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MOTORS AND GENERATORS

Developed by the
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In collaboration with the
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Generating Electricity

A practical method for generating electricity is via **ELECTROMAGNETIC INDUCTION**.

Faraday discovered a voltage was produced across a wire when a magnet, near the wire, was moved. This voltage was called the induced emf (ε)

Faraday's Law of Electromagnetic Induction

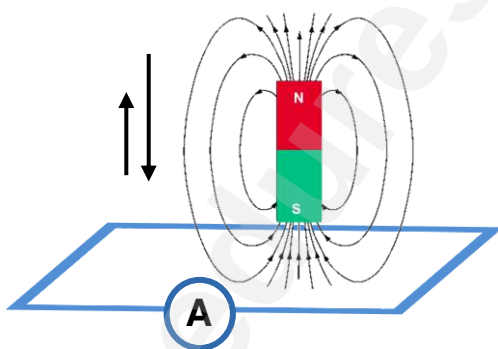
The emf, $\mathcal{E}$, produced around a loop of conductor is proportional to the rate of change of the magnetic flux, ϕ , through the area, A , of the loop

$$\varepsilon = -N \frac{\Delta\phi}{\Delta t}$$

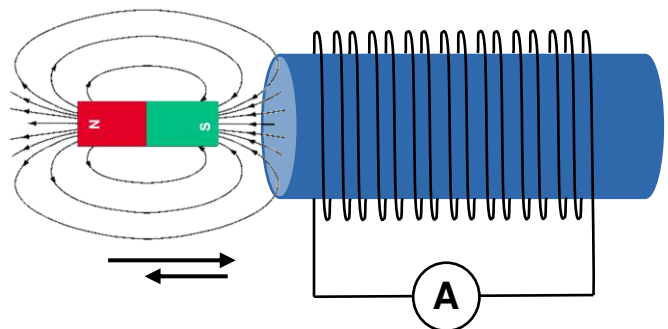
Where N is the number of circuit loops and $\phi = B \cdot A$, B is the magnetic field strength

If the wire was set up in a closed circuit, and the magnet moved near it, then an ammeter connected to this circuit would register a current as the magnet was moved. This current was called the induced current.

An emf, as well as an electric current, are induced in a conductor that is placed in a changing magnetic field



Single Loop Conductor



Solenoid

In all methods of inducing a current, the wire and magnetic field must move **perpendicular** to each other. If they move **parallel** to each other, no current is induced.

The **magnitude** of the induced current can be increase by:

- Moving the conductor faster.
- A stronger magnetic field (using stronger magnets).
- Increasing the length of the conductor (using a coil with more turns of wire).

Electrical Generators

A generator converts mechanical energy into electrical energy.

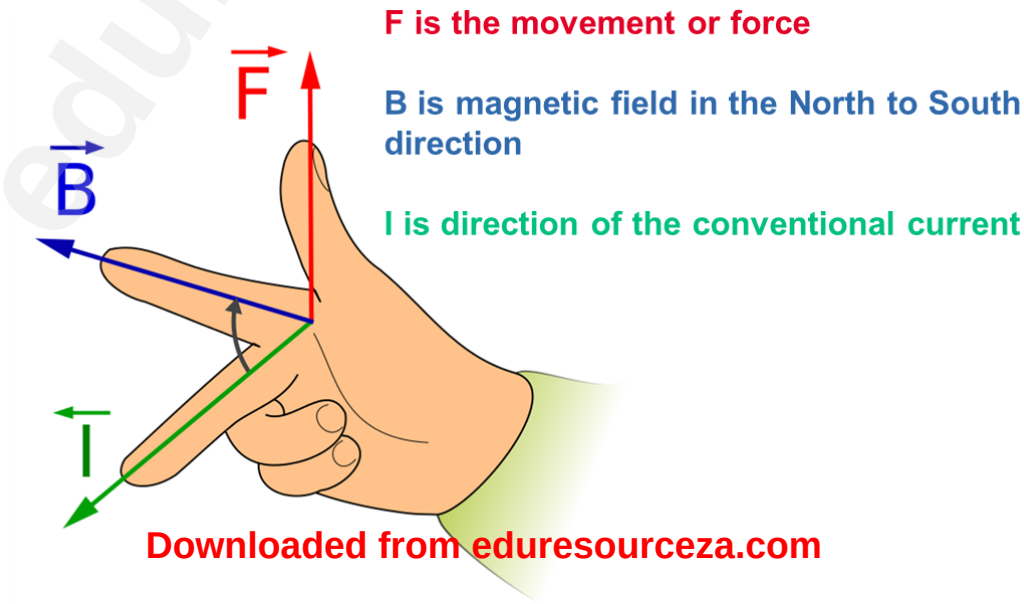
Two Types of Generators	
Alternating Current (AC)	Direct Current (DC)
Coil connect to split rings	Coil connected to split ring commutator
Current in the external circuit changes direction	Current in the external circuit does not change direction

As per Faraday's law of electromagnetic induction, whenever a conductor moves inside a magnetic field, there will be an induced current in it.

