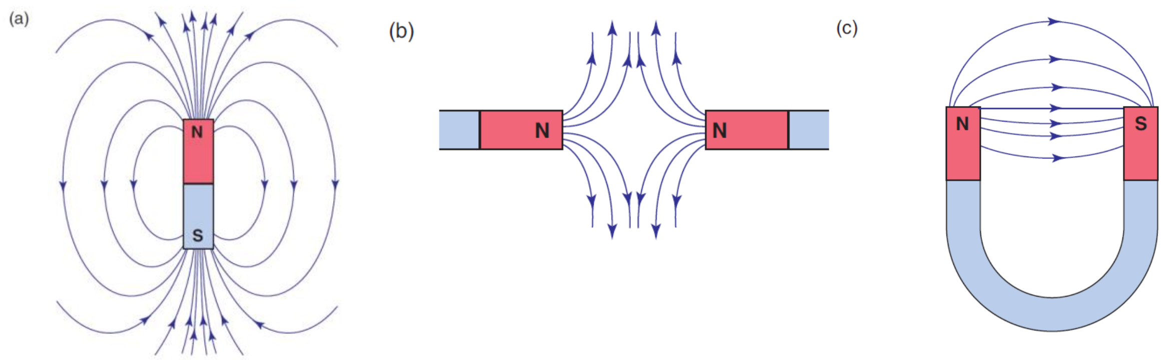
MODULE 2: MOTORS AND GENERATORS

Definitions

- **Motor effect**: the action of a force experienced by a current-carrying conductor in an external magnetic field.
- **Right-hand grip rule**: used to find the direction of a magnetic field around a straight current carrying conductor.
- **Right-hand palm rule**: used to find the direction of the force acting on a moving charged particle or current-carrying conductor in an external magnetic field.

Preliminary Physics

- Moving charged particles produce magnetic fields. The direction of the magnetic field is found using the **right-hand grip rule**. When charged particles enter an external magnetic field, the magnetic field created interacts with the external magnetic field. The direction of the force is determined by the **right hand palm rule**:
  - Fingers point to the direction of the external field
  - Thumb points to the direction of conventional current flow
  - Palm points to the direction of the force on the positive particles
- The **law of magnetic poles** states that opposite poles of magnets attract each other and like poles of magnets repel each other.
- Magnetic field lines show the strength and direction of the field. The spacing of the magnetic field lines represents the strength of the field. Field lines that are an equidistant represent a uniform magnetic field.
- The direction of the magnetic field at a point is given by the **direction of the force on the N pole of a magnet** placed within the magnetic field. It is shown by arrows on the magnetic field lines.
- Magnetic field lines **leave the N pole of a magnet and enter the S pole**
- The following diagrams represent the magnetic fields around a) a single bar magnet, b) two N poles close to each other, c) a horseshoe magnet:



- Magnetic field lines going into the page are represented by using dot points, while magnetic field lines going out of the page are represented by crosses.
- The movement of charged particles produces a magnetic field. The magnetic field is circular in nature around the current-carrying conductor, and can be represented using concentric field lines. The field gets weaker with increasing distance from the current.
- The direction of the magnetic field around a straight current-carrying conductor is found using the **right hand grip rule**. When the right hand grips the conductor with the thumb pointing in the direction of conventional current, the curl of the fingers gives the direction of the magnetic field around the conductor.
- A **solenoid** is a coil of insulated wire that can carry current. The number of times that the wire has been wrapped around a tube to make the solenoid is referred to the number of

'turns' or 'loops'. The magnetic fields around each loop of wire add to produce a magnetic field similar to that of a bar magnet.

- The direction of the magnetic field produced by a solenoid can be determined using another right hand grip rule. In this case, the right hand grips the solenoid with the fingers pointing in the direction of the conventional current flowing in the loops of the wire and the thumb points to the N pole.
- Another method of determining the poles of a solenoid is to look at a diagram of the ends of the solenoid, and mark in the direction of the conventional current around the solenoid. Then mark on the diagram the letter N or S that has the ends of the letter pointing in the same direction as the current. N is for an anticlockwise current, S is for a clockwise current.
- An **electromagnet** is a solenoid with a soft iron core. When current flows through the solenoid, the iron core becomes a magnet. The core produces a much stronger magnetic field than is produced by the solenoid alone. The strength of an electromagnet can be increased by:
    - Increasing the current flowing through the solenoid
    - Adding more loops of wire for a long solenoid
    - Increasing the amount of soft iron
- The magnetic field produced by a current carrying solenoid is affected by the materials inside the coil:
    - Oxygen and aluminium slightly **INCREASE** the strength of the magnetic field (such substances are called paramagnetic)
    - Mercury and bismuth slightly **DECREASE** the strength of the magnetic field (diamagnetic substances)
- A few substances yield a **LARGE INCREASE** in magnetic field strength when placed in a solenoid (these are called **FERROMAGNETIC SUBSTANCES**)

