



LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

PHYSICAL SCIENCES

ELECTRODYNAMICS

MOGALAKWENA DISTRICT

2026 WINTER CAMP

Prepared By Zulu VC

2026/06/27

Mogalakwena District

The heartland of southern Africa - development is about people

ELECTRODYNAMICS

MOTOR

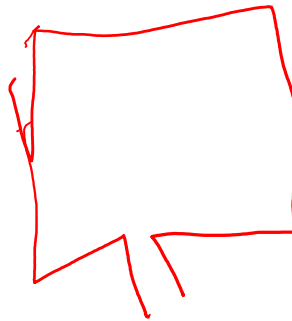
- Converts Electrical energy to Mechanical energy
- Based on Motor effect

GENERATOR

- Converts Mechanical energy to Electrical Energy
- Based on principle of Electromagnetic induction/
Faraday's Law

- **Motor effect**

- Electric motor works on basic principle that a current carrying-conductor in a magnetic field experiences a force
- When a current carrying coil, with the current flowing in opposite directions in the two sides, is placed in the magnetic field, it results in two forces acting in opposite direction in the opposite sides
- The two forces results in a torque that tries to rotate the coil

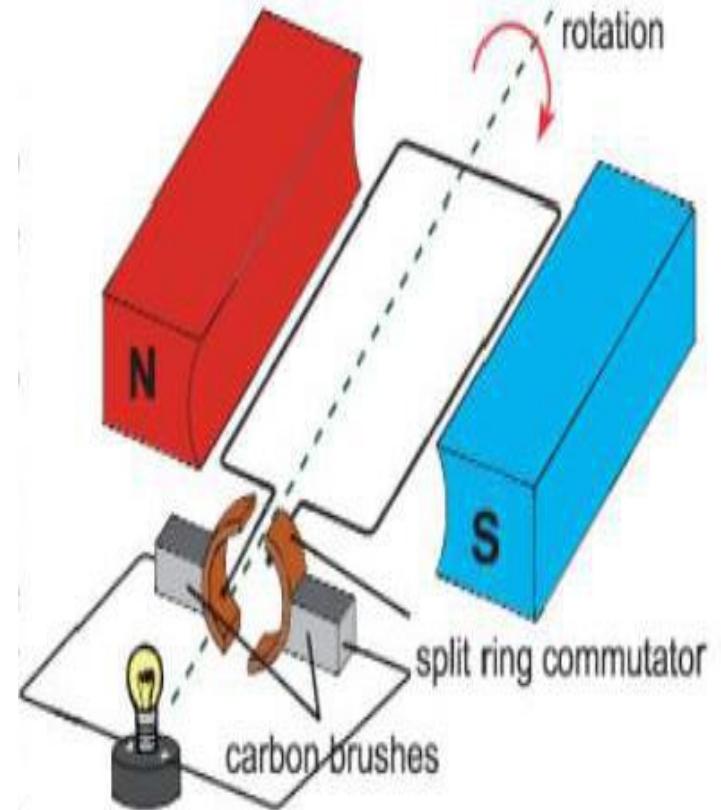
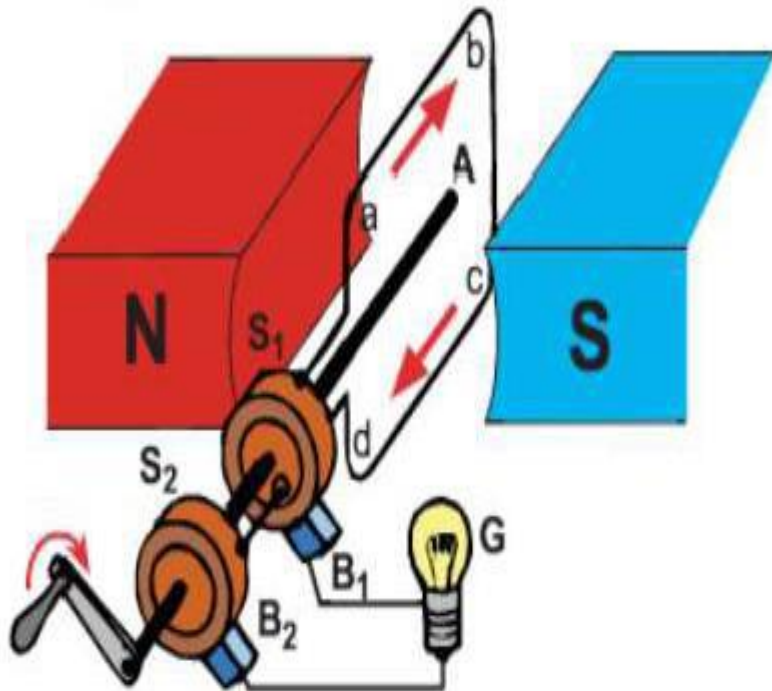


- **principle of Electromagnetic induction/
Faraday's Law**

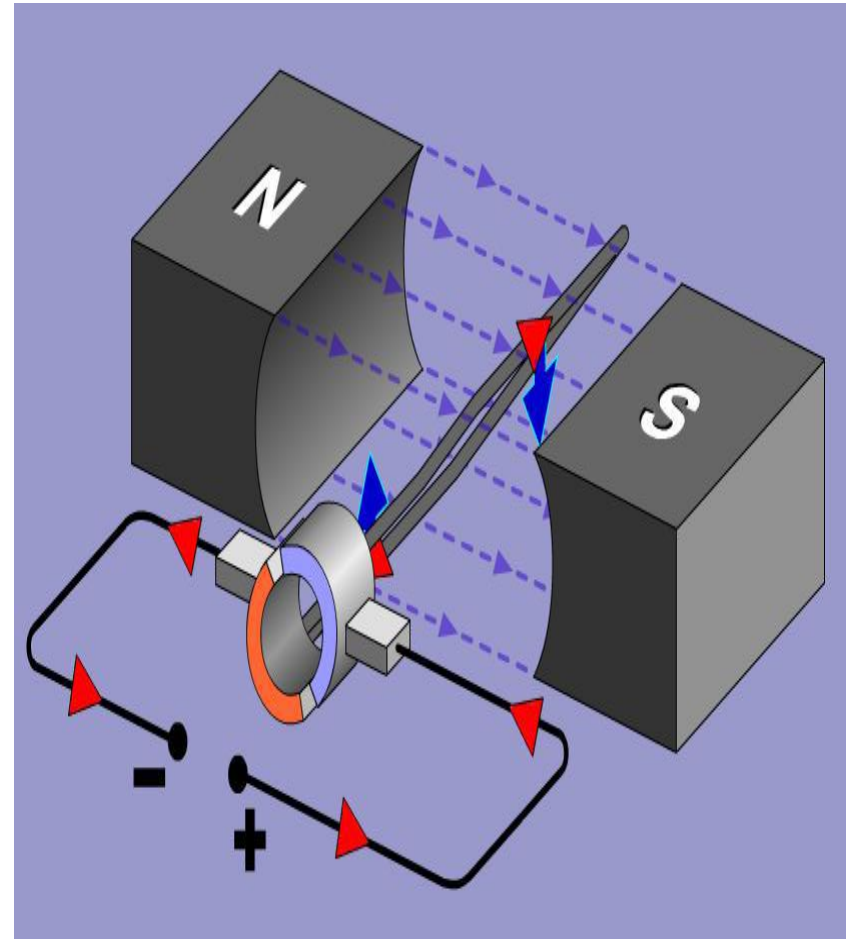
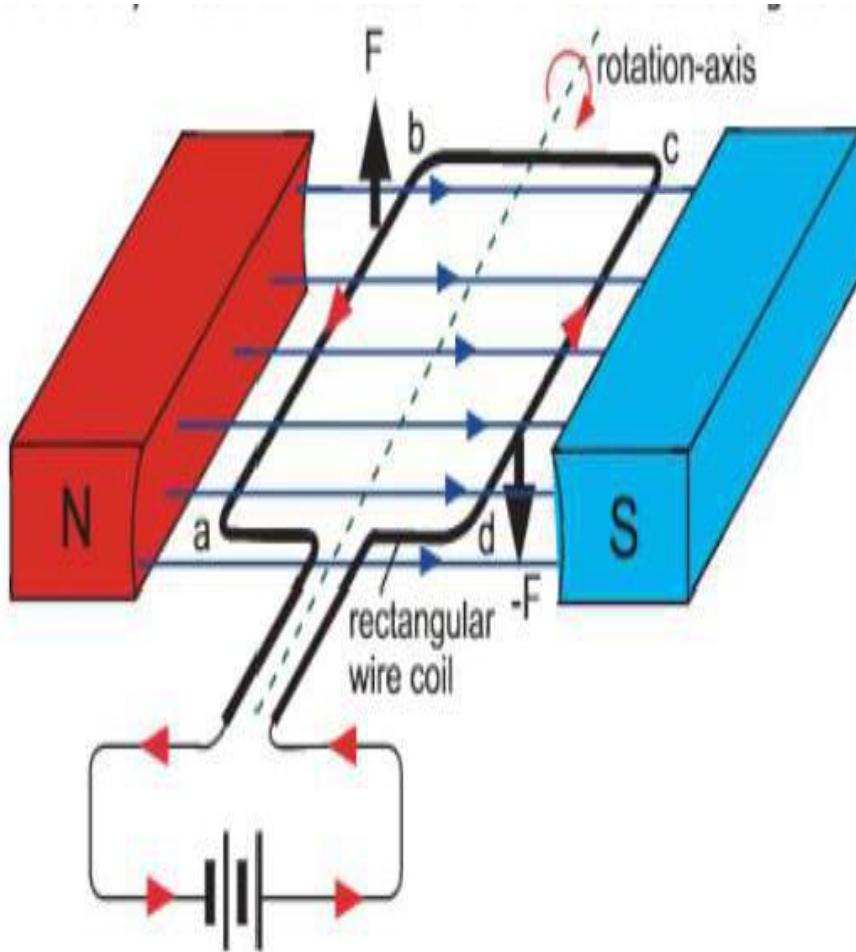
The principle is based on that:

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

GENERATOR



MOTOR



FUNCTIONS OF THE BASIC COMPONENTS GENERATOR/MOTOR

Armature (Coil):

Allows emf and current to be induced through it as it rotates in the magnetic field.

Magnets :

provides magnetic field that passes through the armature (coil)

Slip rings

Allows continuous contact with brushes so that current can be transmitted to terminals without breaking the circuit.

