Phase 2

Trade of Motor Mechanic

Module 2

Unit 1

Magnetism

Produced by

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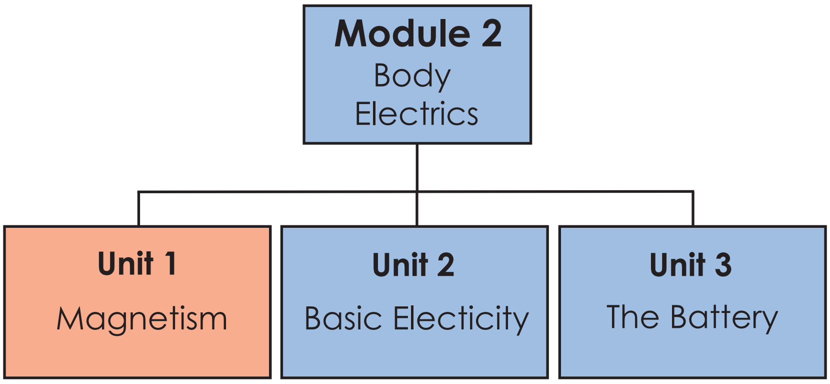
Introduction

There are six Units in this Module. In Theory 1 we cover Units 1, 2 and 3 which focuses on the basics of electricity. In Theory 2 we cover Units 4, 5 and 6 which focuses on the fundamental electrical circuits in the vehicle.



In this Unit One, you begin with a description of the structure of a permanent magnet. This is necessary because all moving electricity produces magnetism. Basic electricity and magnetism consists of very, very small forces. These individual forces cannot be seen or felt by human beings. However, when amounts of these forces are grouped together and then directed into electrical components, they produce the effects of heat, light and magnetism.

The electricity in the house and that in the vehicle has the exact same root and nature as the lightning that you see in an electrical storm. All of this electricity is directly related to magnetism and likewise, magnetism is directly related to electricity.

The magnetism produced by a permanent magnet is simply called magnetism. Magnetism produced by electricity is called electro-magnetism.

Electromagnetism and magnetism are used to operate the relays and many other electrical devices in the automobile.

Unit Objective

On completion of this unit you will be able to describe magnetism. You will learn that magnetism is related to electricity. You will also learn that electricity does not exist without magnetism. You will then be able to describe how electricity and its magnetism are used to operate some electrical devices in automotive vehicles.

By the end of this unit you will be able to:

- Describe the basic physical structure of permanent magnet matter
- Distinguish between magnetic and non-magnetic materials
- Describe the relationship between magnetism and electricity
- Detect magnetic fields produced by magnets and current flows
- Demonstrate the effects of magnetic attraction and repulsion
- Demonstrate the pattern of magnetic force lines provided by permanent magnets
- Describe the effects of an iron path on magnetic reluctance/ field strength/ movement
- Describe the construction and operation of an electromagnet

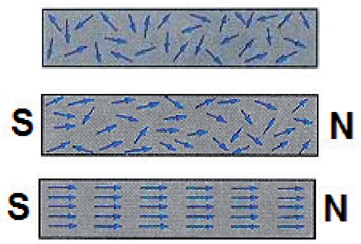
1.0 Structure of Permanent Magnet Matter

Key Learning Points

- Structure of permanent magnet matter, ferromagnetism, unbalanced spin of atomic electrons, domain theory-alignment, thermal agitation-(Curie point) – paramagnetic

1.1 What is Magnetism

Magnetism is a phenomenon that some materials, such as iron, have which causes them to attract or repel other materials. You can think of materials as being made up of a very large number of small magnetised "domains". When a bar of iron is not magnetised, the small magnetic domains are arranged in a random manner. But when the bar of iron becomes a magnet, the magnetic particles are aligned so that their individual effects are added together to form a strong magnetic force, *Domain theory-alignment*.



(Not Magnetised)

(Slightly Magnetised)

(Strongly Magnetised)

The magnetic effect within these small particles is caused by the (unbalanced spin of atomic electrons) spinning electrons within the atoms of the material. Electrons have a circle of force around them and when these electron orbits are aligned, as in a bar of iron, so that the circles of force add together, the bar is magnetised. Excessive vibration by high temperatures or physical shock allows the 'domains' of atoms to re-arrange themselves in a random pattern. The magnet then loses its magnetism.