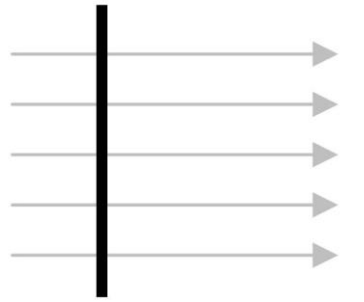
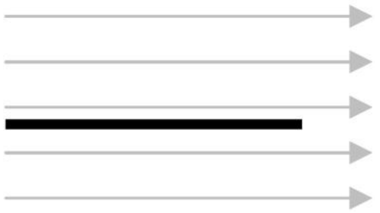
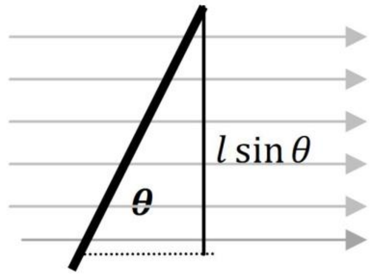
1. Motors use the effect of forces on current-carrying conductors in magnetic fields

- **Discuss the effect on the magnitude of the force on a current-carrying conductor of variations in:**
    - **The strength of the magnetic field in which it is located**
    - **The magnitude of the current in the conductor**
    - **The length of the conductor in the external magnetic field**
    - **The angle between the direction of the external magnetic field and the direction of the length of the conductor**
    - The magnitude of the force on a straight conductor in a magnetic field depends on the following factors:
        - The *strength of the external magnetic field in which it is located*. The force is proportional to the magnetic field strength, ***B***.
        - The *magnitude of the current in the conductor*. The force is proportional to the current, ***I***.
        - The *length of the conductor in the external magnetic field*. The force is proportional to the length, ***l***.
        - The *angle between the conductor and the external magnetic field*. The maximum force is achieved when the conductor is perpendicular to the magnetic field; it is 0 when the conductor is parallel to the field. The magnitude of the force is proportional to the component of the field that is at right angles to the conductor. If θ is the angle between the field and the conductor, then the force is the maximum value multiplied by the sine of θ
    - These factors can be expressed as $F = BIl\sin\theta$ (*include arrows above F, B and I for vectors*), where ***F*** = force experienced by the current-carrying conductor (N); ***B*** = strength of the external magnetic field (Tesla; T); **I** = current flowing through the

conductor (A); ***l*** = length of the conductor within the external magnetic field (m); θ = angle between the field and the conductor (^{O}).

Factors	Symbol	Units
Magnetic Field Strength	B	Teslas
Magnitude of **Current**	I	Amps
Length of Conductor in external magnetic field	l	Meters
Angle between direction of external magnetic field and the direction of the field strength	θ	Degrees

- It is important to understand where the sin θ comes from. Sin θ comes about because the current carrying conductor only experiences a force when it is at right angle to the magnetic field. Hence, when the wire is at an angle θ to the field, it is **only the component of the wire perpendicular to the field that produces the motor effect**.

Wire perpendicular to field	**Wire parallel to the field**	**Wire at an angle θ to field**
		
The wire is perpendicular to the magnetic field and will experience a **maximum** force	The wire is parallel to the magnetic field and will experience **zero** force	Only the component of the wire that is perpendicular to the field (*lsin* θ) will cause the motor effect

- **TALENT TIPS**: Make sure you convert all your units into SI units. This way you can be sure that your final answer will be in SI units. Force is a vector quantity. You must ALWAYS put a direction with your force. Watch out for the angle that they give you. An exam favourite is to give a complementary angle. Mindless substitution will result in the wrong answer. Be aware of questions that give you a red herring for the angle.

The magnitude of the force on a current carrying conductor (MATRIX EDUCATION)
Consider a current carrying wire of length *L* containing positive charges *q* travelling at *v*.

V = $\frac{L}{t}$ and *q = It* (since I = rate of flow of charge = q/t). Also, *F = qvBsin* θ

Equating all of the above yields *F = BIlsin* θ

- **Describe qualitatively and quantitatively the force between long parallel current-carrying conductors:** $\frac{F}{l}$ = k $\frac{I_1 I_2}{d}$
  - If a certain distance separates two parallel current-carrying conductors, each conductor will experience a force due to the interaction of the magnetic fields.
  - When two long parallel conductors carry currents I_1 and I_2 in the **same** direction, conductor 2 experiences a force directed towards conductor 1 based on the RHP rule.

Similarly, conductor 1 experiences a force directed towards conductor 2. This means that the conductors ATTRACT EACH OTHER.