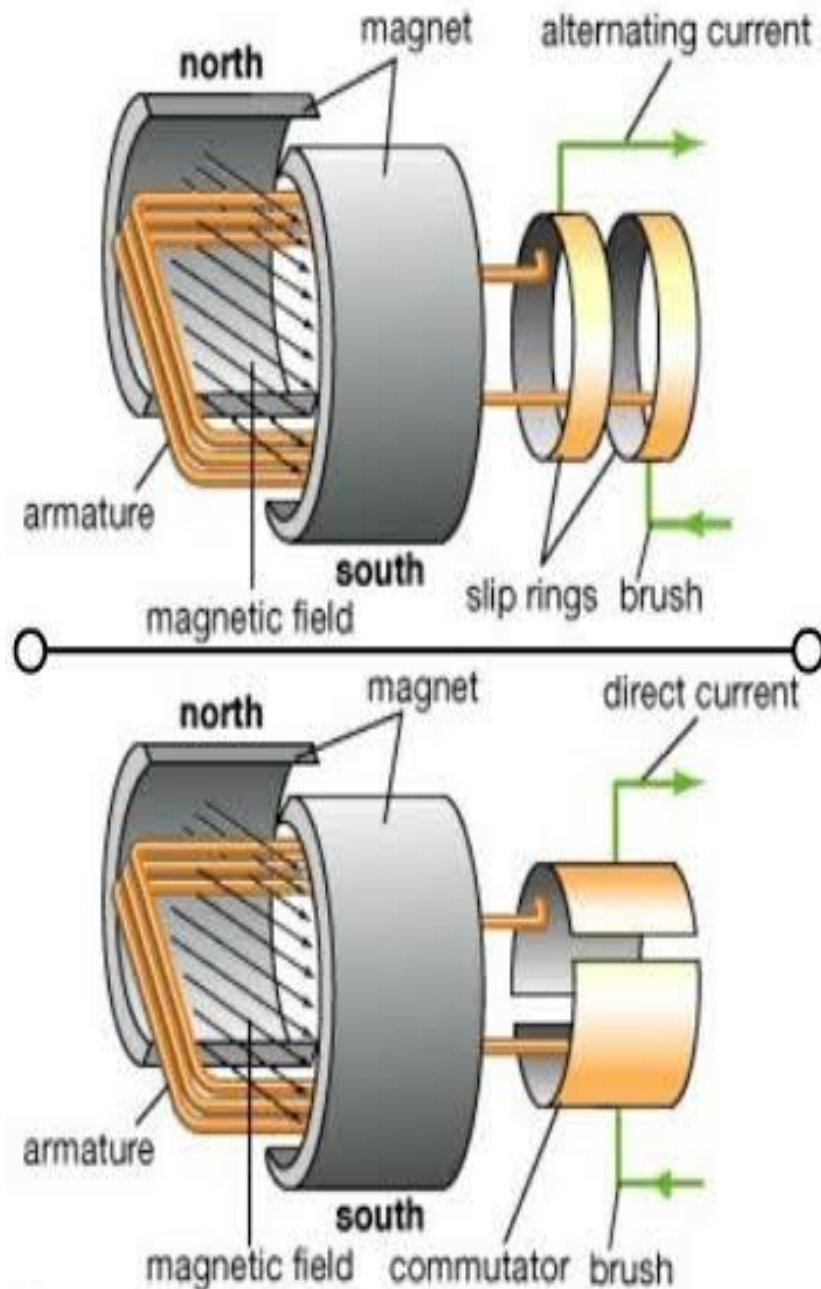
Split rings (or commutator):

a. reverses the current each half turn to keep the torque turning the coil in the same direction.

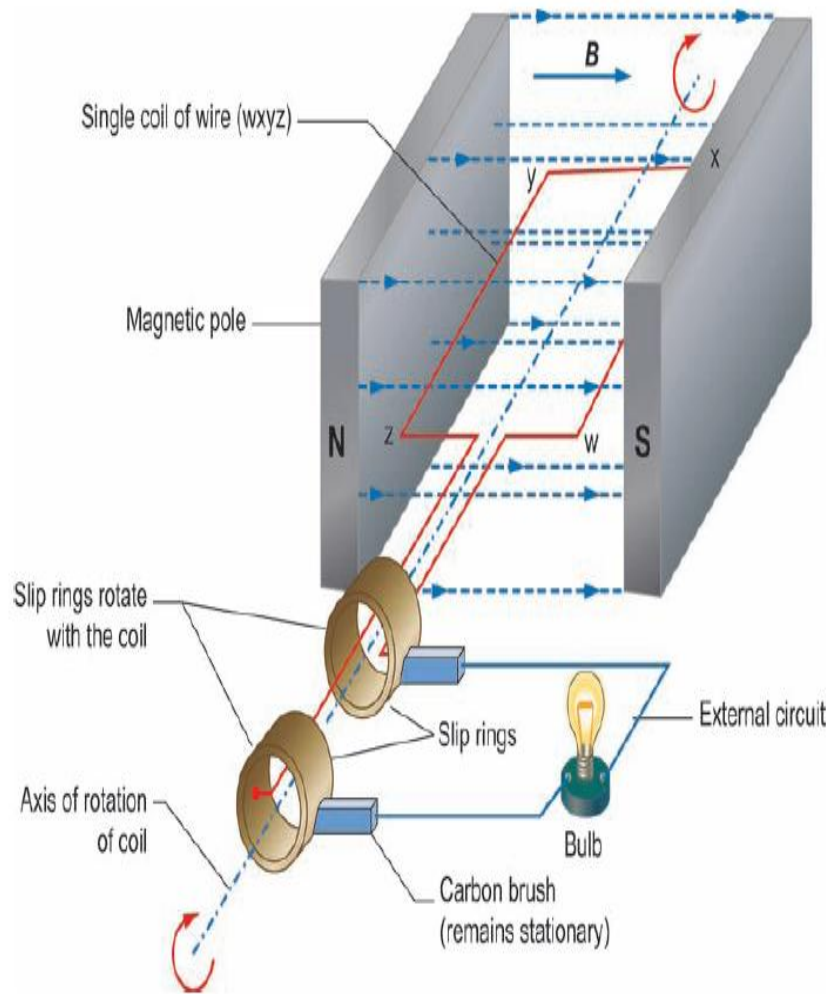
Carbon brushes :

b. Maintains electrical contact with the rings

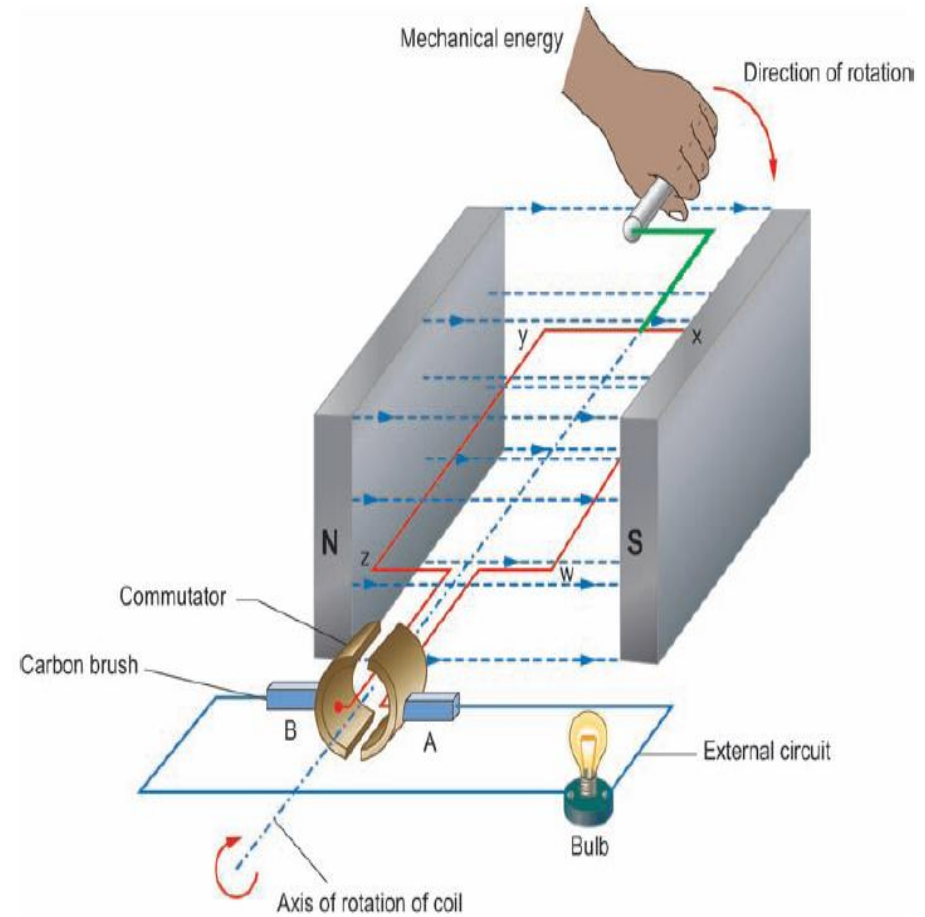
c. Conducts/ takes current out of the coil.