Fleming Right Hand Dynamo Rule is used to determine the direction of the induced current.

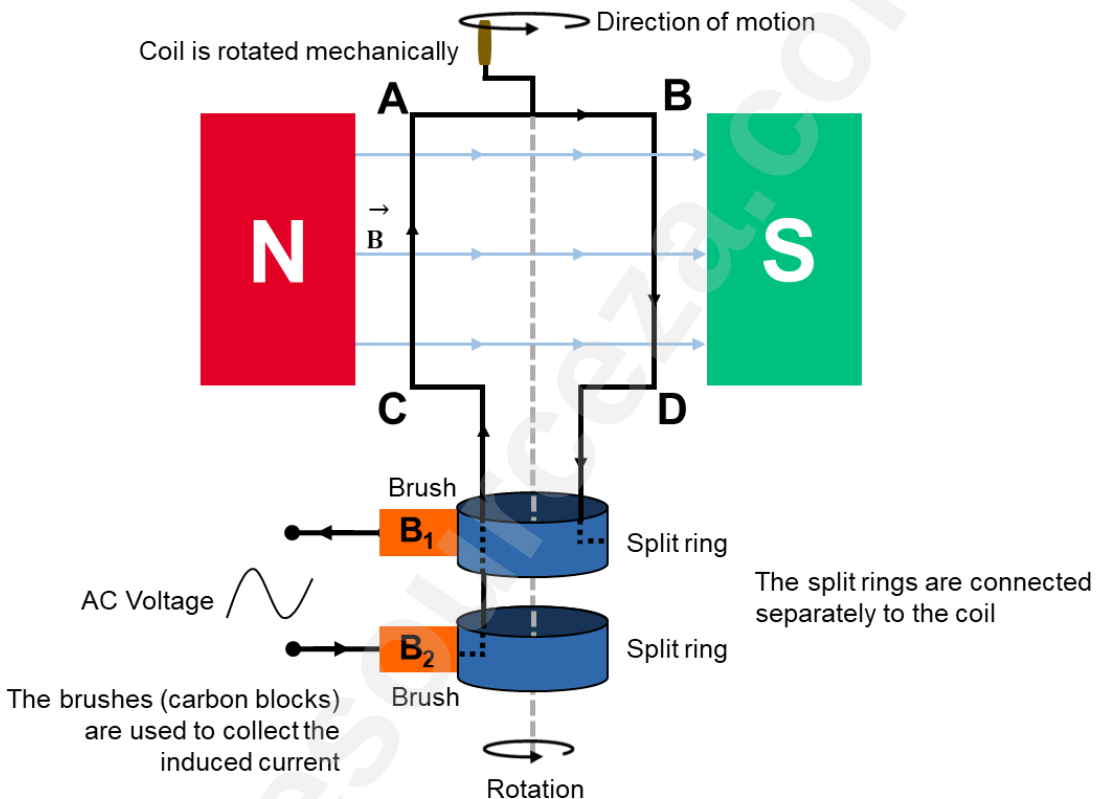
Hold out the right hand with the first finger, second finger and thumb at right angle to each other.

- First Finger is Field (B)
- Second Finger is Current (I)
- Thumb is movement or force (F)



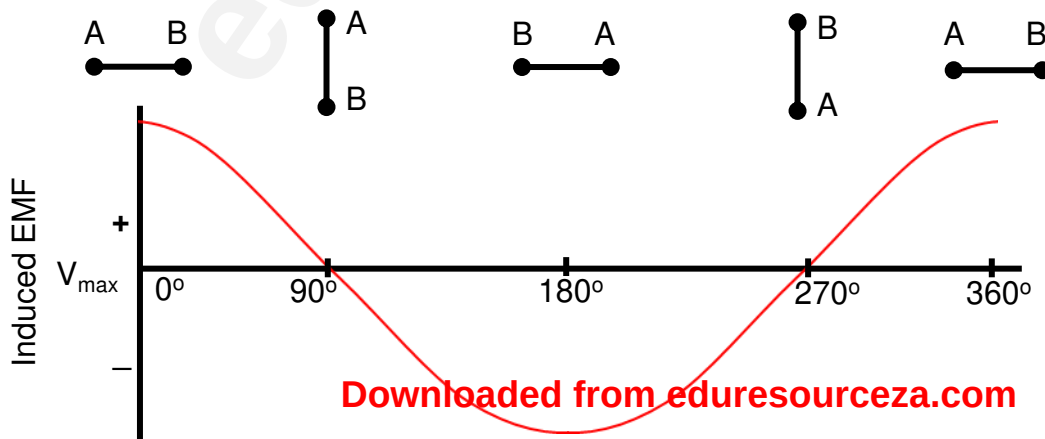
AC Generators

The layout of a simple AC generator. The conductor in the shape of a coil is connected to a slip ring. The conductor is then manually rotated in the magnetic field generating an alternating



The DIRECTION of the INDUCED CURRENT changes with every half turn of the coil, REVERSING after the coil moved through the vertical position.