- When two long parallel conductors carry currents I_1 and I_2 in the **opposite** direction, conductor 2 experiences a force away conductor 1 based on the RHP rule. *Similarly*, conductor 1 experiences a force directed away from conductor 2. This means that the conductors REPEL EACH OTHER.
- *Determining the magnitude of the force between two parallel conductors*: The **magnetic field strength** at a distance, ***d***, from a long straight conductor carrying a current, ***I***, can be found using the formula: $B = \frac{kI}{d}$, where k = 2.0 x 10^{-7} N A^{-2}. Consider two parallel conductors X and Y that are carrying currents I_1 and I_2 respectively. They are separated by a distance *d*.

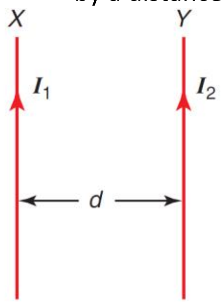


Figure 6.15 *Two parallel current-carrying conductors*

- The magnetic field strength in the region Y due to the current flowing through X is $B_x = \frac{kI_1}{d}$. This is because the strength of the magnetic field decreases with increasing distance and increases with increasing current.
  - **You don't need to perform calculations using this equation**
    - ⇒ Questions might be **qualitative** (descriptive) though
- The magnitude of the force experienced by a length, *l*, of conductor Y due to the external magnetic field provided by conductor X is:
  - $F = I_2 l B_x$ or $F = I_2 l \left(\frac{kI_1}{d}\right)$
- This can be rearranged to give the formula $\frac{F}{l} = k\frac{I_1 I_2}{d}$ (**Ampere's Force Law**)

MATRIX EDUCATION TIP

Questions involving forces in the vertical direction generally obey the following rules:

- 2 forces are involved
- One of the forces is weight, mg, acting vertically downward and the other force is unknown (force between parallel conductors, force between two masses etc.)
- If the word 'balanced' is used in the question, then mg = unknown force

When a mass stops a coil from rotating, EQUATE WEIGHT FORCE (MG) with the FORCE ON A CURRENT CARRYING CONDUCTOR (bilsintheta) – NOT torque

When a question asks for the MAGNITUDE of a force, don't give the direction

- **Define torque as the turning moment of a force using:** $\tau = Fd$
  - **Torque** is the **TENDENCY** of a force to **ROTATE** an object about an axis, fulcrum or pivot. Examples include: turning on a tap, turning a steering wheel etc. it is easier to rotate an

object (torque, τ is greater) if the force, ***F***, is applied at a greater distance, ***d***, from the pivot axis. It is also easier to rotate the object if the force is at right angles to a line joining the pivot axis to its point of application.

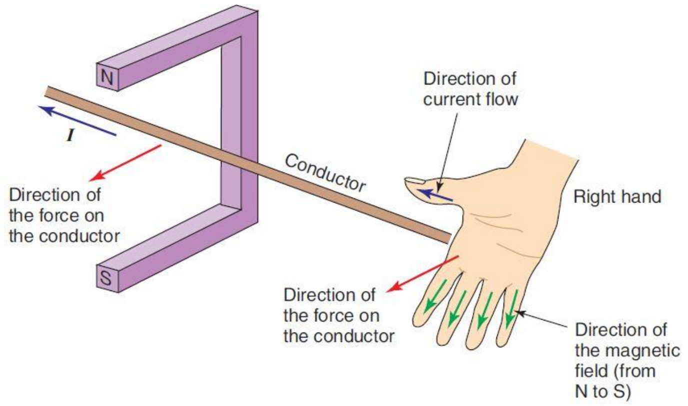
- If the force is perpendicular to the line joining the point of application of the force and the pivot point, the formula is $\tau = Fd$. The SI unit for torque is the **Newton metre** (Nm). If the force isn't perpendicular to the line joining the pivot axis and point of application, the component of the force that is perpendicular to the line can be used. The formula is then: $\tau = Fd \sin\theta$ where θ is the angle between the force and line joining the point of application of the force and pivot axis.

SIDE NOTE: the torque produced by a mass is equal to Fd, where F = mg (its weight)

