SENIOR SECONDARY IMPROVEMENT PROGRAMME 2013

education
Department: Education
GAUTENG PROVINCE

GRADE 12

PHYSICAL SCIENCES

LEARNER NOTES

The SSIP is supported by

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LEARNER NOTES

SESSION 16

TOPIC: CONSOLIDATION EXERCISES ON RATES, CHEMICAL EQUILIBRIUM AND ELECTROCHEMISTRY

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 20 minutes

In order to investigate the rate at which a reaction proceeds, a learner places a beaker containing concentrated nitric acid on a sensitive balance. A few pieces of copper metal are dropped into the nitric acid. Mass readings of the beaker and its contents are recorded every 15 s, from the moment the copper metal is dropped into the acid until shortly after there is no more copper metal present.

The mass readings taken during the investigation are given in the table below. The time at which the copper is dropped into the acid is recorded as 0 seconds.

Time (s)	Mass of beaker and contents (g)	Decrease in mass (g)
0	114,6	0
15	113,0	0,6
30	111,6	2,2
45	110,4	4,2
60	109,4	5,2
75	108,7	5,9
90	108,4	6,2
105	108,3	6,3
120	108,3	6,3
135	108,3	6,3
150	108,3	6,3

1.1 Which of the two physical quantities, time or mass, is the independent variable in this investigation. Explain your answer. (3)

1.2. Using the readings given in the table, plot a graph on this page of *decrease mass* versus *time*.

(7)

1.3. From the gradient of the graph it can be seen that the rate of the reaction change with time. Explain why the following changes in rate occur.

1.3.1 Reaction rate increases between 0 and 30s. (2)

1.3.2 Reaction rate decreases between 45 and 105s. (2)

1.3.3 After 105 s the rate becomes zero. (2)

1.4 State two ways in which the rate of this reaction could be increased. (4)

[20]

QUESTION 2: 20 minutes

A small quantity of cobalt chloride powder is dissolved in ethanol resulting in a blue solution. When a few drops of water are carefully added to the blue solution the colour changes to pink. The following equilibrium has been established:

$$CoCl_4^{2-}(aq) + 6H_2O(l) \rightleftharpoons Co(H_2O)_6^{2+}(aq) + 4Cl^-(aq)$$

blue pink

To investigate the factors which affect this equilibrium, the following experiments were performed:

Experiment 1: A small quantity of concentrated HCl is added to the solution.

2.1 Observation:…………………………………… (1)

Experiment 2: The test tube with the solution is cooled by immersing it in ice water.

2.2 Observation:…………………………………… (1)

Experiment 3: A few drops of silver nitrate are added to the solution.

2.3 Observation:……………………………………………….. (2)

2.4 Tabulate your observations: (3)

2.5 Name the effect that is illustrated in experiment 1. (1)

2.6 Was the forward or reverse reaction favoured as a result of the addition of the concentrated HCl? (1)

2.7 Use your observation in experiment 2 to state whether the forward reaction is exothermic or endothermic. (1)

2.8 Make use of Le Chatelier's principle to justify your answer in 2.7. (4)

2.9 In experiment 3, a white precipitate is formed when the silver nitrate is added.

2.9.1 Give the name of the white solid. (1)

2.9.2 Give the balanced chemical equation to explain the formation of the white precipitate. (3)

2.9.3 Explain how the addition of the silver nitrate affected the equilibrium. (3)

[21]

QUESTION 3: 15 minutes

Two half-cells, Pb^{2+}/Pb and O_2/H_20, in an acid solution are used to set up an electrochemical cell. The cell operates under standard conditions.

3.1 Give the standard conditions that apply to this electrochemical cell. (4)

3.2 Which half-cell represents the anode? (2)

3.3 Give the equation for the oxidation half-reaction. (2)

3.4 Give the equation for the reduction half-reaction. (2)

3.5 Give the balanced equation for the net reaction. (2)

3.6 Calculate the emf of the cell. (4)

[16]

SECTION B: ADDITIONAL CONTENT NOTES

No additional content notes

SECTION C: HOMEWORK

QUESTION 1: 15 minutes

A si!ver-nickel voltaic cell is made under standard conditions.