1.2 Classification of Magnetic Materials

Not every material can be magnetised, some common magnetic and non-magnetic materials are listed below:

- Magnetic Materials: iron, steel, nickel, cobalt.
- Non-Magnetic Materials: air, vacuum, paper, glass, wood, plastics, brass.

Materials that make good permanent magnets are reluctant to change their magnetic direction. Such materials are said to be magnetically "HARD", e.g. Alnico.

Some materials such as soft iron become magnetised more easily than other materials, but they also lose their magnetism easily, so magnets of soft iron are called temporary magnets.

When we consider materials simply as either magnetic or non-magnetic, this division is really based on the strong magnetic properties of iron. However, weak magnetic materials can be important in some applications.

1.3 Ferromagnetism

Ferromagnetism is the "normal" form of magnetism which most people are familiar with, as exhibited in horseshoe and bar magnets.

Ferromagnetic Materials

These include iron, steel, nickel, cobalt and commercial alloys such as Alnico and Permalloy. They become strongly magnetised in the same direction as the magnetic field. For example, if a ferromagnetic material is placed in the magnetic field of a permanent magnet, then the lines of force, which are from the North Pole to the South Pole, are concentrated in the ferromagnetic material.

1.4 Unbalanced Spin of Atomic Electrons

Magnetic forces are fundamental forces that arise due to the movement of electrical charge. Thus, magnetism is seen whenever electrically charged particles are in motion. This can arise either from movement of electrons in an electric current, resulting in "electromagnetism", or from the quantum-mechanical orbital motion (there is no orbital motion of electrons around the nucleus like planets around the sun, but there is an "effective electron velocity") and spin of electrons, resulting in what are known as "permanent magnets".

1.5 Thermal Agitation-Curie Point

A piece of iron will ordinarily be attracted to a magnet, but when you heat the iron to a high enough temperature (called the Curie point), it loses its ability to be magnetized. Heat energy scrambles the iron atoms so that they can't line up and create a magnetic field.

Paramagnetic Materials

These include aluminium, platinum, manganese and chromium. They become weakly magnetised in the same direction as the magnetising field. The electron pairs of paramagnetic matter spin in opposite directions, so cancelling the magnetic effect.

2.0 Magnetic and Non-Magnetic Materials

Key Learning Points

- Magnetic materials; ferromagnetic materials, internal field development in magnetic field, remanence, non-magnetic materials, internal field stronger than external, no reaction to external field force

2.1 Ferromagnetic Materials

Materials that make good permanent magnets are reluctant to change their magnetic direction. Such materials are said to be magnetically "HARD", e.g. alnico.

Some materials such as soft iron become magnetised more easily than other materials, but they also lose their magnetism easily, so magnets of soft iron are called temporary magnets.

Some materials become strongly magnetised in the same direction as the magnetic field. These are called *ferromagnetic* materials. Examples are:

Iron, steel, nickel and cobalt.

Paramagnetic Materials

Some materials become weakly magnetised in the same direction as the magnetising field. These materials are called *paramagnetic* materials. Examples are:

Aluminium, Platinum, Manganese and Chromium.

2.2 Non-Magnetic Materials

There are also many materials that cannot be magnetised. These include: Air, Vacuum, Paper, Glass, Wood, Plastics and brass.

2.3 Remenance

When the permanent magnet is removed from the area of the soft iron core the core will loose most of its induced property, however some of the magnetism will remain and this is known as remenance or residual magnetism. This effect is used in dc motors.