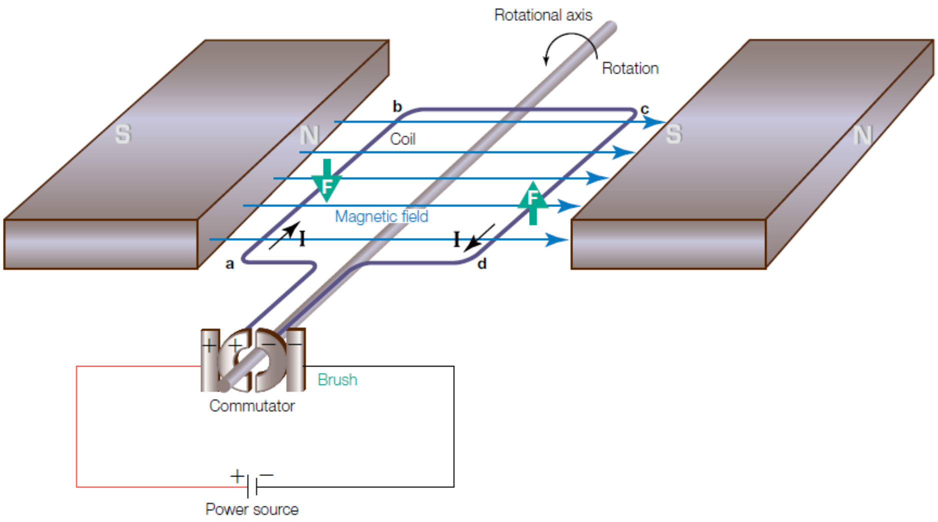
A lever is free to rotate about a point, P. Calculate the magnitude of the torque acting on the lever if a force of 24N acts at right angles to the lever at a distance of 0.75m from P.

$\tau = Fd$ = 24 x 0.75 = 18 N m.

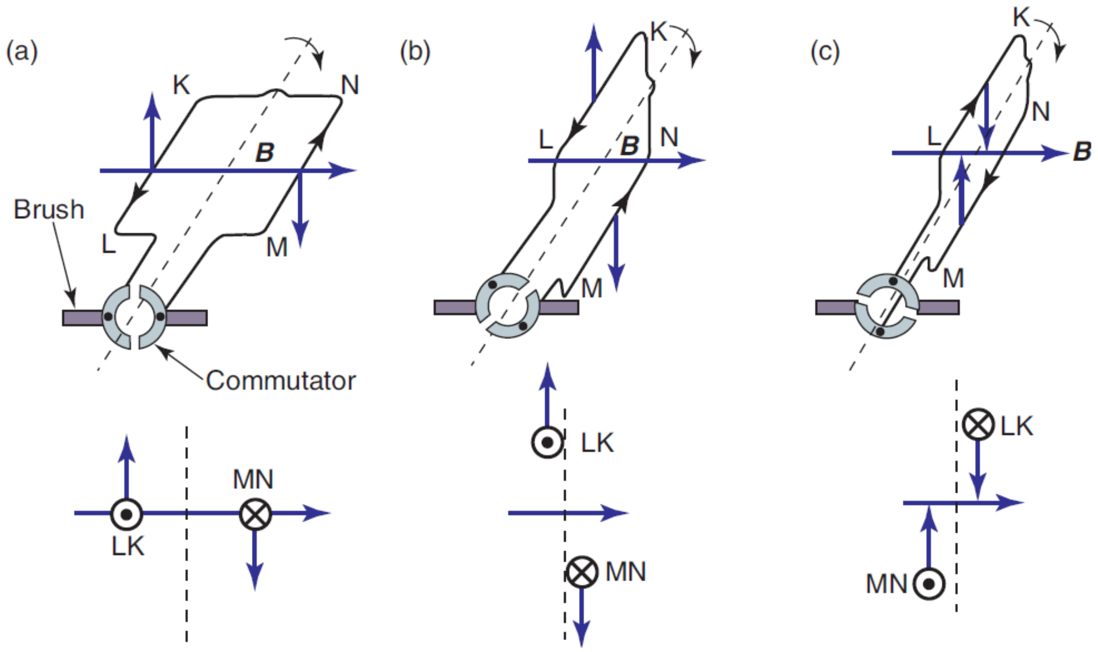
- **Identify that the motor effect is due to the force acting on a current-carrying conductor in a magnetic field**
  - Charged particles moving in an external magnetic field will experience a force. If the charged particles are flowing through a conductor that is in an external magnetic field, the conductor will also experience a force. This effect was discovered in 1821 by Michael Faraday and is called the **motor effect**.
  - The direction of the force on the current-carrying conductor in an external magnetic field can be determined using the **right hand palm rule**:



- **Describe the forces experienced by a current-carrying loop in a magnetic field and describe the net result of the forces**
  - A current carrying loop in a magnet can be used to create an electric motor. An electric motor is a device which **converts electrical potential energy into rotational kinetic energy**. They can be either DC or AC run.