1.1 Give the reduction half-reaction. (2)

1.2 Write the half-reaction that occurs at the anode. (2)

1.3 Which electrode increases in mass when the cell is used? (2)

1.4 Give the cell notation for this cell. (3)

1.5 What is the emf of this cell? (4)

[13]

QUESTION 2: 16 minutes

2.1 Lowering the temperature of an equilibrium reaction will:

A decrease the rate of the forward reaction only.

B decrease the rate of the reverse reaction only.

C decrease the rate of both the forward and reverse reactions.

D have no effect on the rate of reaction.

2.2 Assuming equilibrium is reached in the reaction:

$2CO(g) \quad O_2(g) \rightleftharpoons 2CO_2(g)$; $\Delta H = -565kJ$

A greater yield of carbon dioxide can be obtained by …

A raising the temperature and pressure.

B raising the temperature and lowering the pressure.

C lowering the temperature and pressure.

D lowering the temperature and raising the pressure.

2.3 Carbon, carbon dioxide and carbon monoxide are in equilibrium in a container of which the volume can change. The balanced equation for the equilibrium reaction is as follows:

$$C(s) + CO_2(g) \rightleftharpoons 2CO(g)$$

While the temperature is kept constant, the volume of the container is decreased and a new equilibrium is established. Which one of the following statements regarding the number of moles of CO and the concentration of CO at the new equilibrium condition is correct?

	Number of moles of CO	[CO]
A	the same	greater
B	Less	greater
C	Less	less
D	More	the same

2.4 A saturated solution of NaCl in water is prepared at 60°C. The equation for this solubility equilibrium is:

$$NaCl(s) \rightleftharpoons Na^+(aq) + Cl^-(aq) \qquad \Delta H > 0$$

Which one of the following changes will cause more $NaCl_{(s)}$ to form?

A add H_2O.
B add a catalyst.
C increase temperature.
D decrease temperature.

2.5 Two substances, A and B, are in equilibrium with their product, AB, at a temperature of 10°C as indicated by the following equation:

$$A(g) + B(g) \rightleftharpoons AB(g) \qquad \Delta H > 0$$

At 10°C the rate of the forward reaction is equal to x $mol \cdot s^{-1}$.

The temperature is then increased. Which statement regarding the forward and reverse reaction rates is correct at the higher temperature?

	Forward rate	Reverse rate
A	equal to x	equal to x
B	less than x	less than x
C	greater than x	greater than x
D	less than x	greater than x

2.6. When an amount of sulphur and oxygen are sealed in a container at 700K, an equilibrium is established according to the following equation:

$$S(s) + O_2(g) \leftrightharpoons SO_2(g) \quad \triangle H < 0$$

If the pressure is increased, while the temperature of 700K is maintained, the:

A value of K_c increase

B volume of the gases increase

C amount of SO_2 decreases

D amount of O_2 remains the same.

2.7. The following equilibrium exists in a saturated salt solution.

$$NaCl\ (s) \leftrightharpoons Na^+(aq) + Cl^-(aq)$$

What can be done in order to obtain a precipitate of NaCl ?

A Increase the pressure on the system

B Heat the solution

C Add concentrated Hydrochloric acid (HCl)

D Bubble chlorine (Cl_2) through the solution.

2.8. In which of the following reactions will a *decrease* in pressure cause the yield of the product(s) to *increase*?

A $2\ SO_{2(g)} + O_{2(g)} \leftrightharpoons 2SO_{3(g)}$

B $2\ H_2O_{(g)} \leftrightharpoons 2H_{2\ (g)} + O_{2(g)}$

C $2\ NO_{2(g)} \leftrightharpoons N_2O_{4(g)}$

D $2\ HI_{(g)} \leftrightharpoons H_{2\ (g)} + I_{2\ (g)}$

2.9. Consider the following system which is in equilibrium:

$$4HCl\ (g) + O_2(g) \leftrightharpoons 2Cl_2(g) + 2H_2O(l) \quad (\triangle H < 0)$$

The yield of chlorine gas can best be *increased* by the following combination of changes in temperature and pressure:

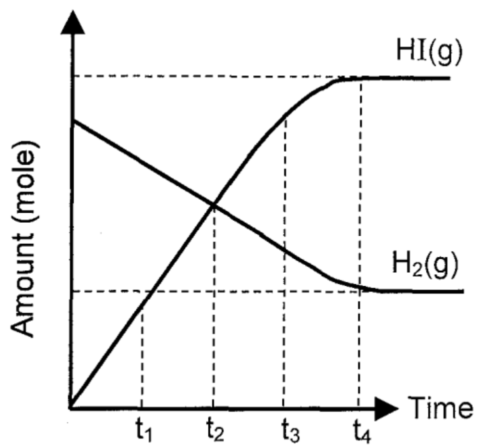
	Temperature	Pressure
A	Increase	Decrease
B	decrease	Decrease
C	decrease	Increase
D	increase	Increase