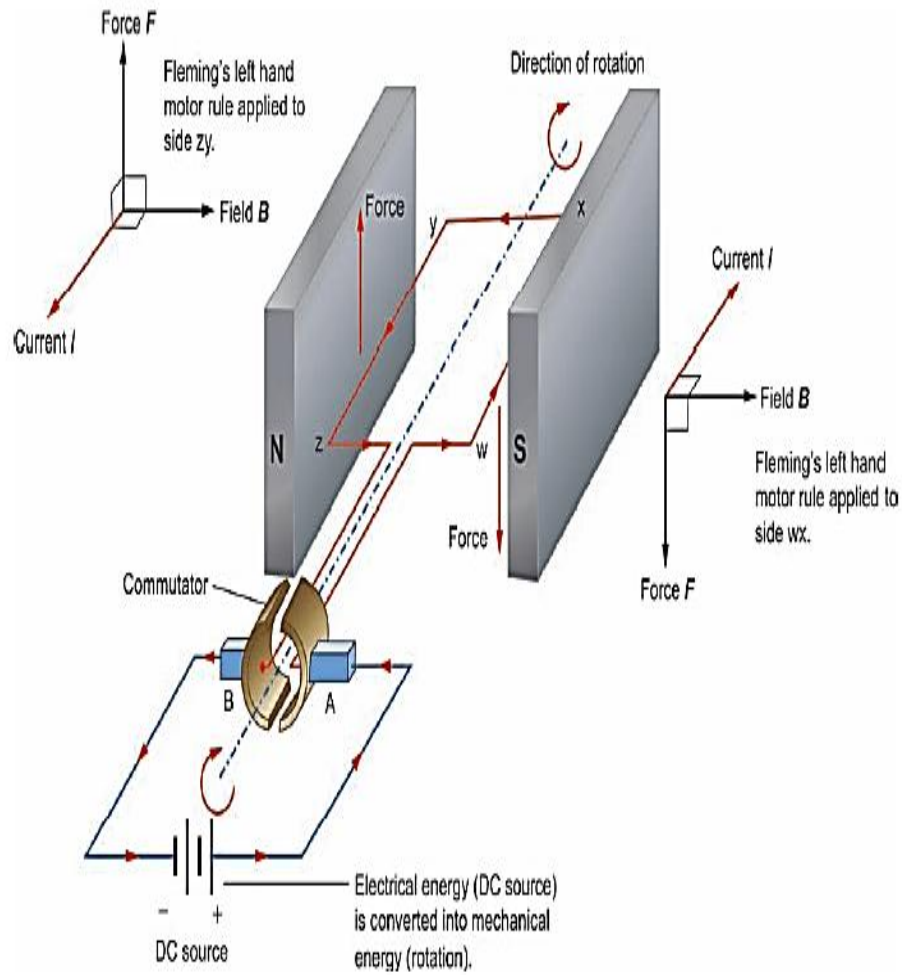
Difference Between AC & DC



AC Generator

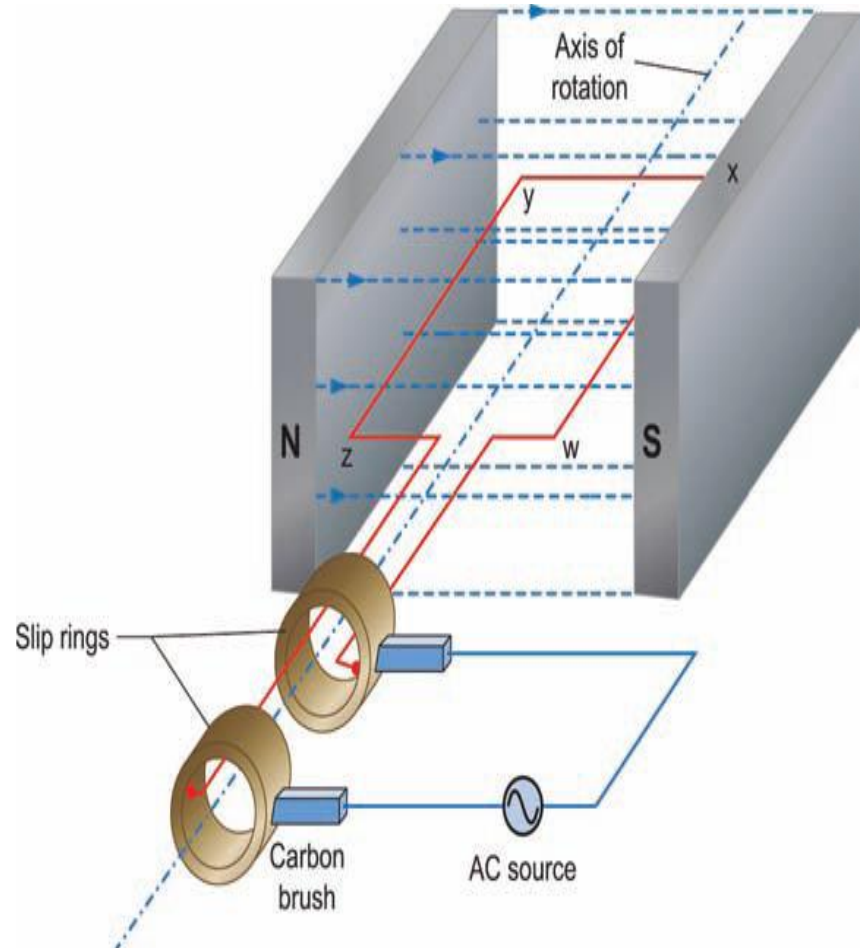


DC Generator



DC MOTOR

2026/06/27



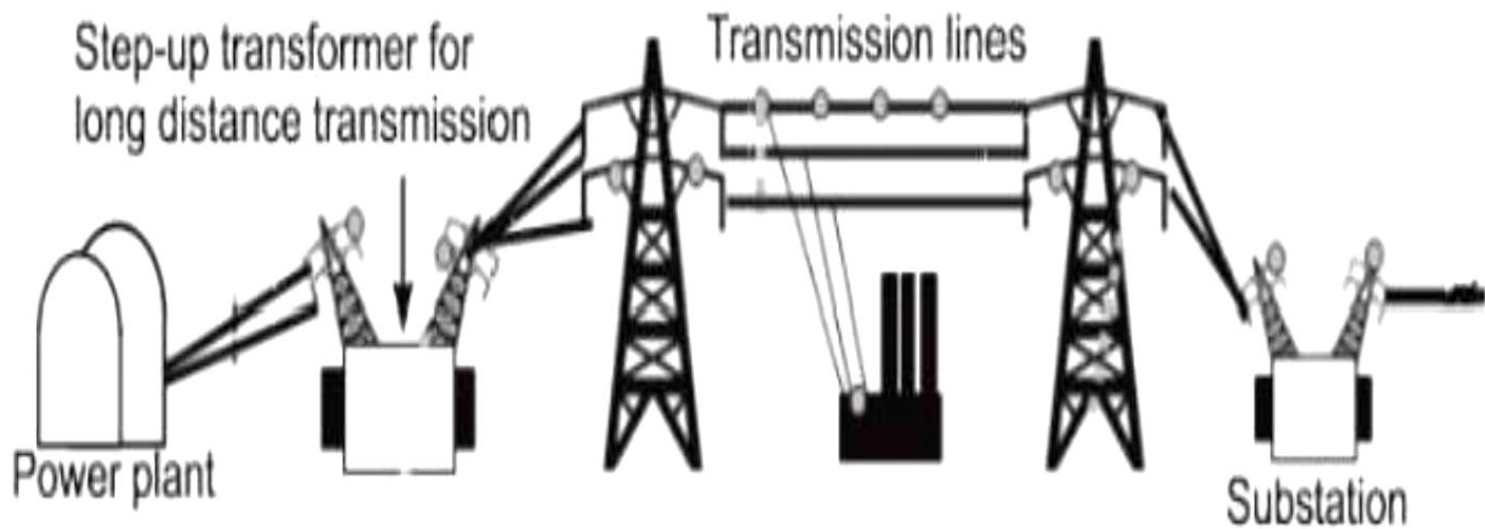
AC MOTOR

Mogalakwena District

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ADVANTAGES OF AC OVER DC

- Alternating current can be stepped-down or stepped-up (using transformers)
- It can be transferred over long distances with minimal or no loss of power.
- AC can be generated in much higher voltages than DC.
- AC generators are easier and cheaper to construct than DC generators as they do not consist of commutator.
- Its easier to convert AC to DC than reverse



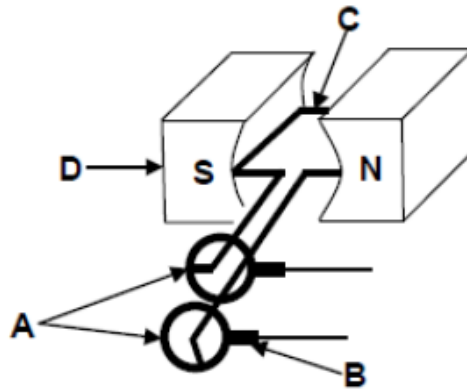
Activity 1

Date:

(6 minutes)

QUESTION 10 (Start on a new page.)

The simplified sketch represents an AC generator. The main components are labelled **A**, **B**, **C** and **D**.



10.1 Write down the name of component:

10.1.1 **A** (1)

10.1.2 **B** (1)

10.2 Write down the function of component **B**. (1)

10.3 State the energy conversion which takes place in an AC generator. (1)

QUESTION 10/VRAAG 10

10.1

10.1.1 slip rings / *sleepringe* ✓

10.1.2 brush(es) / *borsel(s)* ✓

10.2 Maintains electrical contact with the slip rings.
Handhaaf elektriese kontak met die sleepringe.

OR/OF

To take current out/in of the coil.
Om die stroom uit/in die spoel te neem.

10.3 Mechanical /kinetic energy to electrical energy. ✓
Meganiese / kinetiese energie na elektriese energie.

Activity 2

Date:

(6 minutes)

Electric motors are important components of many modern electrical appliances. AC motors are used in washing machines and vacuum cleaners, and DC motors are used in toys and tools.

- 1.1 What energy conversion takes place in electric motors? (2)
- 1.2 What is the essential difference in the design between DC and AC motors? (2)

QUESTION 1

- 1.1 Electrical energy ✓ converted to rotational mechanical energy. ✓ (2)
- 1.2. A DC motor reverses current direction with the aid of the commutator whenever the coil is in the vertical ✓ position to ensure continuous rotation.
- An AC motor, with alternating current as input, works without commutators since the current alternates. ✓ (2)

maximise the force created by the motor effect we can:

- Increasing the number of turns of the coil.
- Increasing the current through the coil.
- Increasing the area of the coil.
- Increasing the strength of the magnetic field
i.e. using stronger magnets.

maximise the efficiency of generator by:

- Increasing the number of turns of the coil.
- Increasing the speed of rotation.
- Increasing the area of the coil.
- Increasing the strength of the magnetic field
i.e. using stronger magnets.

INERTIA OF THE COIL

- Since the DC motor has split-rings which are separated from each other, there is a point (when the coil is perpendicular to the magnetic field) during the rotation of the armature where the carbon brushes are not in contact with the split rings.
- At this point, there is no current flowing in the armature.
- **What keeps the armature rotating at this point, is the inertia of the coil.**
- Inertia is the tendency of an object to resist any change in its state of motion.

SIMULATION

Motor

The direction of the magnetic field is from North to South (N to S)

The current direction is the direction of flow of the conventional current (+'ve to -'ve)



Fleming's Left Hand Rule can be used to predict the direction of the force acting on the conductor in a magnetic field.

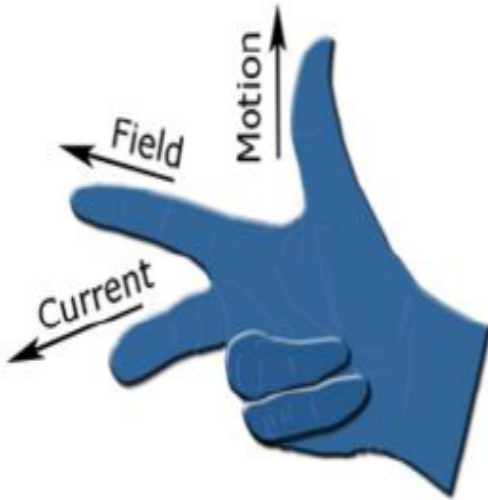
Using the LEFT HAND:

- The first (pointer) finger points in the direction of the field, from North to South.
- The second (middle) finger points in the direction of conventional current, from positive to negative.
- The thumb will then point in the direction of the resultant force.

In an electric motor, an electric current passes through the coil in a magnetic field the combination of the two force fields produces a torque which turns the motor.

Generator

Fleming's Right Hand Dynamo Rule can be used to predict the direction of the induced current.



Using the RIGHT HAND:

- The first (pointer) finger points in the direction of the field, from North to South.
- The thumb points in the direction of the movement.
- Then the second (middle) finger points in the direction of the induced conventional current, from positive to negative.