This type of current is called an ALTERNATING CURRENT (AC)



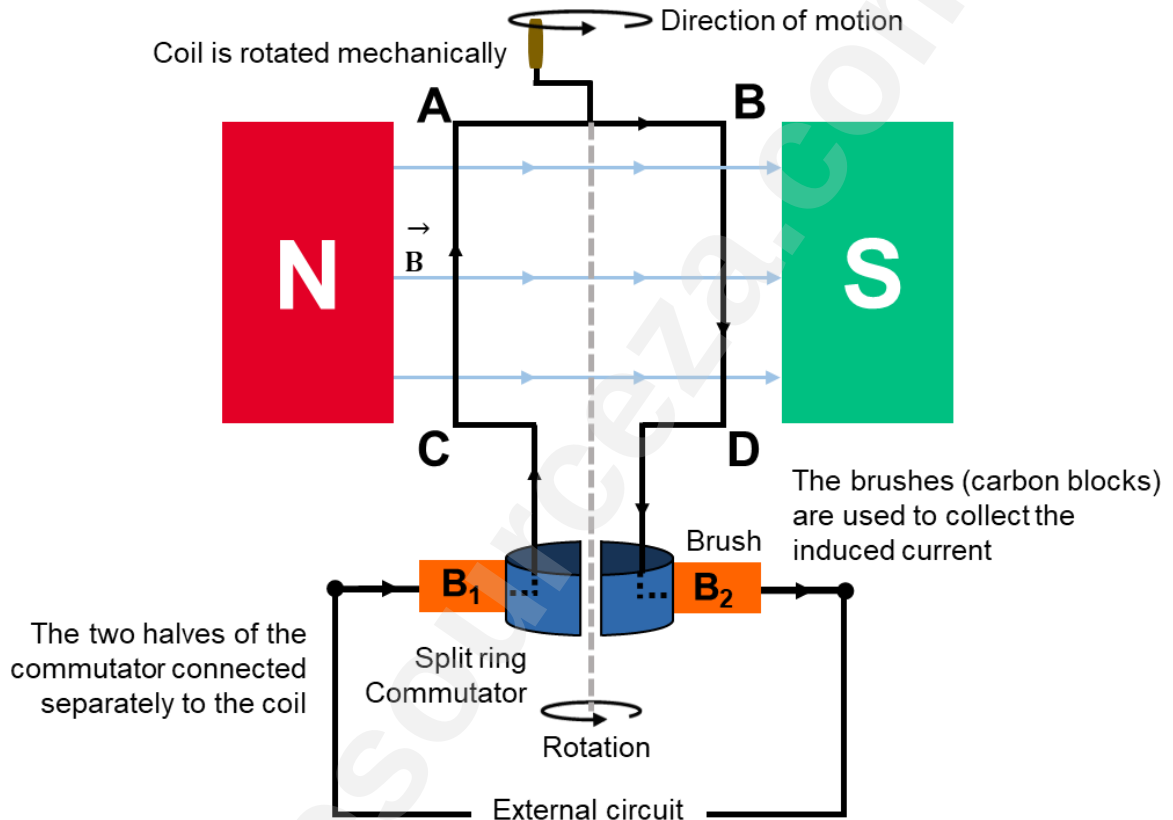
The induced current is maximum when the coil is in the horizontal position

At the vertical position, magnetic flux is zero and no voltage or current is generated

A graph of the INDUCED CURRENT would follow the same trend

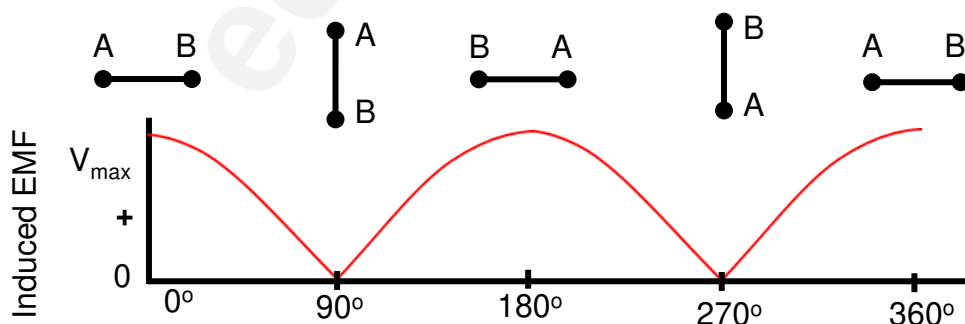
DC Generators

When the **slip rings** are replaced by a **split-ring commutator**, Direct Current (DC) is generated instead of AC.



The **SPLIT RING COMMUTATOR** ensure the **DIRECTION** of the **INDUCED CURRENT DOES NOT** changes with every half turn of the coil.