3.0 Magnetism and Electricity

Key Learning Points

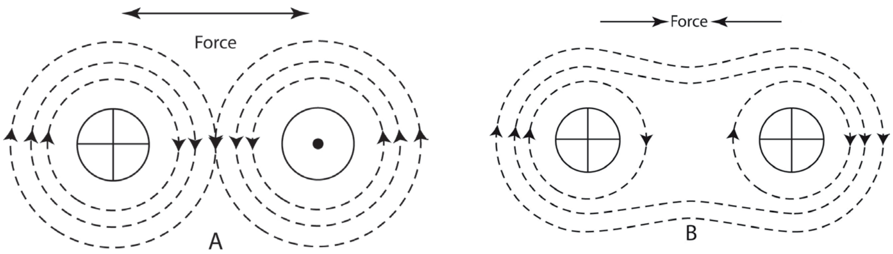
- Magnetism and electricity relationship; current flow-magnetic flux, current direction and magnetic polarity determination - right hand grip rule

3.1 Current Flow-Magnetic Flux

Magnetic Field Strength Between Current Carrying Conductors

Figure A below illustrates the magnetic fields between two conductors through which current is flowing in opposite directions. There will be a force of repulsion exerted between the conductors.

Conversely, *Figure B* below illustrates the magnetic fields between two conductors in which current is flowing in the same direction. There will be a force of attraction exerted between the conductors.



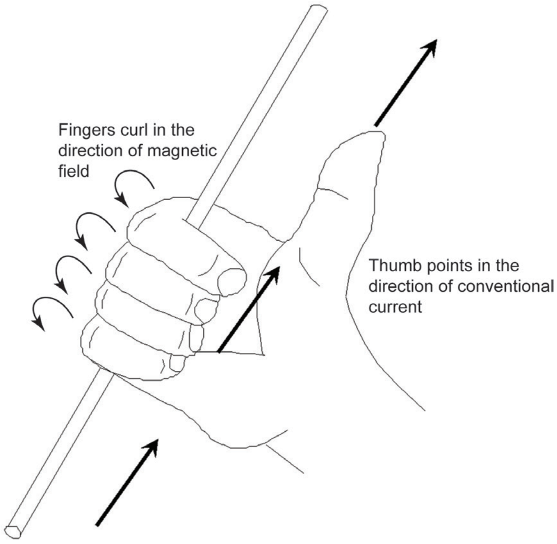
3.2 Current Direction and Magnetic Polarity Determination

Hand Rules

There is a definite relationship between the direction of current flow in a conductor and the direction of the magnetic field around that conductor. The direction can be determined by the use of either the Right Hand Grip Rule or the Corkscrew Rule.

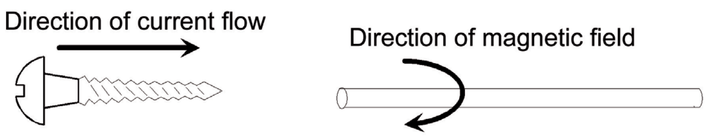
Right Hand Grip Rule

In a current carrying conductor which is a straight wire, the direction of the magnetic field lines may be found quite simply by using the method shown below.



Corkscrew Rule

Refer to the figure below, visualise a screw being twisted into or out of the end of a conductor in the same direction as the current flow. The direction of rotation of the screw will indicate the direction of the magnetic field.



4.0 Magnetic Fields

Key Learning Points

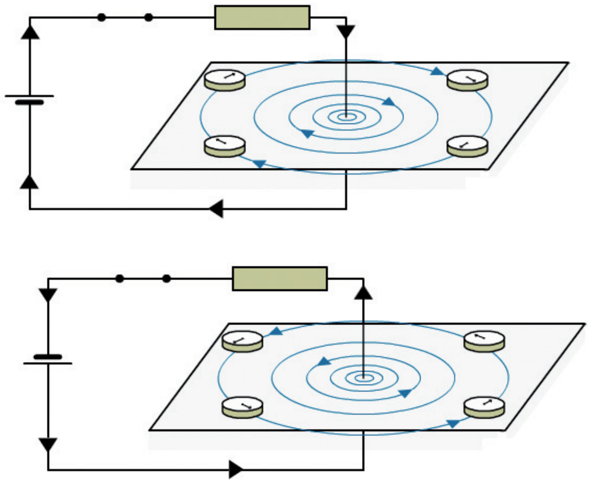
- Magnetic field detection; use of compass, iron filings

4.1 Use of Compass

Experiment

Refer to the figure below and assemble the circuit shown. Use a number of plotting compasses to view the direction of the magnetic field, the larger the current the more effective it will be.