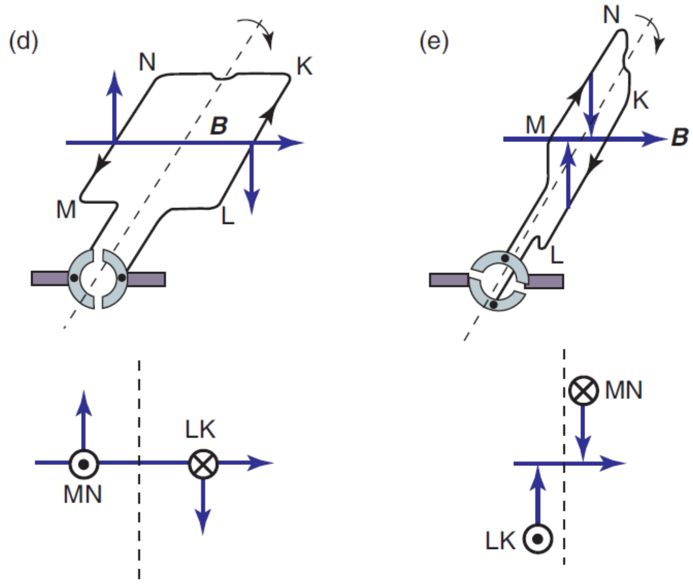


- There are several possible positions for the coil to be in, and the forces on the coil can be worked out for each situation by considering the direction of the current and magnetic field. From this, the torque and hence net result of the force can be determined. In this series of rotations, the magnetic field is to the right and conventional current enters from the right brush:



- In figure (a), LK experiences a force upwards as per the RHP rule. MN has a force of equal magnitude that is downwards. The forces applied to the sides of the coil are perpendicular to the axle (or pivot line), meaning the torque is maximum. This will cause the coil to rotate clockwise until it reaches (b).
- In figure (b), LK still has a force acting on it that is vertically upwards. *Similarly*, MN has a force of equal magnitude that is acting downwards. The forces are almost parallel to the line joining the axle to the place of application of the force, resulting in a torque close to 0. It is after this that the **commutator changes the direction of the current** through the coil. The **momentum of the coil** keeps it rotating even though the torque is ~0.
- In figure (c), the coil has rotated slightly more due to the momentum. The force acting on LK is now downwards and the force on MN is upwards. This change in the direction of the current and momentum of the coil enable the coil to continue rotating in the same direction. The torque is still clockwise.

- **If the direction of the current had not changed, the coil would rock back and forth about its position (oscillate to rest).**



- Figure (d) shows the position of the coil when the torque is again a maximum. In this case the side MN is experiencing a force upwards.
- Figure (e) shows the position of the coil when the torque is ~0 again and the current has been reversed again. The current is again flowing from K to L and there is still clockwise torque acting on the coil.

How can you improve the efficiency of a DC motor?

We can improve the efficiency of a DC motor by:

- Using a curved magnet to produce a radial magnetic field so that the coil remains in the plane of the magnetic field so that the torque is maximum.
- Using three rotor coils instead of one to ensure that at least one coil is in the plane of the magnetic field. The total torque on the three coils will then remain constant.
- Using electromagnets instead of permanent magnets to achieve greater control of the magnetic field.
- Placing an iron core in the armature to concentrate the field lines in the centre, thus increasing the magnetic field threading the coil.
- Decreasing the load on the motor. If it has a greater load on it, it will be likely to spin slower and provide a lower power output. Thus, by decreasing the load we can increase the speed of the rotation and the power output.
- Increasing the number of turns in the armature, causing the torque on the armature to increase and the power output of the motor to increase.

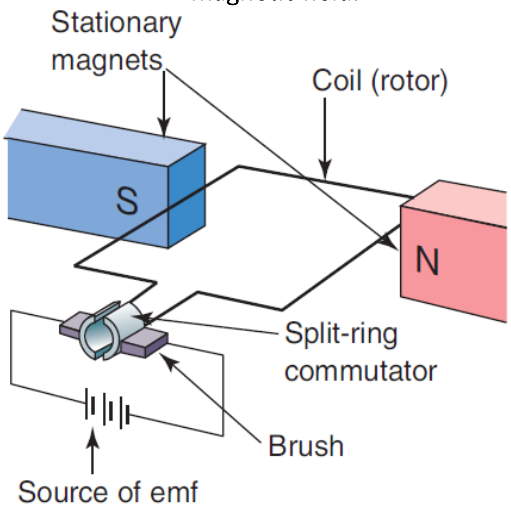
Explain why the torque on a current loop in a magnetic field is zero when the magnetic flux through the coil is at a maximum (4 marks – CSSA 2004)

For full marks: *states definition of torque and magnetic flux, what is the angle between the magnetic field and plane of the coil when magnetic flux is 0?, links the torque and magnetic flux with the movement through a magnetic field and the situation leading to a torque being 0.*

Torque is the tendency of a force to rotate an object about an axis, fulcrum or pivot. Magnetic flux is the number of field lines passing through a given area. The magnetic flux is a maximum when the plane of the coil is perpendicular (at 90°) to the magnetic field lines. Since $\tau = nBIA\cos\theta$, and cos90° = 0, the torque acting on the current loop is 0 in this position.