USE OF AC GENERATORS

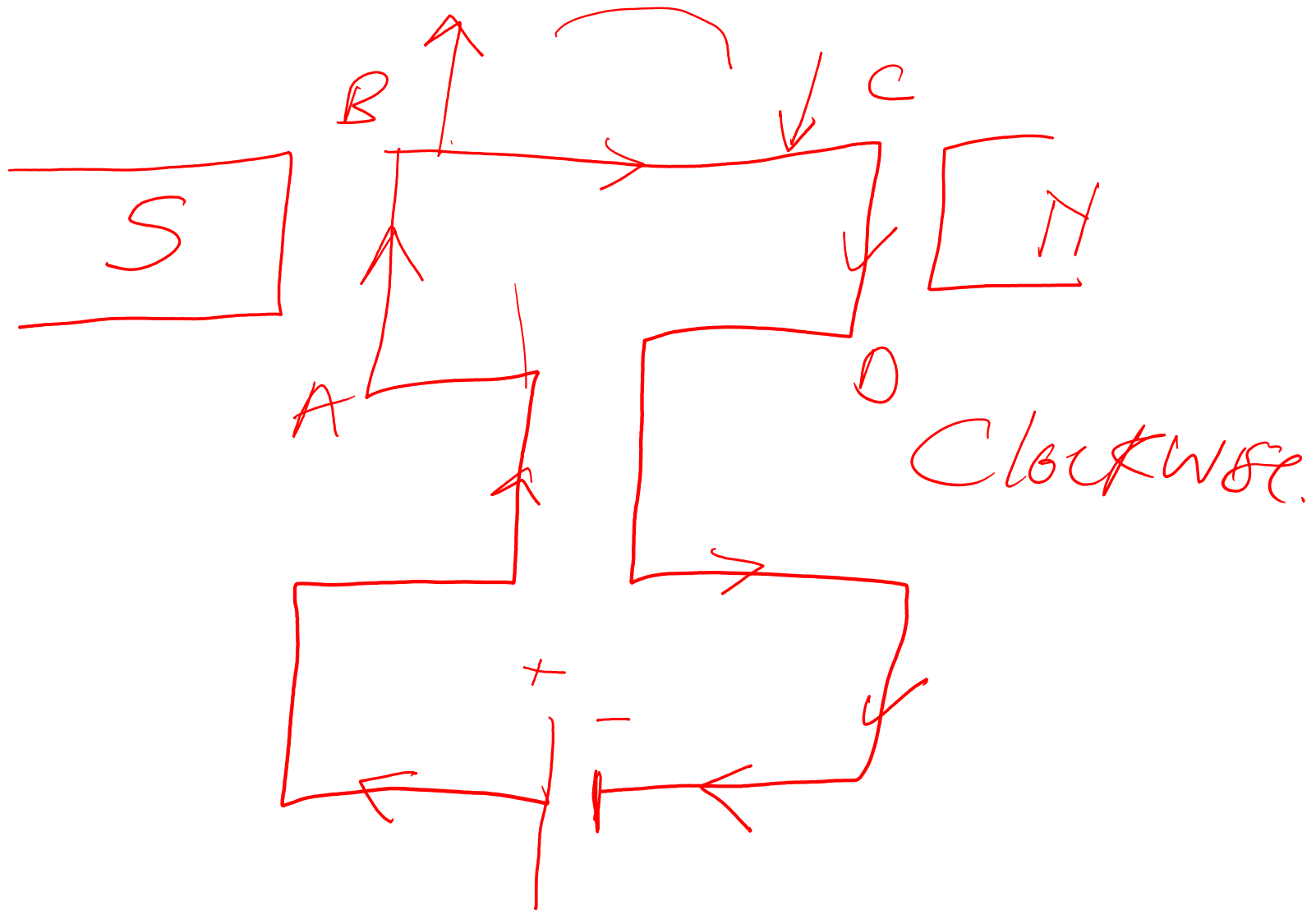
- Generation of electric power in power plants (e.g. hydroelectric power plants, wind power plants, nuclear power plants, coal-fired power plants and geothermal power plants).
- Alternating current is easy to step-up (increase by using a step-up transformer) and step-down (decrease by using a step-down transformer).
- Most household appliances (appliances found at 'home') work on alternating current.

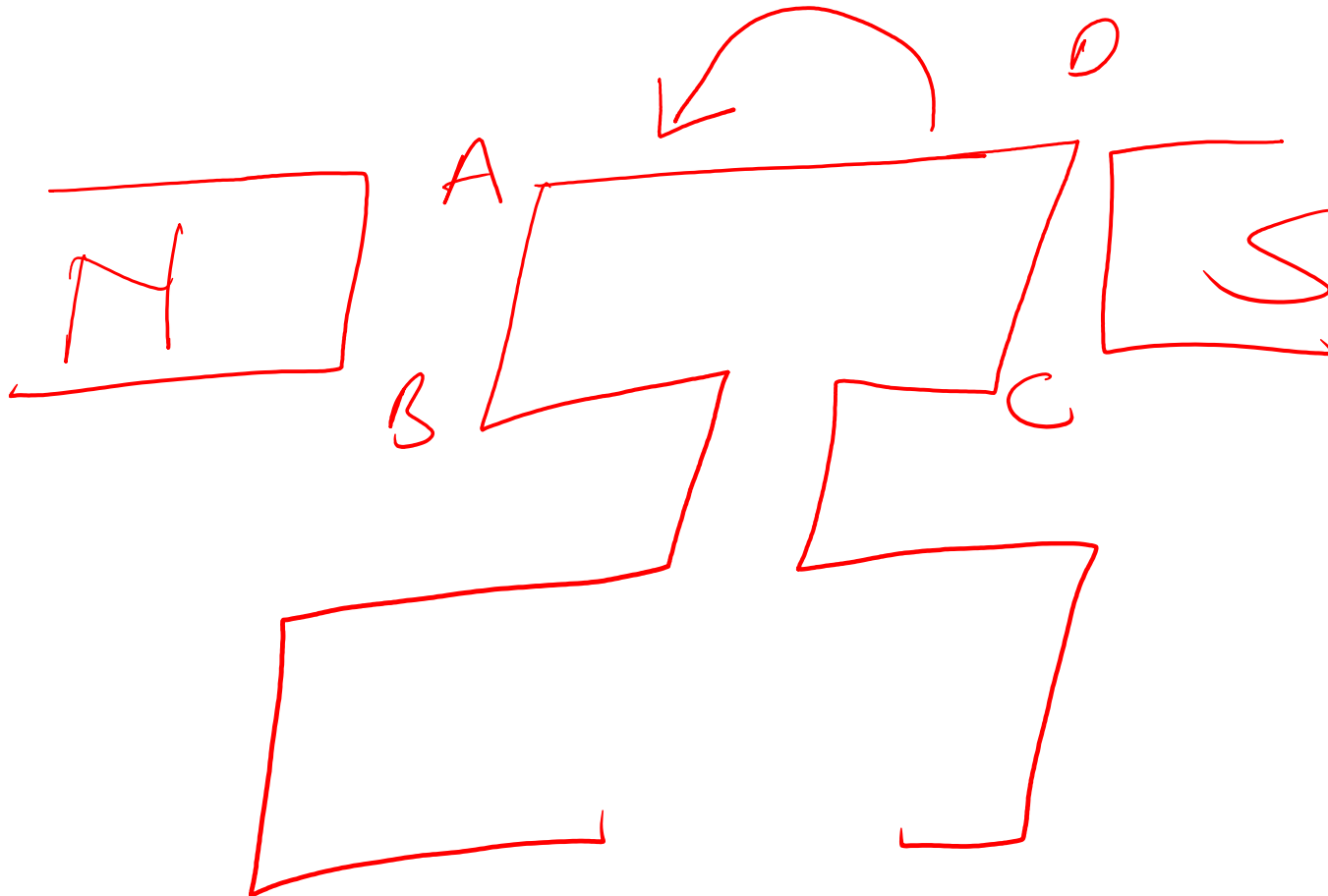
USES OF DC GENERATORS

- In factories that does electroplating (covering a metal with another metal).
- In factories that produce chemicals such as chlorine and aluminium through electrolysis (use of electricity to make a chemical reaction occur).
- In locomotives that are driven by diesel-electric motors.
- Due to the use of commutators (which are expensive), many DC generators are being replaced by AC generators.

USES OF ELECTRIC MOTORS

- Escalators and elevators.
- Cars e.g. starter, windscreen wipers.
- CD players.





A to B
B to A

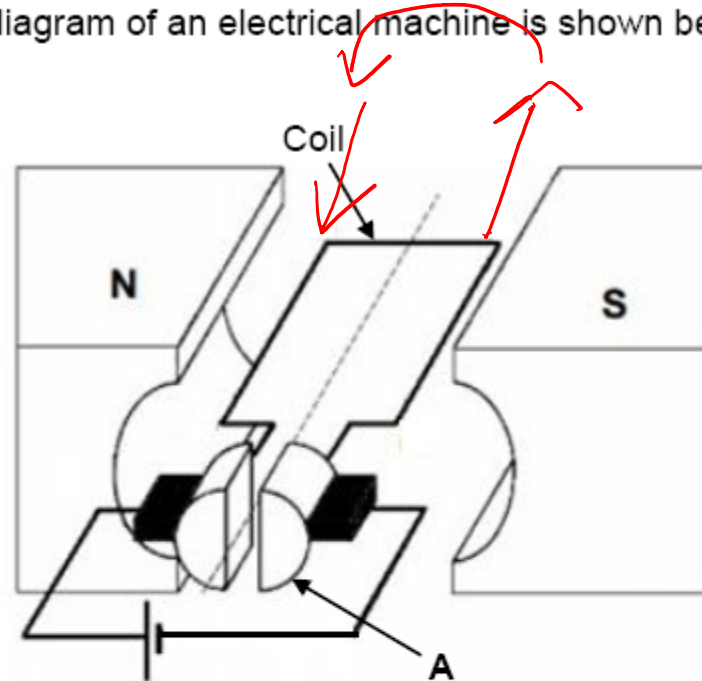
Activity 3

Date:

(8 minutes)

QUESTION 9 (Start on a new page.)