Reverse the polarity and notice the difference in direction of the plotting compasses.

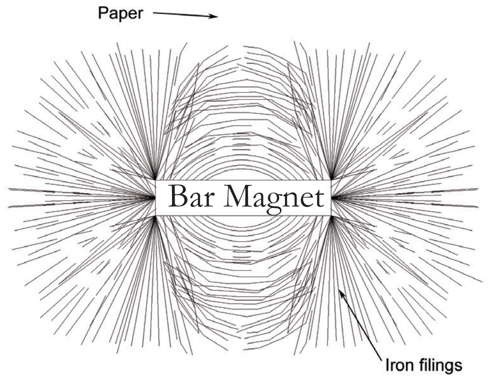


Is this conventional current flow or electron current flow?

4.2 Iron Filings

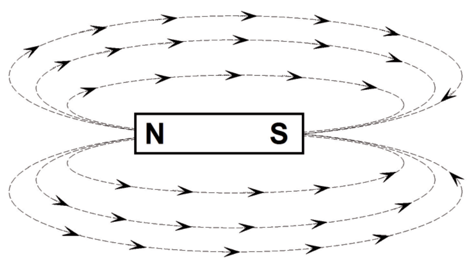
The space around a magnet where a magnetic effect can be detected is called a magnetic field.

The magnetic field around a bar magnet can be shown by sprinkling iron filings around a magnet placed under a piece of paper. If the paper is tapped gently, the iron filings arrange themselves as shown in the figure below. This arrangement of iron filings shows the pattern of the magnetic field around the magnet.



4.3 North, South Poles and Arrows

In this example the magnetic field appears to be a series of curved lines, which conventionally are drawn running from the North Pole to the South Pole external to the magnet as illustrated below. These lines are called the magnetic field lines or magnetic lines of force. The arrows show the direction of the magnetic lines of force at each point.



5.0 Magnetic Attraction and Repulsion

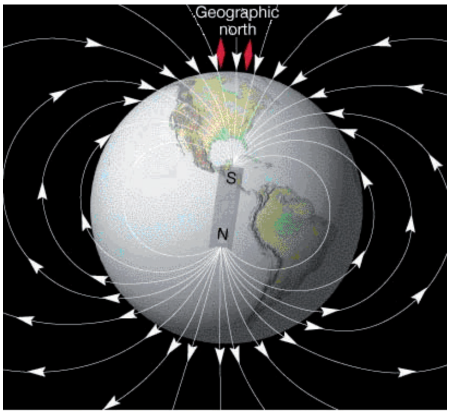
Key Learning Points

- Magnetic attraction and repulsion; use of magnets, magnetic materials

5.1 The Earth's Magnetic Poles

The Earth behaves as if a huge bar magnet were inside it, the south pole of the magnet being near the geographic North Pole and the North Pole at the geographic South Pole. The Earth is a truly permanent magnet.

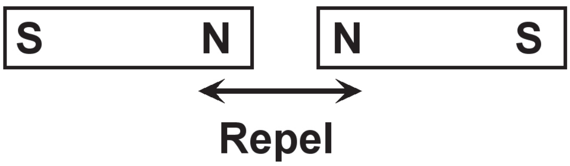
Permanent magnets will attract objects made of iron. If a magnet is suspended in free air, it will come to rest with one end pointing north. This is called the North-seeking Pole and the opposite pole is the South-seeking Pole.



If two magnets are brought together, they obey the laws of magnetism. These are:

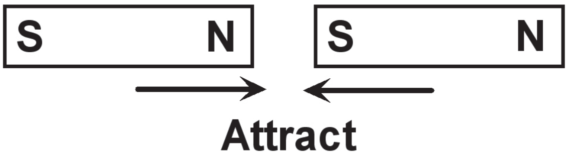
Like Poles Repel

Two North Poles or two South Poles will try to push apart or repel.



Unlike Poles Attract

A North Pole and a South Pole will try to come together or attract.