When the **PLANE OF THE COIL IS PARALLEL TO THE MAGNETIC FIELD LINES**, then the force vector is perpendicular from the point of rotation. Hence **maximum torque** is produced.

- **Describe the main features of a DC electric motor and the role of each feature**
  - An electric motor transforms electrical potential energy into rotational kinetic energy. Electric motors produce rotational motion by passing a current through a coil in a magnetic field.



Main Feature	Description	Role
A pair of permanent magnets	Two permanent magnets on opposite sides of the motor, with opposite poles facing each other.	The magnets supply the magnetic field which interacts with the rotor coils to produce a torque.
Armature	A conductor that is shaped in a loop.	To rotate as the current is fed through it due to the motor effect.
Split Ring Commutator	A split ring that is connected to the armature as well as conducting brushes.	Reverse the current in the armature every half cycle to ensure continuous torque in the same direction.
Conducting Brushes	Carbon brushes that connect the external circuit to the split ring commutator.	To provide electrical contact between the electrical circuit and split ring commutator to ensure current is fed through to the armature.
Axle	A cylindrical bar of hardened steel passing through the centre of the armature and the commutator	The axle provides a centre of rotation for the moving parts of the motor

NB: The commutator is **NOT** fixed to the power supply. It is a part of the loop. As the coil rotates, the current is reverse **ONCE EVERY HALF TURN** as the commutator segments make contact alternately with the brushes.

- **Identify that the required magnetic fields in DC motors can be produced either by current-carrying coils or permanent magnets**
  - Magnets are essential for the functioning of the DC motor, as they provide the magnetic field which allows the motor effect to occur.

- The magnetic field of a DC motor can be provided either by permanent magnets or by electromagnets. The permanent magnets are fixed to the body of the motor. Electromagnets can be created using a soft iron shape with wire coiled around it. The current that flows through the armature coil can be used in the electromagnet coils.

- **Solve problems using $\frac{F}{l} = k\frac{I_1 I_2}{d}$**

What is the magnitude and direction of the force acting on a 5.0 cm length of conductor X if I_1 is 3.2A and I_2 is 1.2A and the separation of X and Y is 25cm.

F= $kl\frac{I_1 I_2}{d} = \frac{2*10^{-7}*5*10^{-2}*3.2*1.2}{0.25}$ = 1.5 x 10^{-7} N right. NB: To determine the direction of the force, first find the direction of the magnetic field at X due to the current in Y by using the RHG rule. The field is out of the page. Then determine the direction of the force on X using the RHP rule. This shows that the force is to the right.

Calculate the force per unit length between two parallel wires of length 75m that are 62cm apart if they carry 750A in the same direction.

$\frac{F}{l} = k\frac{I_1 I_2}{d}$

F = $\frac{2*10^{-7}*750^2}{0.62}$

F = 0.18 Nm^{-1} attractive

A metal wire of length 25 cm is carefully placed on top of an electronic balance with a current of 40A running from right to left. The balance gives a reading of 8.56A. A second wire, parallel to the first is brought to within 50mm of the first wire. If the reading on the scales is 9.12N, find the current in the second wire. The top wire is fixed.

Weight change = F = 9.12-8.56 = 0.56N

$\frac{F}{l} = k\frac{I_1 I_2}{d}$

$\frac{0.56}{0.25} = \frac{2*10^{-7}*40*I}{0.05}$

I = 14 000 A

Two wires that carry electricity <u>into a factory</u> are separated by a distance of 0.20m. If each wire carries a current of 6.0 x 10^3 A, state the force acting per unit length of the wires. Explain why the wires need to be held firmly.

$\frac{F}{l} = k\frac{I_1 I_2}{d}$

$\frac{F}{l} = \frac{2*10^{-7}*6*10^3*6*10^3}{0.2}$ = 36 Nm^{-1}

Because the wires are carrying current in the same direction, they attract each other and may cause a short circuit. As a result, they must be firmly held together.

- **Perform a first-hand investigation to demonstrate the motor effect**

Aim: To observe the motor effect, and the effect of increasing the current on the size of the electromagnetic force acting on the conductor.

Equipment: variable DC supply (power pack), variable resistor (rheostat), electrical leads (two with alligator clips on one end), ammeter, retort stand, boss head, wooden dowel, strip of aluminium foil 30 cm x 1 cm, horseshoe magnet.