This type of current is called an **DIRECT CURRENT (DC)**



At the vertical position, magnetic flux is zero and no voltage or current is generated

Remember AC is generated in the coil BUT DC is established in the external circuit

A graph of the **INDUCED CURRENT** would follow the same trend

The induced current is always in the same direction in the external circuit

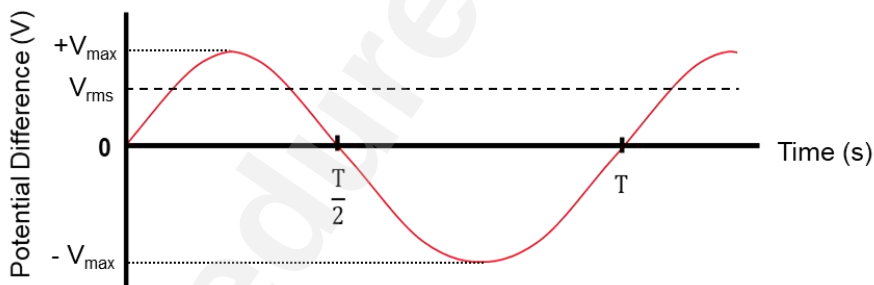
The Root Mean Square (rms)

The root mean square (rms) values are the AC equivalent of the DC emf.

AC	$V_{RMS} = \frac{V_{MAX}}{\sqrt{2}}$	AC equivalent of the DC	V	DC
	$I_{RMS} = \frac{I_{MAX}}{\sqrt{2}}$		I	
	$R = \frac{V_{RMS}}{I_{RMS}}$		$R = \frac{V}{I}$	
	$P_{avg} = V_{RMS} I_{RMS}$ $= I_{RMS}^2 R$ $= \frac{V_{RMS}^2}{R}$		$P = V I$ $= I^2 R$ $= \frac{V^2}{R}$	

Potential Difference (V)

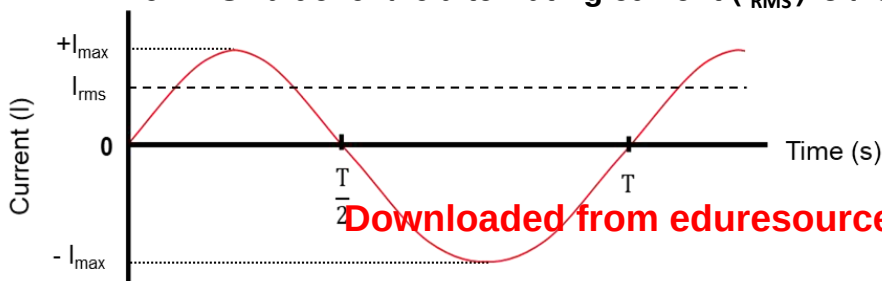
The **RMS value** for the **alternating voltage** (V_{RMS}) is the equivalent DC potential difference V that produces the same heating effect or power as the changing AC.



$$V_{RMS} = \frac{V_{MAX}}{\sqrt{2}}$$

Current (I)

The **RMS value** for the **alternating current** (I_{RMS}) is the effective current value of the AC



$$I_{RMS} = \frac{I_{MAX}}{\sqrt{2}}$$

Electrical Motors

In a motor, electrical energy is converted into mechanical energy

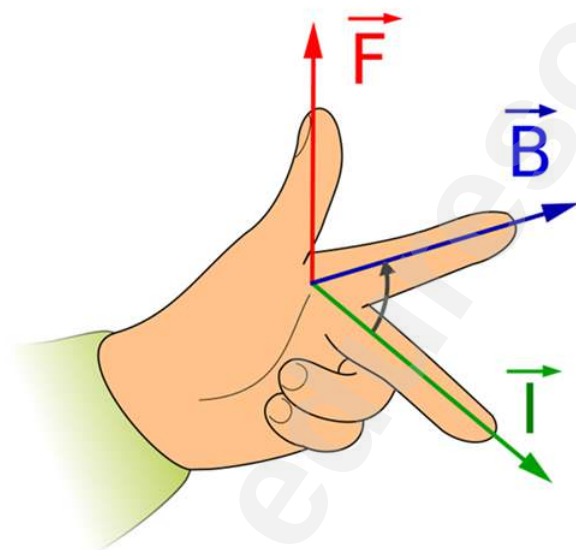
This is based on the **motor effect**.

A CURRENT CARRYING CONDUCTOR in a MAGNETIC FIELD experiencing a MAGNETIC FORCE

Fleming's Left Hand Motor Rule is used to determine the direction of the magnetic force.

Hold out your left hand with forefinger, second finger and thumb at right angle to one another.