5.2 Use of magnets

Magnets have many applications in a typical Modern Car, these include:

- Window lift motor
- Starter motor
- Cooling fan motor
- Throttle and Crankshaft position sensors
- Liquid level indicators
- Windscreen washer pump
- Electric sunroof motor
- Ignition systems

6.0 Magnetic lines of Force

Key Learning Points

- Demonstration of force lines; use of iron filings, field/flux lines not crossing each other, concentrated at poles

6.1 Magnetic Fields

The space around a magnet where a magnetic effect can be detected is called a magnetic field.

A magnetic field is made up of imaginary lines, which cannot be seen, felt or heard. Lines of magnetic force (called flux) have two proven characteristics:

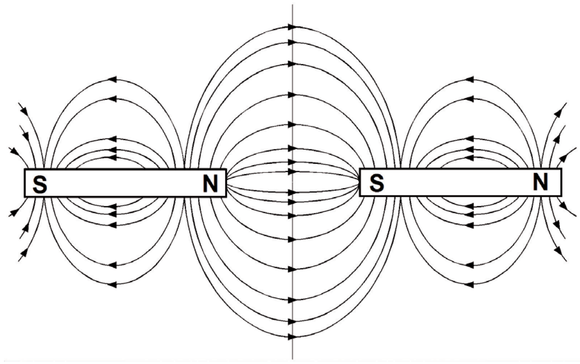
They act in a certain definite direction.

They appear endless.

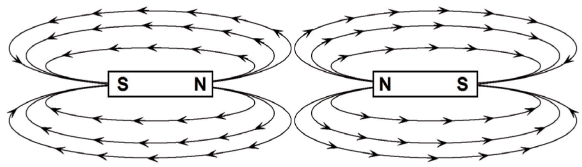
These lines of magnetic force are more concentrated around the North and South poles of a magnet and have the following properties:

- They always form complete loops.
- They never cross one another.
- They have a definite direction, North to South external to the magnet.
- They try to contract as if they were stretched elastic threads.
- They repel one another when lying side-by-side in the same direction.

When two bar magnets are placed close together with the North Pole of one facing the South Pole of the other, the lines of magnetic force in the fields inter-act and their directions are altered and appear to be as shown below. Lines of magnetic flux attempt to contract and the magnets attract and try to pull together.



If two bar magnets are placed so that their North poles are very close to each other, then the magnetic lines of force will arrange them as shown below.



Since magnetic flux lines running side-by-side with the same direction repel each other, the two magnets try to push each other apart.

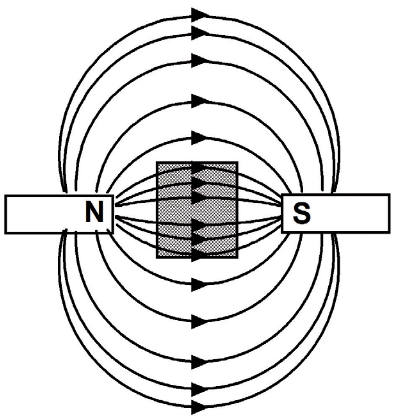
7.0 Effect of an Iron Path on Magnetic Fields

Key Learning Points

- Effect of an iron path; field/flux movement-focus, ease of force line movement through ferromagnetic matter compared to air

7.1 Behaviour of Non-Magnetic Materials in a Magnetic Field

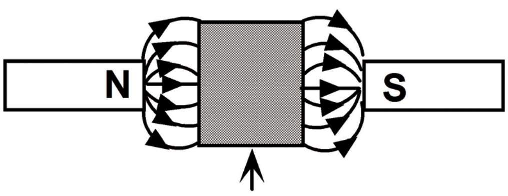
When a non-magnetic material is placed into the magnetic field of a magnet, the magnetic field lines of the magnet are unaffected and they behave as though the non-magnetic material was not there, *see below.*



Non magnetic material

7.2 Behaviour of Magnetic Materials in a Magnetic Field

On the other hand, if a magnetic material, such as soft iron, is introduced into a magnetic field, the field lines become more concentrated within the soft iron *see below.*