Theory: A current carrying conductor in a magnetic field will experience a force. This is known as the motor effect because this is the principle we use to build electric motors. It is important when you talk about how the motor effect arises to remember that:

- Currents DO NOT interact with each other
- Currents DO NOT interact with magnetic fields
- Magnetic fields DO interact with each other

Method:

1. A strip of aluminium foil (30 cm x 1 cm) was cut using scissors. The strip was folded half lengthways twice, such that the dimensions of the strip were 30 cm x 0.25 cm.
2. The apparatus below was set up.
3. It was ensured that the aluminium strip was connected to the wooden dowel at the top of the alligator clip so that good electrical contact could be made.
4. The rheostat was adjusted to its highest resistance setting.
5. The power supply was set to its lowest setting and then switched on.
6. The rheostat was adjusted to 1 A. The current was then switched off.
7. The magnets on either side of the aluminium strip were held.
8. Before the current was switched back on, the RHP rule was used to predict the direction of the force on the aluminium strip and was recorded in a table.
9. Steps 6-8 were repeated with currents of 2 A, 3 A, 4 A and 5 A.

Conclusion: The force experienced by the aluminium foil was successfully predicted using the RHP rule. With increasing current, the magnitude of the force also increased.

- **Solve problems and analyse information about the force on current-carrying conductors in magnetic fields using:** $F = BIl\sin\theta$

A wire 12 cm long running North-South, carrying 6A lies in a magnetic field of 7T running East-West. Calculate the force on the wire.

$F = BIl\sin\theta$

$F = 7 \times 6 \times 0.12 \times \sin 90^{O}$

F = 5.04 N into the page (using RHP rule)

- **Solve problems and analyse information about simple motors using:** $\tau = nBIA\cos\theta$

Symbol	Quantity	S.I. Units
τ	Torque	Nm
n	Number of Coils	-
B	Magnetic Field Strength	T
I	Current	Amp
A	Area	m^2
θ	The angle between the armature and the field	$^\circ$

A coil contains 15 loops and its plane is sitting at an angle of 30^O to the direction of the magnetic field of 7.6mT. The coil has dimensions of 12 cm x 8 cm and a 15 mA current passes through the coil. Determine the torque acting on the coil.

τ = n*BIA*cosθ

τ = 15 x 7.6 x 10^{-3} x (0.12 x 0.08) x 15 x 10^{-3} x cos30^O

τ = 1.42 x 10^{-5} anticlockwise (using the RHP rule)

Finding an expression for the torque acting on a single current loop in its horizontal position if the length of the coil is *l* metres:

DERIVATION OF FORMULA

Torque = Fd + Fd

= BILd + BILd

= 2BILd

= BI(2dL)

= BIA

- **Identify data sources, gather and process information to qualitatively describe the application of the motor effect in:**
  - **The galvanometer**
  - **The loudspeaker**
  - The motor effect can be applied in:
    - **Galvanometer**: A galvanometer is a device used to measure the magnitude and direction of small DC currents. The coil consists of many loops of wire and is connected in a series circuit so that the current flows through the coil. The coil experiences a force due to the presence of the external magnetic field (motor effect). The iron core increases this force. The needle is rotated until the magnetic force on the coil is balanced by a spring. The magnets around the core are curved. This results in a radial magnetic field; the plane of the coil is always parallel to the magnetic field and the torque will remain constant. This also means that the scale of the galvanometer is linear, with the degree of deflection being proportional to the current.
      - ⇒ *Current flows → force on wire → torque on coil so coil rotates → stops when motor torque equals spiral spring back torque → deflection indicates current reading*

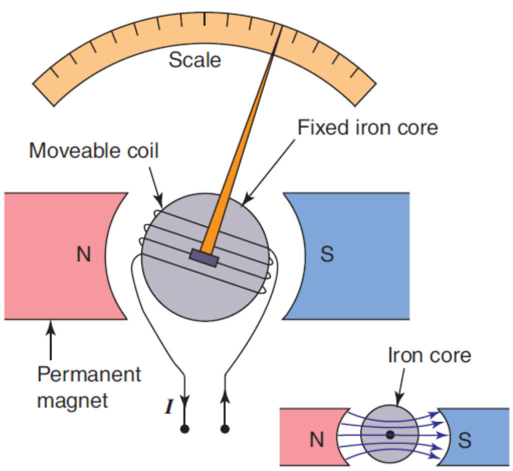


Figure 6.27 *The galvanometer*

A description of the main parts of a galvanometer is tabulated below (MATRIX):

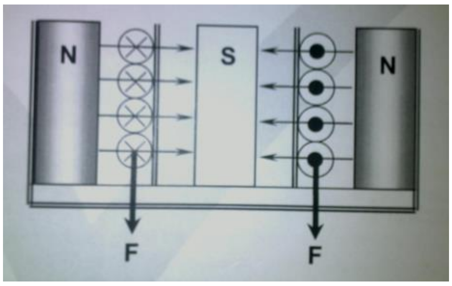
Component	Description	Role
Coils	A large number of turns of copper coil are wound around a soft iron core	The coil provides torque, as the current passing through them interacts with the magnetic field.
Strong radial permanent magnets	Magnetic pole faces are curved	The magnets supply the magnetic field which interacts with the magnetic field produced by the current in the coil to produce the motor effect. The radial magnets produce a radial magnetic field so that the plane of the coil is always parallel to the magnetic field. This ensures that **torque is maximum** at any position and allows a **linear scale** to be established.
Soft iron core	A cylinder of laminated iron mounted on an axle. There are longitudinal grooves into which the coils are wound	The iron core concentrates the magnetic field, increasing the torque on the coil. Enhances the torque developed when the unknown current is passed through it and thus makes the instrument more **sensitive**.
A hair spring	A fine spiral spring attached to the soft iron core	Provide the restoring torque and stop the rotation. Keeps the pointer at 0 when there is no current. When a current flows, the coil rotates as far as it can against the opposing torque of the spring.
A linear scale	The divisions of the scale are uniformly spaced and are equal in value	Provide reading of the angle and calibrate to the current flowing within the coil.