- First Finger is Field (B)
- Second Finger is Current (I)
- Thumb is direction of the magnetic force (F)



F is the direction of the force

B is magnetic field in the North to South direction

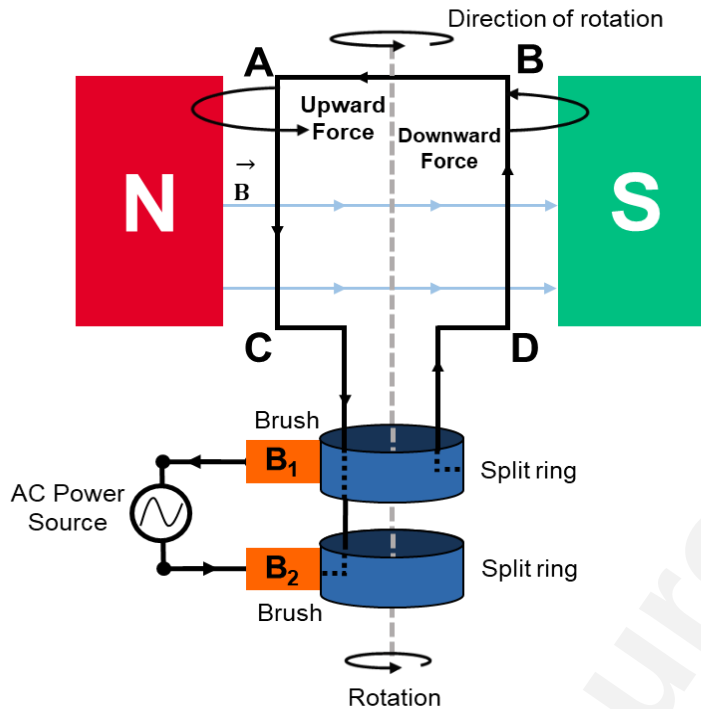
I is direction of the conventional current

The force is the GREATEST when the conductor, and therefore the direction of current, is placed PERPENDICULAR to the magnetic field.

The force is ZERO when the conductor, and therefore the direction of the current, is placed PARALLEL to the magnetic field.

AC Motor vs DC Motor

AC Motor



Uses an AC power supply

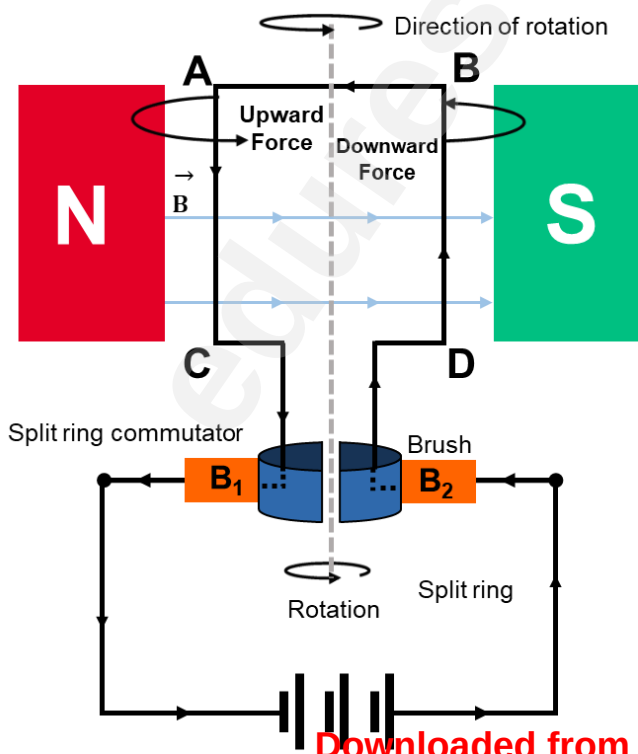
Side AC and BD experiences a force in opposite directions, causing the coil to experience **torque** which rotates the coil.

Since the motor uses a AC current, which changes direction periodically, the **coil will continue to rotate in the direction.**

There is reverse its direction every time the coil is in the vertical position.

The frequency of the alternating current will affect the speed of rotation.

DC Motor



Uses a DC power supply (battery)

Side AC and BD experiences a force in opposite directions, causing the coil to experience **torque** which rotates the coil.

The split ring **commutator reverses the direction of the current** in the coil **every half of a revolution**, as the coil rotates through the vertical position.

This ensures the coil continues to spin in the same direction.

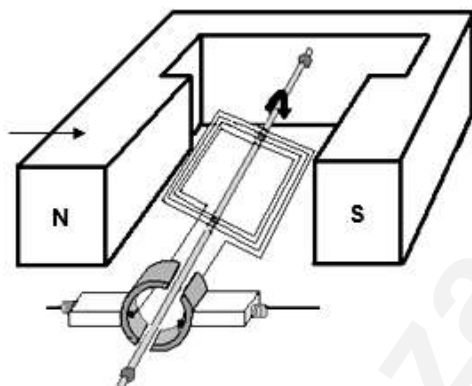
There is zero current every time the coil is in the vertical position

The speed of rotation can be changed by:

- Increasing the current
- Increasing the strength of the magnet (stronger magnetic field)
- Increasing the number of turns on the coil

WORKED Exam Question**Paper 1, Oct/Nov 2019, Q.9**

9.1 A simplified diagram of an electric generator is shown below. When the coil is rotated with a constant speed, an emf is induced in the coil.