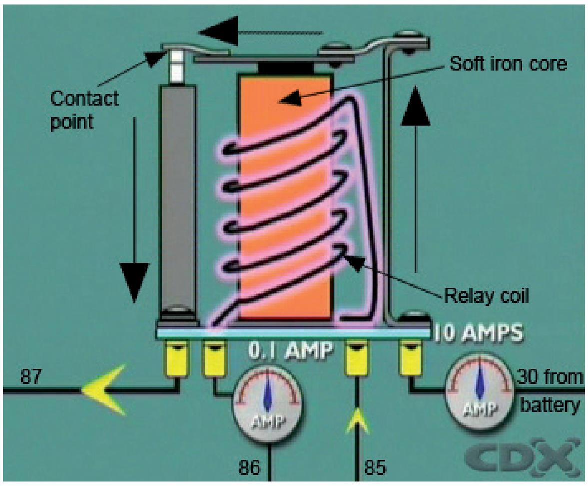
Ferromagnetic material

8.0 The Electromagnet

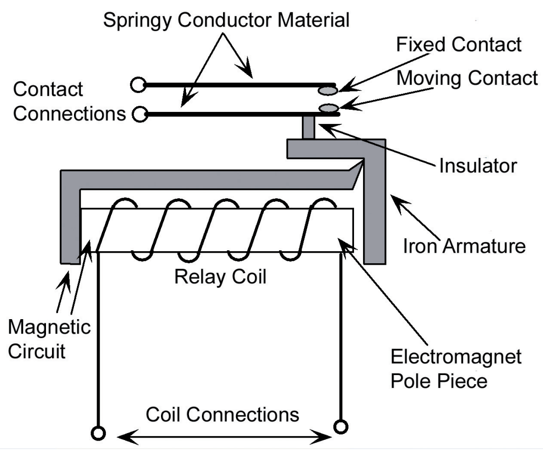
Key Learning Points

- Construction and operation of electromagnet; soft iron core, cumulative magnetic effect of current flow through a coiled conductor, quantity of remenance

8.1 Relays



A relay is an electro-magnetically operated switch. A relay consists of a coil, an armature and one or more sets of contacts. When current flows through the coil the armature is attracted towards it and operates the contact. The pole piece is magnetically soft so that when the current in the coil is switched off it retains virtually no magnetism, thus allowing the contact return to their de-energised or normal state.



Principle of an Electrical Relay

A typical relay in which a low voltage and current can operate the relay and cause the contact to close, the contact controlling a larger current and voltage. A relay or contactor may have several sets of contacts, which are operated simultaneously by the armature mechanism.

Inside a relay is an electromagnet. When a small current energizes this electromagnet, it attracts an armature blade and closes contact points. The current that the relay is switching (on or off) can then flow across these points.

As long as the small switching current flows to the relay, the much larger current will flow through its contact points. Because a relay is able to control an output circuit of higher power than the input circuit, it can be considered, in a broad sense, to be a form of electrical amplifier.

These contacts can be either normally-open, normally-closed, or change-over contacts.

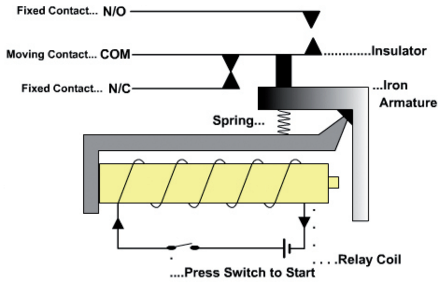
Normally-open *(N/O)* contacts connect the circuit when the relay is activated; the circuit is disconnected when the relay is inactive.

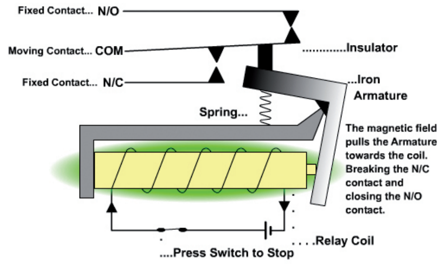
Normally-closed *(N/C)* contacts disconnect the circuit when the relay is activated; the circuit is connected when the relay is inactive.