- **Loudspeakers**: Loudspeakers are devices that transform electrical energy into sound energy. A loud-speaker consists of an ***E-shaped magnet*** that has two south poles on both ends and one North Pole in the middle. A coil of wire is wound around the north pole in between. The voice coil is connected to the output of an amplifier. The amplifier supplies a current that changes the direction at the same frequency as the sound. The voice coil vibrates in and out of the magnet by the motor effect. When the current in the coil is anticlockwise, the force on the coil is out of the page. When the current is clockwise, the force of the coil is into the page. The voice coil is connected to a paper speaker cone that creates sound waves as it vibrates. When the current increases → force on coil increases → louder sound is produced.

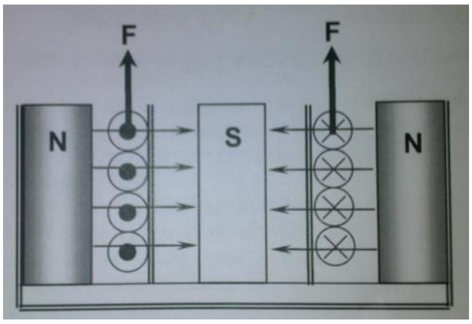
<u>MATRIX EDUCATION NOTES</u>

A coil is wrapped around the middle row of an E-shaped magnet. The 1st and 3rd row on the E-shaped magnet have the same poles, while the 2nd row has opposing poles. The voice coil is attached to the amplifier that provides an AC signal (current) of varying frequency. When the current flows through the voice coil, it experiences a force due to the presence of an external magnetic field produced by the permanent magnets (motor effect).

If the current flows in the voice as shown in the diagram, then the force acting on the voice coil is downwards (RHPR):



When the **polarity** of the AC signal switches, the direction of the current in the coil also reverses. Therefore the force on the voice coil is reversed:



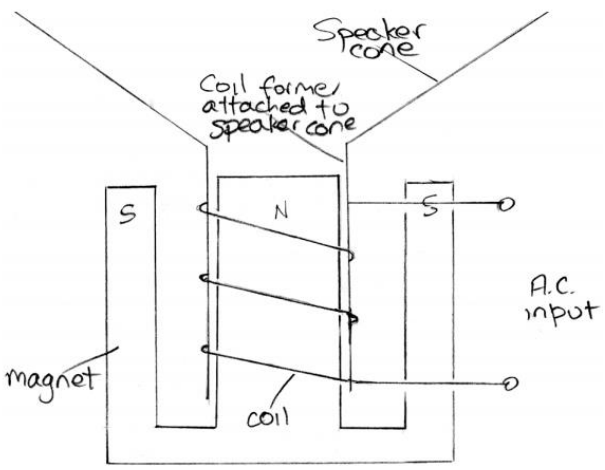
The coil is forced to vibrate according to the frequency and amplitude of the current variations. This oscillation causes movement of speaker cone. The speaker cone vibrates with the coil, and causes air particles to vibrate sending sound waves into the surrounding air.

How is the motor effect used to produce different sounds in a loudspeaker? Include a labelled diagram (5 marks – 2012 HSC)

Criteria Marks:

- Draws a labelled diagram showing the coil, magnet and speaker cone with the wire in the coil cutting across the magnetic field
- Describes the oscillation of the cone produced by AC in the coil in a magnetic field (motor effect) and states the vibration of the cone produces the sound
- Accounts for the production of louder sounds through the use of larger currents in the coil
- Relates the pitch (frequency) of sound to the changes in the current through the speaker coil.

When a current passes through the wire in the coil, a force is exerted on it because the current has a component perpendicular to the magnetic field direction – this is the motor effect. By passing AC through the coil, the force produced on the coil causes it to oscillate, moving the speaker cone correspondingly to produce sound waves. The pitch of the sound can be altered by changing the AC frequency and the volume of the sound can be increased by increasing the magnitude of the current through the coil.


Speaker cone
Coil former attached to speaker cone
S
N
S
A.C. input
magnet
coil