is the **Weber** (Wb) and it is denoted by the symbol **Φ** in formulae.

**Magnetic flux density**

Whilst the magnetic flux is a measure of how many lines of flux there are it gives us no indication of how compacted or spread out these lines are. The closer the lines are concentrated the stronger will be the effect of the magnetic field; flux density is a measure of ‘compacted’ these lines of flux are.

Flux density is a measure of the number of lines of flux passing through an area of one metre2 and can be found by:

The unit for flux density is the **Tesla**, abbreviated to **T**.