9.1 A simplified diagram of an electrical machine is shown below.



9.1.1 Is this machine a DC motor or a DC generator? (1)

9.1.2 Write down the energy conversion that takes place while this machine is in operation. (2)

9.1.3 Write down the name of component **A** in the diagram. (1)

9.1.4 In which direction will the coil, shown in the diagram above, rotate? Choose from **CLOCKWISE** or **ANTICLOCKWISE**. (2)

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QUESTION 9/VRAAG 9

- 9.1.1 (DC) motor/(GS-)motor ✓ (1)
- 9.1.2 **POSITIVE MARKING FROM QUESTION 9.1.1**
POSITIEWE NASIEN VANAF VRAAG 9.1.1
 Electrical to mechanical /kinetic (energy) ✓✓ (2 or 0)
Elektriese na meganiese/kinetiese (energie) (2 of 0) (2)
- 9.1.3 Split ring/commutator/Splitring/kommutator ✓ (1)
- 9.1.4 Anticlockwise/antikloksgewys ✓✓ (2)

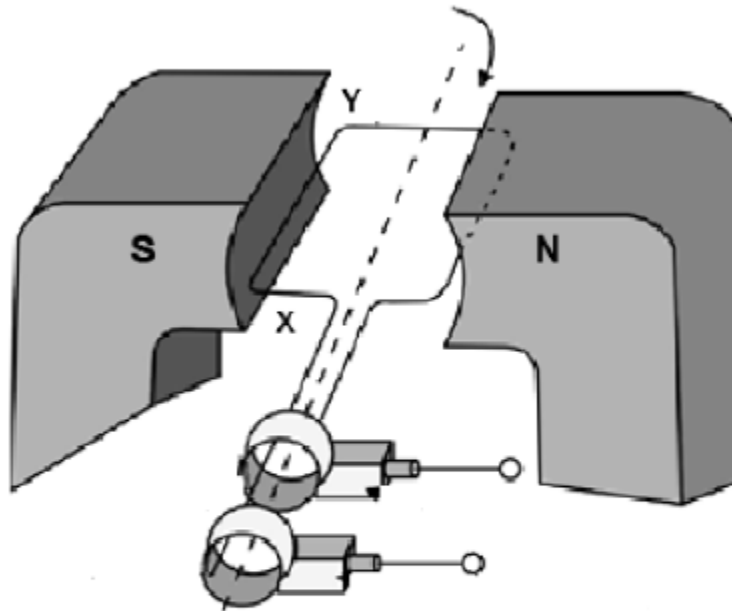
Activity 4

Date:

(6 minutes)

QUESTION 10 (Start on a new page.)

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)

QUESTION 10/VRAAG 10

10.1.1 Y to/na X  (1)

10.1.2 Faraday's Law Electromagnetic Induction 
Faraday se wet van Elektromagnetiese Induksie

OR/OF

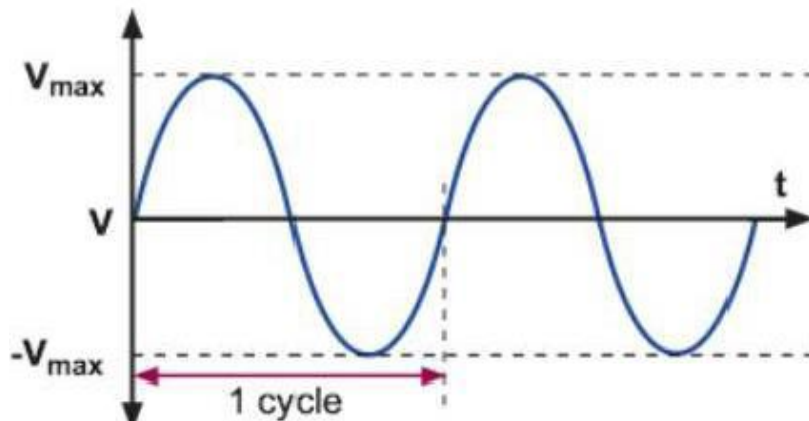
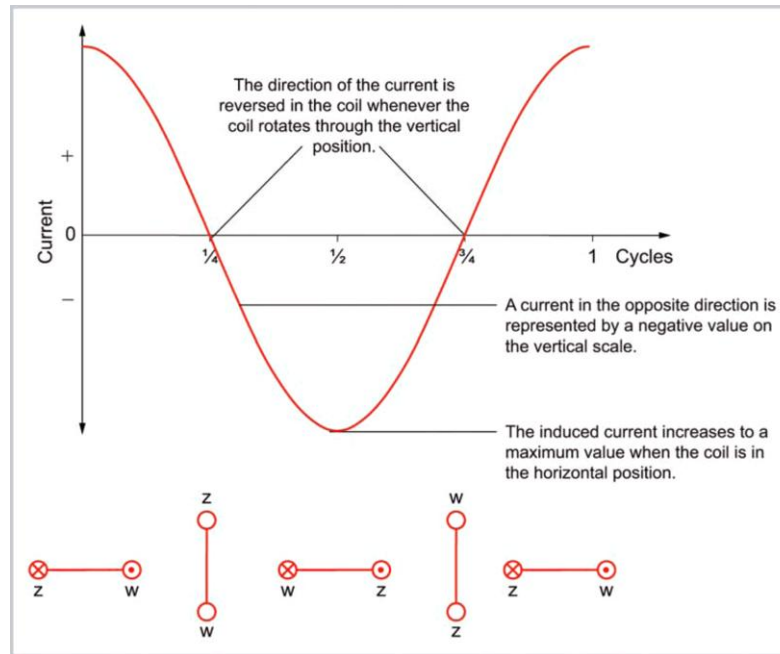
Electromagnetic induction/Faraday's Law 
Elektromagnetiese Induksie/Faraday se wet (1)

10.1.3 Mechanical (kinetic) energy  to electrical energy 
Meganiese (kinetiese) energie na elektriese energie (2)

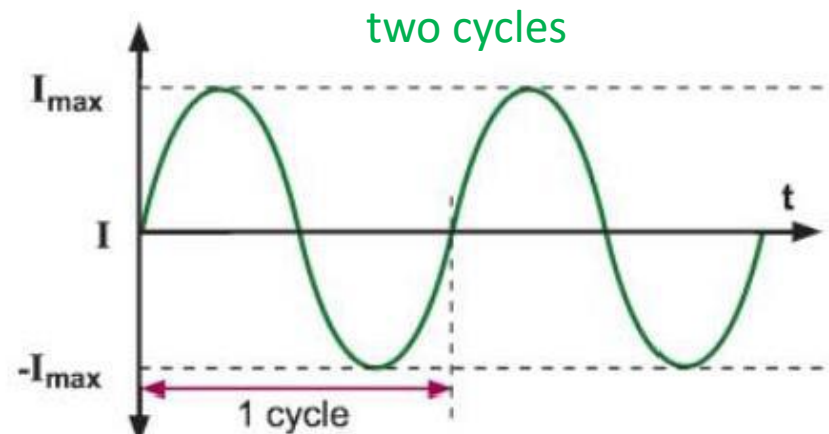
AC GRAPHS

Parallel

Vertical



2026/06/27



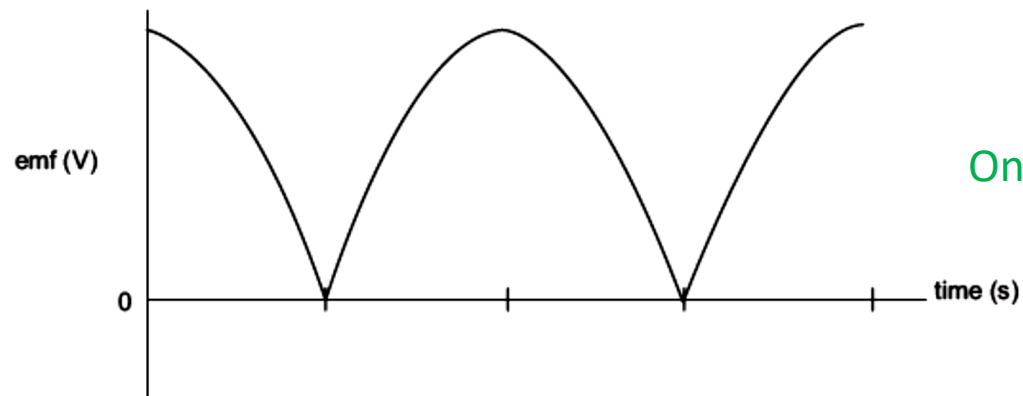
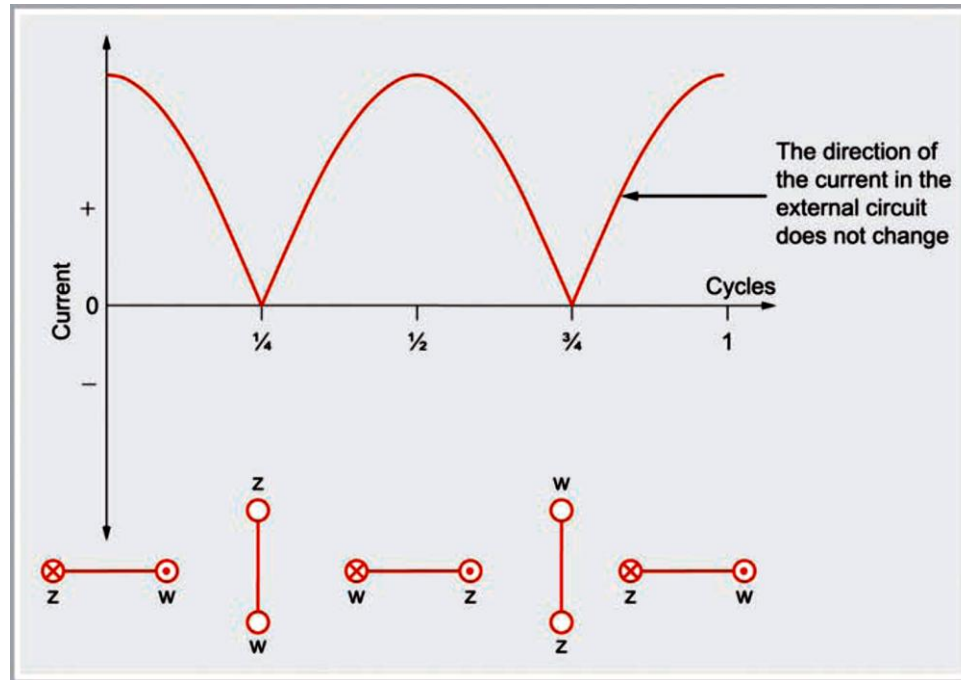
Mogalakwena District

All direction

DC GRAPHS

Parallel

Vertical



One cycle

One direction

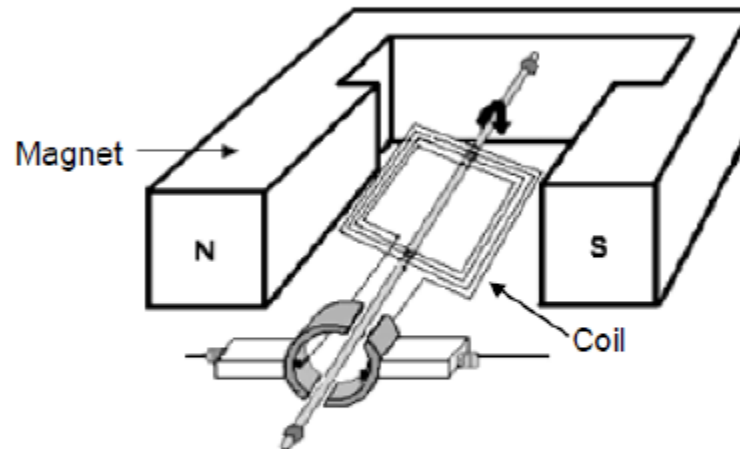
Activity 5

Date:

(6 minutes)

QUESTION 9 (Start on a new page.)