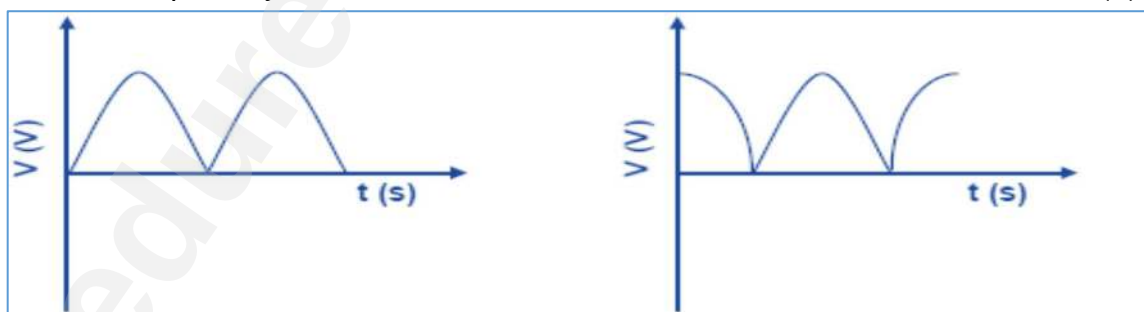
9.1.1 Is this an AC generator or a DC generator? (1)

DC

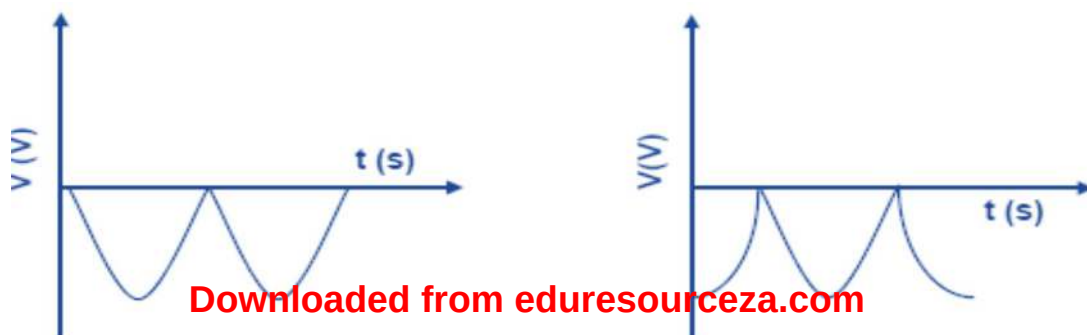
9.1.2 Briefly explain how an emf is generated in the coil when the coil is rotated by referring to the principle of electromagnetic induction. (2)

Emf is induced as a result of change of magnetic flux (linked) with the coil

9.1.3 Draw a sketch graph of the output voltage versus time for this generator. Show ONE complete cycle. (2)



OR



Continued...

Paper 1, Oct/Nov 2019, Q.9

9.2 A $200\ \Omega$ resistor is connected to a DC voltage supply, as shown in diagram A. The energy dissipated in the resistor in 10 s is 500 J.

The same resistor is now connected to an AC source (diagram B) and 500 J of energy is also dissipated in the resistor in 10 s.

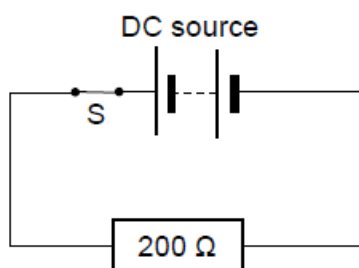


Diagram A

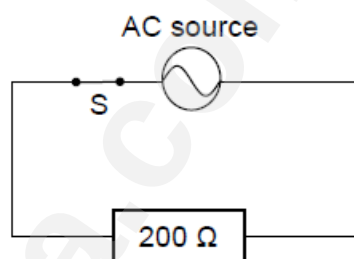


Diagram B

9.2.1 Define the term *rms voltage* of an AC source. (2)

The AC potential difference/voltage which dissipates the same amount of energy as DC potential difference.

OR

(The rms value of AC is) the DC potential difference/voltage which dissipates the same amount of energy as AC potential difference/voltage.