Change-over contacts control two circuits: one normally-open contact and one normally-closed contact.

Operation

When a current flows through the coil, the resulting magnetic field attracts an armature that is mechanically linked to a moving contact. The movement either makes or breaks a connection with a fixed contact. When the current is switched off, the armature is usually returned by a spring to its resting position.





Types of Relay

A *latching relay* is mechanically arranged so that the armature can rest in either of two positions. There are two coils that pull the armature in opposite directions, so the relay can be switched to one position or the other and then left in that state indefinitely. This type of relay has the advantage that it consumes power only for an instant, while it is being switched and it retains its last setting across a power outage. (Some common relays may be wired to electrically latch, which offers no power saving but does ensure that the relay returns to a known state during and after a power outage.)

A *contactor* is a very heavy-duty relay used for switching electric motors and lighting loads. Such devices are often used for motor starters and may be built up with overload protection devices attached. The overload sensing devices are a form of heat operated relay where a coil heats a bi-metal strip to open contacts, or where a solder pot melts, releasing a spring to operate contacts.

Self Assessment

Q1. Lines of magnetic flux are considered to have a number of properties. Identify the property in the following list that is INCORRECT:

- ❑ 1. They have a definite direction
- ❑ 2. They always form closed loops
- ❑ 3. They never cross one another
- ❑ 4. They attract each other when lying side by side and having the same direction.

Q2. If the south-seeking poles of two magnets are brought close together they will:

- ❑ 1. Repel each other
- ❑ 2. Be unaffected
- ❑ 3. Pull together
- ❑ 4. Attract each other

Q3. Lines of magnetic flux are considered to have the direction:

- ❑ 1. Towards a north pole
- ❑ 2. North to south outside a magnet
- ❑ 3. North to South inside the magnet
- ❑ 4. South to north outside a magnet

Q4. The shape of a magnetic field can be found by using:

- ❑ 1. A plotting compass or iron filings
- ❑ 2. An ordnance survey map
- ❑ 3. A land surveyor
- ❑ 4. An ammeter

Suggested Exercises

- Identify magnetic materials, demonstrate lines of force, attraction and repulsion.
- Examine the construction and operation of electromagnets, e.g. relays.

Training Resources

- Magnetic field detection; use of compass, iron filings.
- Magnetic attraction and repulsion; use of magnets, magnetic materials
- Demonstration of force lines; use of iron filings, field/flux lines not crossing each other, concentrated at poles

Suggested Further Reading

- Advanced Automotive Diagnosis. Tom Denton. ISBN 0340741236
- Automobile Electrical and Electronic Systems (3rd Edition). Tom Denton. ISBN 0750662190
- Automotive Mechanics (10th Edition). William H. Crouse and Donald L. Anglin. ISBN 0028009436
- Bosch Automotive Electrics Automotive Electronics: Systems and Components (4th Edition). Robert Bosch. ISBN 0837610508
- Bosch Automotive Handbook (6th Edition). Robert Bosch. ISBN 1860584748
- Bosch Automotive Technology Technical Instruction booklet series (numerous titles)
- Hillier's Fundamentals of Motor Vehicle Technology: Book One (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780823
- Hillier's Fundamentals of Motor Vehicle Technology: Book Two (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780998
- Modern Automotive Technology. James E. Duffy. ISBN 1566376106
- Motor Vehicle Craft Studies - Principles. F.K. Sully. ISBN 040800133X
- National Car Test (NCT) Manual (Department of Transport, Vehicle Testers Manual - DoT VTM). Department of Transport
- Transmission, Chassis and Related Systems (Vehicle Maintenance and Repair Series: Level 3) (3rd Edition) John Whipp and Roy Brooks. ISBN 186152806X
- Vehicle and Engine Technology (2nd Edition). Heinz Heisler. ISBN 0340691867
- http://www.cdxglobal.com/
- http://auto.howstuffworks.com/
- http://www.autoshop101.com/
- http://www.cdxetextbook.com/
- Automotive Encyclopedia and Text Book Resource (CD version of e-textbook), Available from your instructor.

Notes

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