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

QUESTION 9/VRAAG 9

9.1

9.1.1 DC/GS ✓

(1)

9.1.2

NOTE: -1 mark for each key word/phrase omitted in correct context.

LET WEL: -1 punt vir elke sleutel woord/frase weggelaat in die korrekte konteks.

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

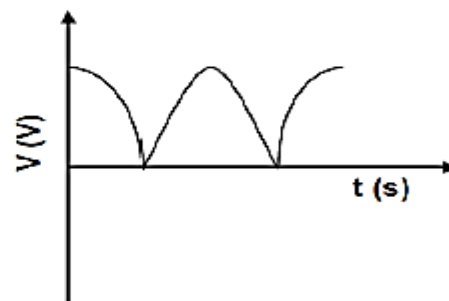
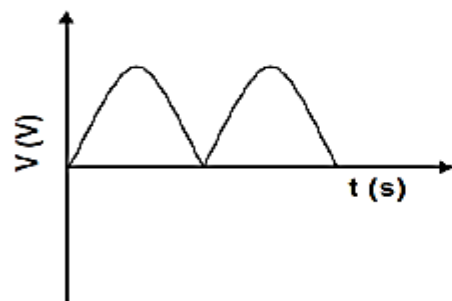
Emk word geïnduseer as gevolg van verandering van die magnetiese vloedkoppeling

(2)

9.1.3

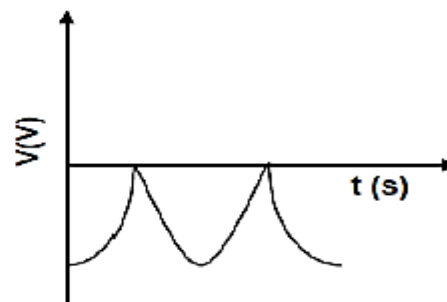
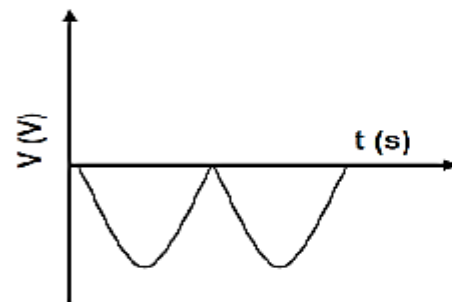
POSITIVE MARKING FROM QUESTION 9.1.1

POSITIEWE NASIEN VANAF VRAAG 9.1.1



OR/OF

Marking criteria for graph:	
Correct shape <i>Korrekte vorm</i>	✓
One complete cycle <i>Een volledige siklus</i>	✓



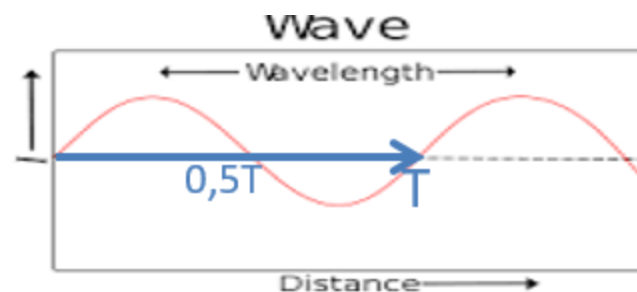
ALTERNATING CURRENT/WISSELSTROOM

$I_{\text{rms}} = \frac{I_{\text{max}}}{\sqrt{2}}$	/	$I_{\text{wgk}} = \frac{I_{\text{maks}}}{\sqrt{2}}$	$P_{\text{ave}} = V_{\text{rms}} I_{\text{rms}}$	/	$P_{\text{gemiddeld}} = V_{\text{wgk}} I_{\text{wgk}}$
$V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}}$	/	$V_{\text{wgk}} = \frac{V_{\text{maks}}}{\sqrt{2}}$	$P_{\text{ave}} = I_{\text{rms}}^2 R$	/	$P_{\text{gemiddeld}} = I_{\text{wgk}}^2 R$
			$P_{\text{ave}} = \frac{V_{\text{rms}}^2}{R}$	/	$P_{\text{gemiddeld}} = \frac{V_{\text{wgk}}^2}{R}$

$$T = \frac{\text{total time}}{\text{total number of complete rotations}}$$

$$T = \frac{1}{f}$$

$$F = \frac{1}{T}$$

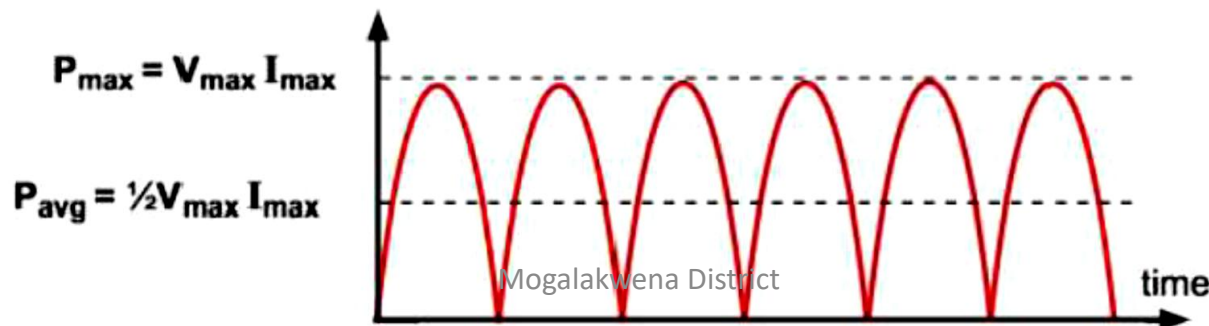
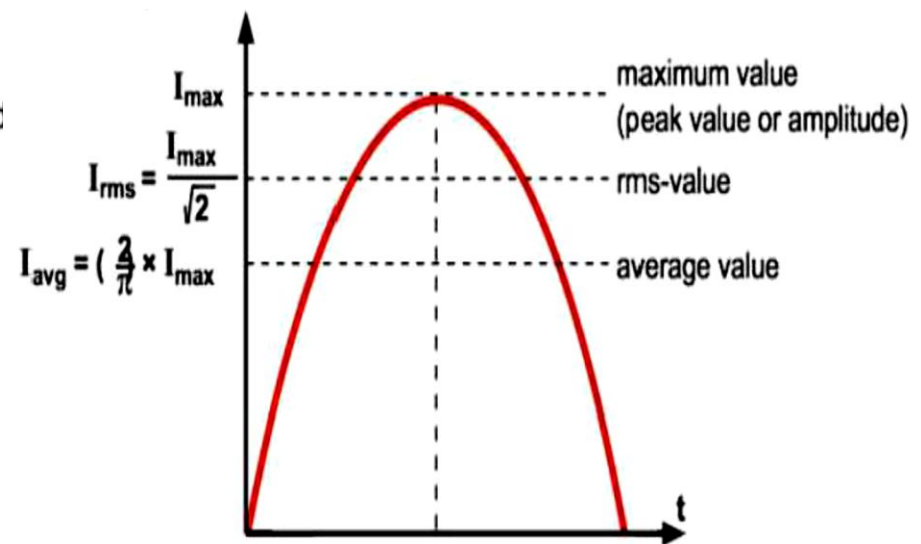
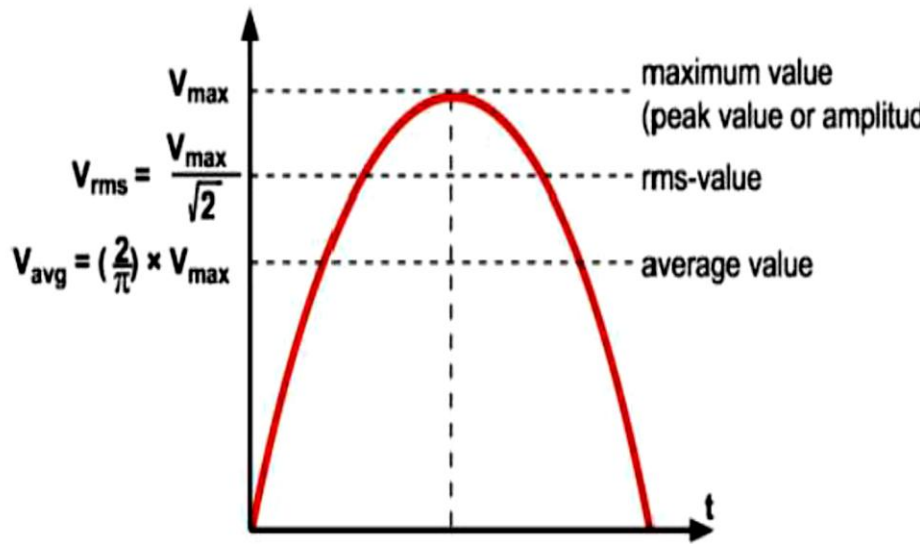