9.2.2 Calculate the maximum (peak) voltage of the AC source. (5)

$$P_{\text{avg}} = I_{\text{rms}}^2 R$$

$$\therefore I_{\text{rms}}^2 = P_{\text{avg}} \frac{1}{R} = \left(\frac{500}{10} \right) \left(\frac{1}{200} \right) = 0,25\ \text{A}$$

$$I_{\text{rms}} = \sqrt{0,25} = 0,5\ \text{A}$$

$$P_{\text{avg}} = I_{\text{rms}} V_{\text{rms}}$$

$$\therefore V_{\text{rms}} = \frac{P_{\text{avg}}}{I_{\text{rms}}} = \frac{\left(\frac{500}{10} \right)}{0,5} = 100\ \text{V}$$

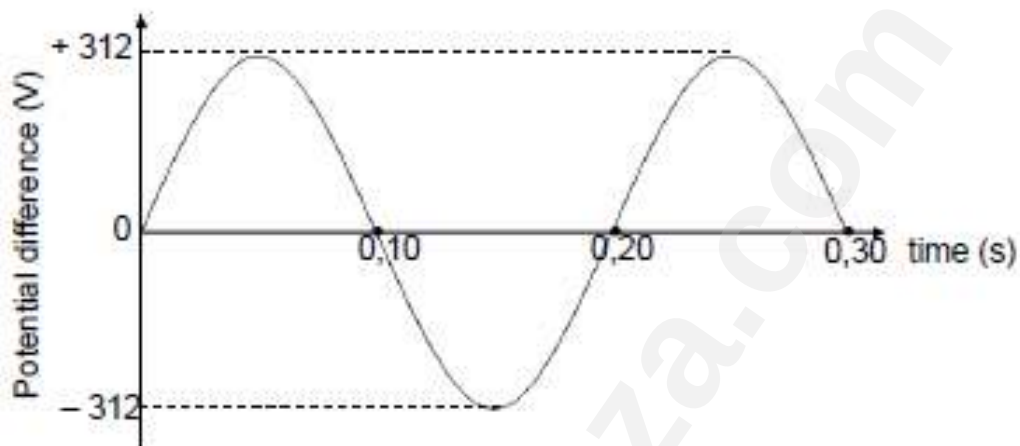
$$V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}}$$

$$V_{\text{max}} = \sqrt{2} V_{\text{rms}} = \sqrt{2} \times 100 = 141,42\ \text{V}$$

Past Exam Question

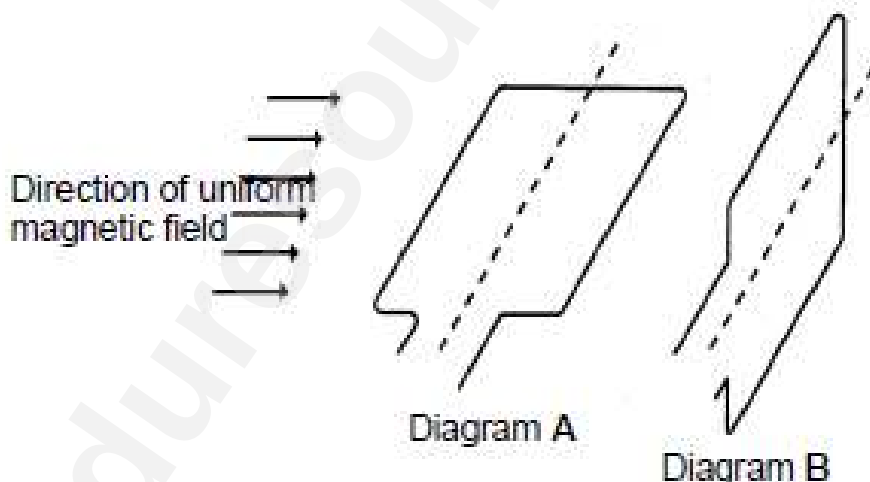
Paper 1, May/June 2019, Q.9

The diagram below shows the voltage output of a generator.



9.1 Does this generator have split rings or slip rings? (1)

9.2 Which ONE of the diagrams below, **A** or **B**, shows the position of the generator's coil at time = 0,10 s?



(1)

9.3 Calculate the root mean square (rms) voltage for this generator. (3)

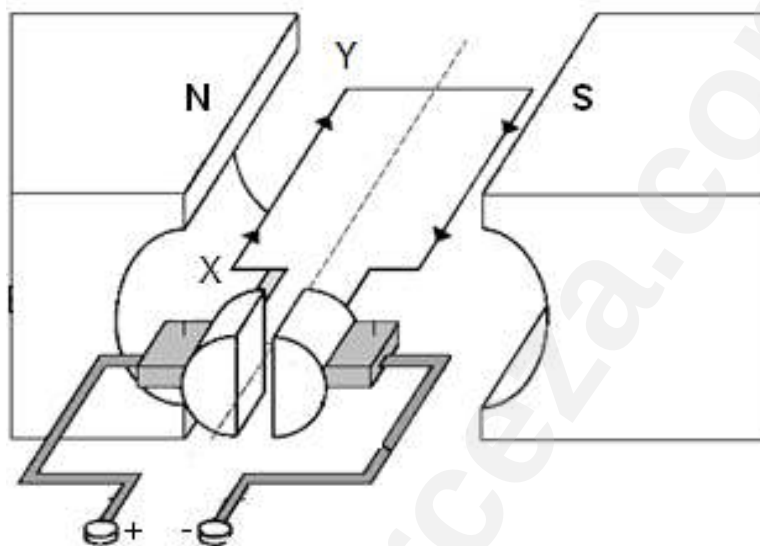
9.4 A device with a resistance of $40\ \Omega$ is connected to this generator
Calculate the:

9.4.1 Average power delivered by the generator to the device (3)

9.4.2 Maximum current delivered by the generator to the device (4)

Past Exam Question**Paper 1, May/June 2018, Q.10**

10.1 The diagram below is a simplified representation of a DC motor. The current in the coil is in the direction XY.



10.1.1 Name the component that ensures that the coil rotates continuously in ONE DIRECTION. (1)

10.1.2 In which direction will the coil rotate? Write down only CLOCKWISE or ANTICLOCKWISE. (2)

10.1.3 Write down the energy conversion which takes place while the motor is working. (2)

An AC generator, producing a maximum voltage of 320 V, is connected to a heater of resistance 35 Ω .

10.2.1 Write down the structural difference between an AC generator and a DC generator. (1)

Calculate the:

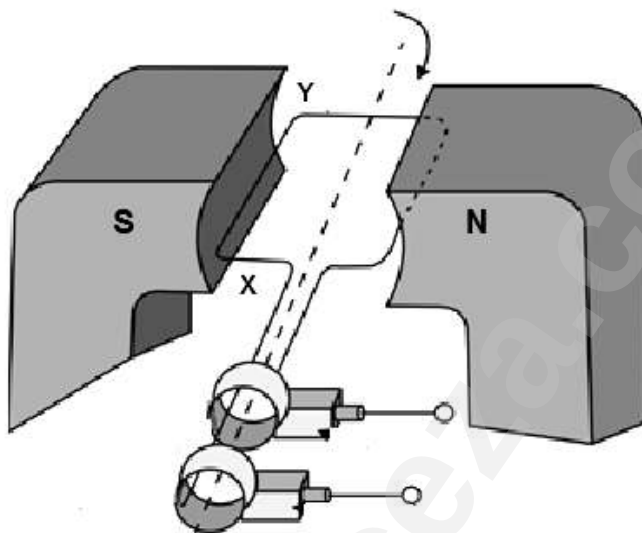
10.2.2 Root mean square (rms) value of the voltage (3)

10.2.2 Root mean square (rms) value of the voltage (3)

Past Exam Question

Paper 1, Nov 2018, Q.10

10.1 In the simplified AC generator below, the coil is rotated clockwise.



10.1.1 In which direction does the induced current flow in the coil?

Choose from: **X to Y** or **Y to X**.

(1)

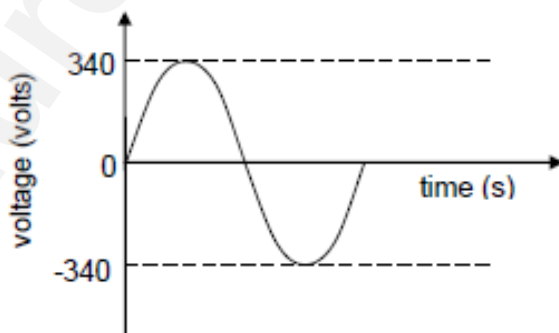
10.1.2 On which principle or law is the working of the generator based?

(1)

10.1.3 State the energy conversion that takes place while the generator is in operation.

(2)

10.2 The voltage output for an AC generator is shown below.



10.2.1 Write down the maximum (peak) output voltage of the generator.

(1)

A stove is connected to the generator above, and delivers an average power of 1 600 W.

10.2.2 Calculate the rms voltage delivered to the stove.

(3)

10.2.3 Calculate the resistance of the stove.

(3)

Past Exam Paper

Multiple Choice Questions

Paper 1, Oct/Nov 2018

- 1.9 Which ONE of the following actions will NOT cause an **increase** in the induced emf in a coil if the coil is rotated in a uniform magnetic field?
- A. Rotating the coil faster
 - B. Increasing the strength of the magnetic field
 - C. Increasing the number of turns of the coil
 - D. Replacing the coil with a coil of lower resistance
- (2)

Paper 1, May/June 2019

- 1.9 The direction of the induced current in the coil of a generator depends on the ...
- A. length of the coil.
 - B. speed of rotation of the coil.
 - C. direction of the magnetic field.
 - D. strength of the magnetic field.
- (2)

Paper 1, May/June 2018

- 1.9 A learner lists the following as factors that affect the magnitude of the current induced in an AC generator:
- (i) The number of turns (windings) of the coil
 - (ii) The strength of the magnetic field
 - (iii) The speed of rotation of the coil

Which ONE of the combinations below is CORRECT?

- A. (i) and (ii) only
- B. (i) and (iii) only
- C. (ii) and (iii) only
- D. (i), (ii) and (iii)

(2)