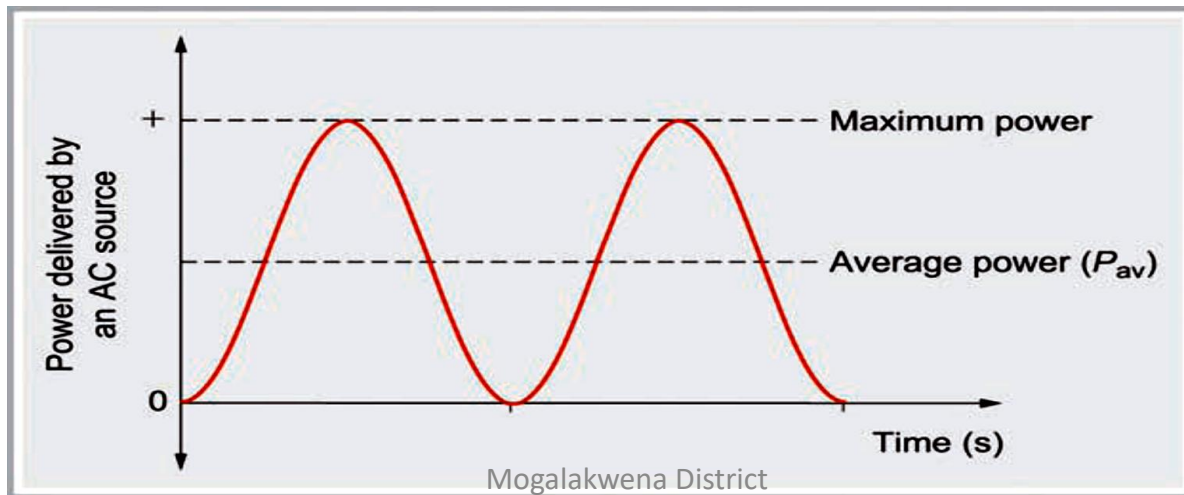
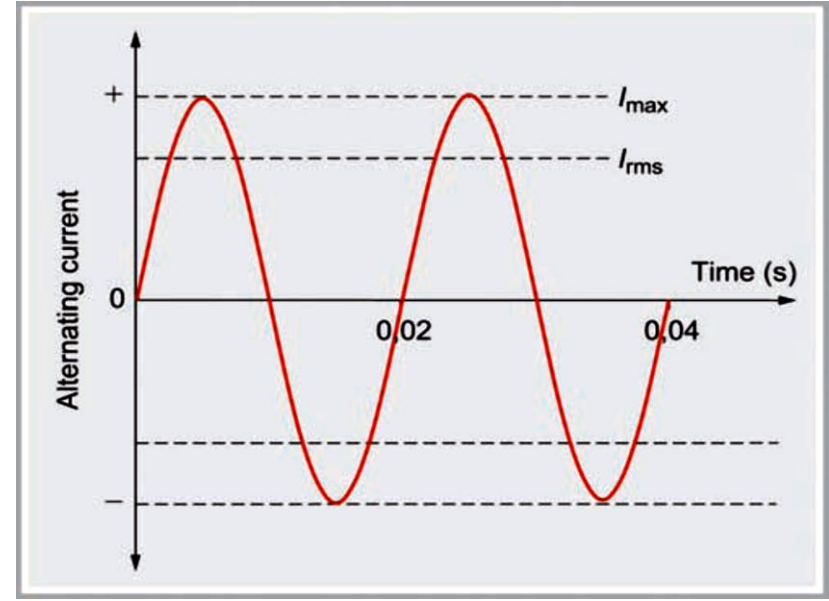
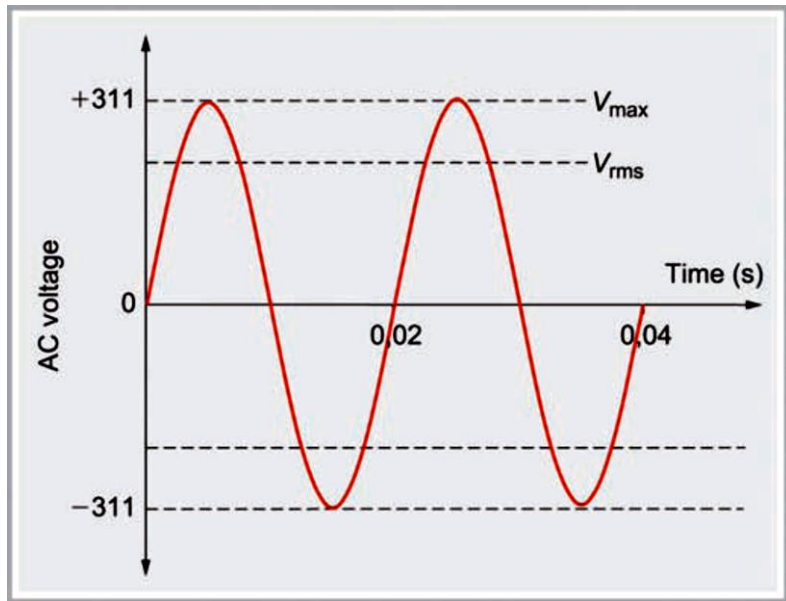
Define the term *rms* for an alternating voltage/current.

- The rms potential difference is the AC potential difference which dissipates/produces the same amount of energy as an equivalent DC potential difference.
- The rms current is the alternating current which dissipates/produces the same amount of energy as an equivalent direct current (DC).

ALTERNATING CURRENT/WISSELSTROOM

$I_{rms} = \frac{I_{max}}{\sqrt{2}}$	/	$I_{wgk} = \frac{I_{maks}}{\sqrt{2}}$	$P_{ave} = V_{rms} I_{rms}$	/	$P_{gemiddeld} = V_{wgk} I_{wgk}$
$V_{rms} = \frac{V_{max}}{\sqrt{2}}$	/	$V_{wgk} = \frac{V_{maks}}{\sqrt{2}}$	$P_{ave} = I_{rms}^2 R$	/	$P_{gemiddeld} = I_{wgk}^2 R$
			$P_{ave} = \frac{V_{rms}^2}{R}$	/	$P_{gemiddeld} = \frac{V_{wgk}^2}{R}$



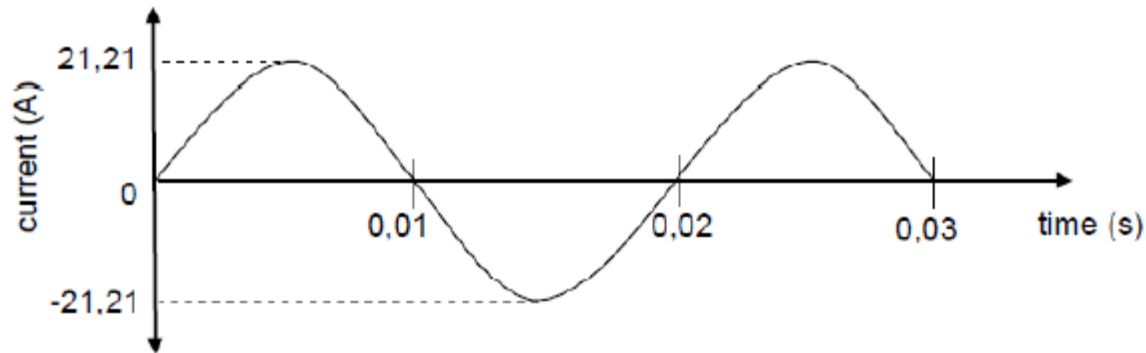


Activity 6

Date:

(12 minutes)

A similar coil is rotated in a magnetic field. The graph below shows how the alternating current produced by the AC generator varies with time.



- 10.4 How many rotations are made by the coil in 0,03 seconds? (1)
- 10.5 Calculate the frequency of the alternating current. (3)
- 10.6 Will the plane of the coil be PERPENDICULAR TO or PARALLEL TO the magnetic field at $t = 0,015$ s? (1)
- 10.7 If the generator produces a maximum potential difference of 311 V, calculate its average power output. (5)

10.4 $1\frac{1}{2}$ ✓ (1)

10.5

OPTION 1/ OPSIE 1

$$f = \frac{1}{T} \checkmark$$

$$= \frac{1}{0,02} \checkmark$$

$$= 50 \text{ Hz} \checkmark$$

(3)

OPTION 2/ OPSIE 2

$$f = \frac{\text{number of cycles}}{\text{time}} \checkmark$$

$$= \frac{1,5}{0,03} \text{ or/of } \frac{1}{0,02} \text{ or/of } \frac{0,5}{0,01} \checkmark$$

$$= 50 \text{ Hz} \checkmark$$

(3)

(3)

10.6 Parallel to / *Parallel aan* ✓ (1)

10.7

OPTION 1/ OPSIE 1

$$P_{\text{ave}} = V_{\text{rms}} I_{\text{rms}} \checkmark$$

$$= \left(\frac{V_{\text{max}}}{\sqrt{2}} \right) \left(\frac{I_{\text{max}}}{\sqrt{2}} \right) \checkmark \quad (1 \text{ mark for both formulae} / 1 \text{ punt vir beide formules})$$

$$= \left(\frac{311}{\sqrt{2}} \right) \checkmark \left(\frac{21,21}{\sqrt{2}} \right) \checkmark$$

$$= 3\,298,16 \text{ W} \checkmark \quad (\text{Accept range} / \text{Aanvaar gebied: } 3298,13 - 3299,18 \text{ W})$$

OPTION 2/ OPSIE 2

$$P_{\text{ave}} = \frac{V_{\text{max}} I_{\text{max}}}{2} \checkmark \checkmark$$

$$= \frac{(311)(21,21)}{2} \checkmark \checkmark$$

$$= 3298,16 \text{ W} \checkmark$$

OPTION 3 / OPSIE 3

$$V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}} = \frac{311}{\sqrt{2}} \checkmark = 219,91 \text{ V}$$

$$I_{\text{rms}} = \frac{I_{\text{max}}}{\sqrt{2}} = \frac{21,21}{\sqrt{2}} \checkmark = 14,998 \text{ A}$$

$$P_{\text{ave}} = V_{\text{rms}} I_{\text{rms}} \checkmark$$

$$= (219,91)(14,998)$$

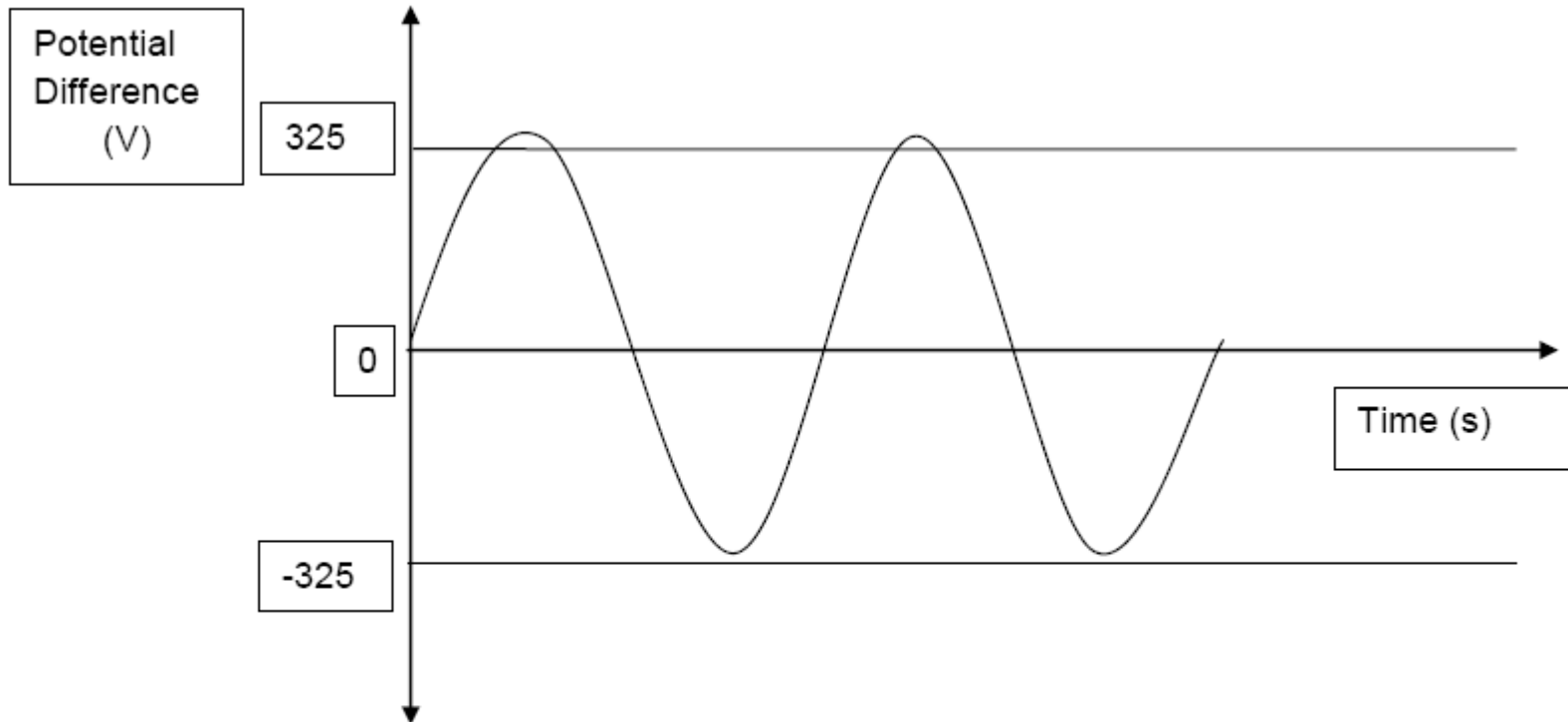
$$= 3\,298,21 \text{ W} \checkmark$$

Activity 7

Date:

(10 minutes)

The waveform on the following page is a graphical representation of the variation of voltage (V) versus time (t) for an alternating current.



- 3.1 Explain the advantage of using alternating current at power stations. (2)
- 3.2 Calculate the average power dissipated by this generator if the rms current produced is 13A. (5)
- [7]

QUESTION 3

3.1 The voltage can be altered by using transformers. ✓ Transformers only operate on AC current. Electrical energy can be transmitted over long distances at low current ✓, and experience low energy loss. (2)

$$\begin{aligned}
 3.2. \quad V_{\text{RMS}} &= V_{\text{max}} / \sqrt{2} \quad \checkmark \\
 &= 325 / \sqrt{2} \quad \checkmark \\
 &= 0,707 (325) = 230 \text{ V}
 \end{aligned}$$

$$\begin{aligned}
 P_{\text{ave}} &= V_{\text{RMS}} I_{\text{RMS}} \quad \checkmark \\
 &= 230 \times 13 \quad \checkmark \\
 &= 2990 \text{ W} \quad \checkmark
 \end{aligned}$$

(5)
[7]

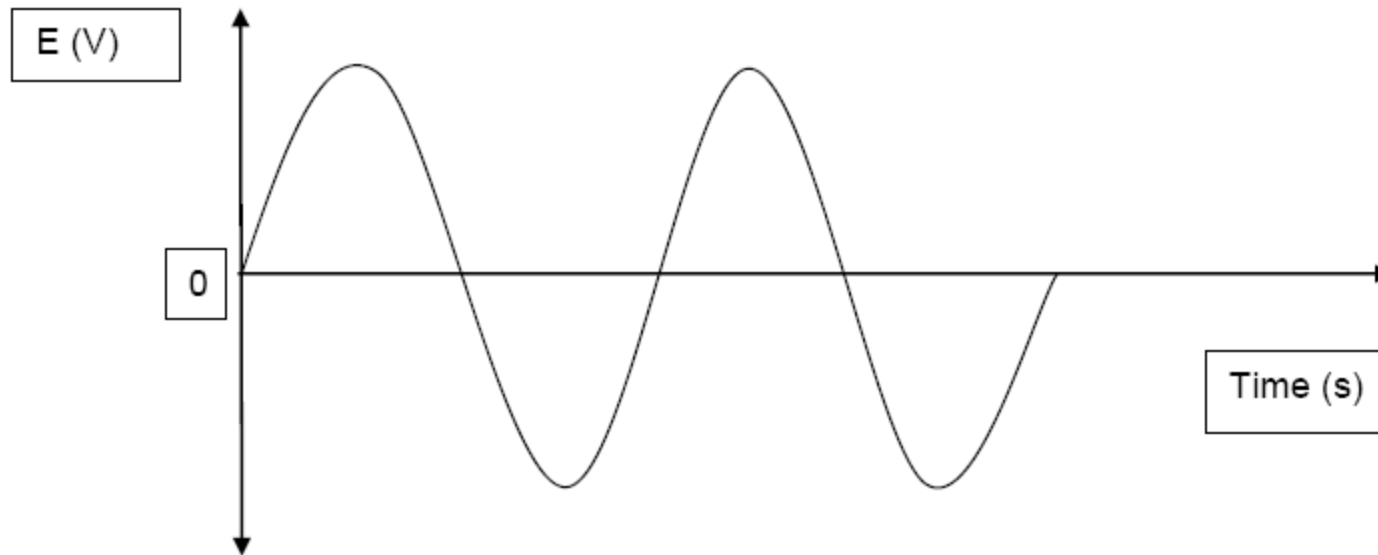
QUESTION 4

Activity 8

Date:

(7 minutes)

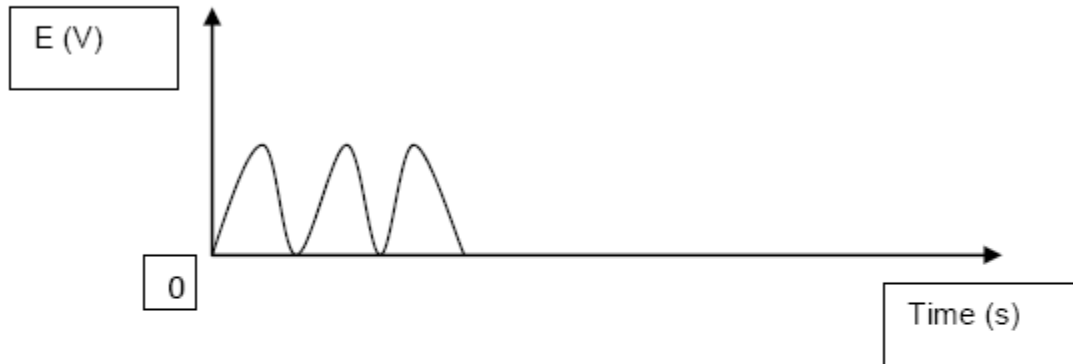
The induced emf versus time graph for an AC generator is shown below:



- 4.1 Sketch a graph to show how the above waveform changes, if at all, after changing this generator into a DC generator. (2)
- 4.2 State TWO advantages of using AC over DC for the long-distance transmission of electrical power. (2)
- [4]

QUESTION 4

4.1 Correct shape ✓ ✓



(2)

4.2 Any two:

Easier to generate and transmit from place to place ✓

Easier to convert from AC to DC than the reverse ✓

Voltage can be easily changed by stepping it up or down

High frequency used in AC make it more suitable for electric motors

(2)

[4]

Activity 9

Date:

(12 minutes)

9.2 An electrical device is marked 200 W ; 220 V.

9.2.1 Define the term *rms voltage*. (2)

9.2.2 Calculate the resistance of the device. (3)

This device is now connected to a 150 V AC source.

9.2.3 Calculate the energy dissipated by the device in 10 minutes. (5)

- 9.2.1 (The rms voltage/value of AC is) the AC voltage/potential difference which dissipates the same amount of energy/heat/power as an equivalent DC voltage/potential difference. ✓✓ (2 or 0)
 (Die wgk-waarde van WS is) die WS-potensiaalverskil/spanning wat dieselfde hoeveelheid energie/hitte/drywing verbruik as 'n ekwivalente GS-spanning/potensiaalverskil. (2 of 0)

ACCEPT/AANVAAR

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

Die wgk-waarde van WS is die GS-potensiaalverskil wat dieselfde hoeveelheid energie/hitte/drywing verbruik as die WS.

(2)

9.2.2

<u>Marking criteria/Nasienriglyne</u>		
- Appropriate formula for P_{ave}/Gesikte formule vir P_{ave} ✓ - Substitution to calculate/Vervanging vir berekening van R ✓ - Final answer/Finale antwoord: 242Ω ✓		
<u>OPTION 1/OPSIE 1</u>	<u>OPTION 2/OPSIE 2</u>	<u>OPTION 3/OPSIE 3</u>
$P_{ave} = \frac{V_{rms}^2}{R} \checkmark$ $200 = \frac{220^2}{R} \checkmark$ $R = 242 \Omega \checkmark$	$P_{ave} = V_{rms} I_{rms} \checkmark$ $200 = I_{rms} (220)$ $I_{rms} = 0,909 \text{ A (0,91)}$ $R = \frac{V_{rms}}{I_{rms}} \text{ or/of } R = \frac{V}{I}$ $R = \frac{220}{0,909} \checkmark$ $R = 242 \Omega \checkmark (241,76 \Omega)$	$P_{ave} = V_{rms} I_{rms} \checkmark$ $200 = I_{rms} (220)$ $I_{rms} = 0,909 \text{ A (0,91)}$ $P_{ave} = I_{rms}^2 R$ $200 = (0,909)^2 R \checkmark$ $R = 242 \Omega \checkmark$ $(241,52 \Omega)$

(3)

$$W = \frac{V^2 \Delta t}{R} \checkmark \checkmark$$

$$= \frac{(150^2)(10 \times 60)}{242} \checkmark$$

$$= 55\,785,12 \text{ J} \checkmark$$

OPTION 2/OPSIE 2

$$P_{\text{ave}} = \frac{V_{\text{rms}}^2}{R} \checkmark$$

$$= \frac{150^2}{242} \checkmark$$

$$P_{\text{av}} = 92,975 \text{ W}$$

$$P = \frac{W}{\Delta t} \checkmark$$

$$92,975 = \frac{W}{(10)(60)} \checkmark$$

$$W = 55\,785,12 \text{ J} \checkmark$$

$$(55\,785,12 - 55\,896 \text{ J})$$

OPTION 3/OPSIE 3

$$R = \frac{V_{\text{rms}}}{I_{\text{rms}}} \checkmark / R = \frac{V}{I}$$

$$242 = \frac{150}{I_{\text{rms}}} \checkmark$$

$$I_{\text{rms}} = 0,620 \text{ A}$$

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

$$= (0,62)(150)$$

$$= 92,97 \text{ W (93 W)}$$

$$P = \frac{W}{\Delta t} \checkmark$$

$$92,975 = \frac{W}{(10)(60)} \checkmark$$

$$W = 55\,785,12 \text{ J} \checkmark$$

$$(55\,785,12 - 55\,896 \text{ J})$$

OPTION 4/OPSIE 4

$$R = \frac{V_{\text{rms}}}{I_{\text{rms}}} \checkmark / R = \frac{V}{I}$$

$$242 = \frac{150}{I_{\text{rms}}} \checkmark$$

$$I_{\text{rms}} = 0,620 \text{ A}$$

$$W = I^2 R \Delta t \checkmark$$

$$= (0,62)^2 (242)(10)(60) \checkmark$$

$$= 55\,814,88 \text{ J} \checkmark$$

$$(55\,785,12 - 55\,896 \text{ J})$$

OR/OF

$$W = VI \Delta t$$

$$= (150)(0,62)(600)$$

$$= 55\,800 \text{ J}$$