2.10. The following reversible reaction is used in the production of hydrogen iodide gas:

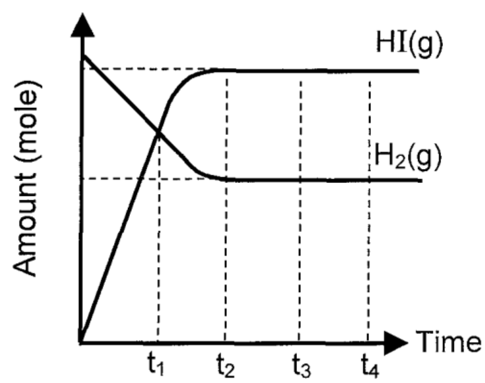
$$H_2\,(g) \; + \; I_2\,(g) \; \rightleftharpoons \; 2HI\,(g) \qquad \Delta H < 0$$

The graph X of amount of reagents against time was obtained when the reaction was carried out under certain conditions.

The graph Y was obtained for the same experiment using the same amount of H_2 (g), but certain changes were made to the conditions affecting the system.



GRAPH X



GRAPH Y

2.11 Which one of the following sets of changes could have been introduced to the system to obtain graph Y?

A More $I_{2(g)}$ was added and the temperature was decreased.
B The temperature and pressure was decreased.
C A catalyst was added and the temperature was increased.
D A catalyst was added and the temperature was decreased.

2.12. Assuming equilibrium is reached in the reaction:

$$2CO(g) \; + \; O_2(g) \; \rightleftharpoons \; 2CO_2(g) \qquad \Delta H = -565 \text{ kJ}$$

A greater yield of carbon dioxide can be obtained by:

A raising the temperature and pressure.
B raising the temperature and lowering the pressure.
C lowering the temperature and the pressure.
D lowering the temperature and raising the pressure.

2.13. Consider the following equilibrium reaction:

$$2N_2(g) + O_2(g) \rightleftharpoons 2N_2O(g) \qquad \Delta H = 160\ kJ \cdot mol^{-1}$$

Which ONE of the following changes gives the greatest increase in the equilibrium yield of N_2O?

	TEMPERATURE	PRESSURE
A	Decrease	Increase
B	Decrease	Decrease
C	Increase	Increase
D	Increase	Decrease

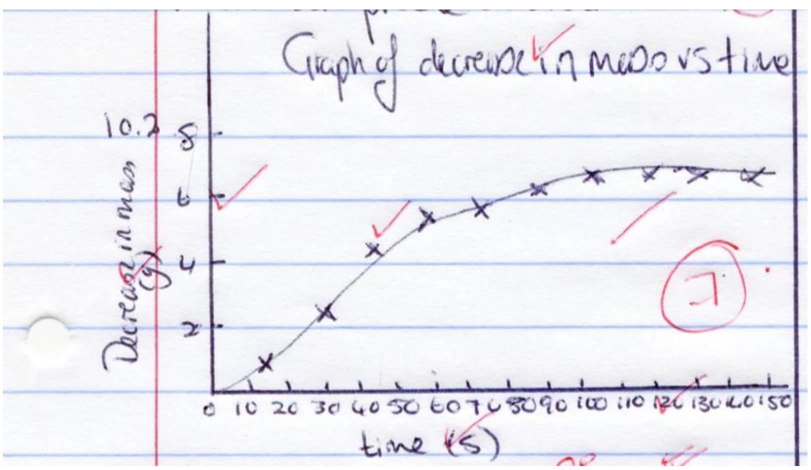
(13 x 2) [26]

SECTION D: SOLUTIONS AND HINTS TO SECTION A

QUESTION 1

1.1 Time. √ It was decided to measure mass at predetermined times. √√ (3)

1.2



(7)

1.3.1 Cu and HNO_3 reacting together initially and rate is quick√√ (2)

1.3.2 HNO_3 concentration and Cu surface area decreasing√√ (2)

1.3.3 reaction has reached completion. √√ (2)

1.4. heated, √√copper surface area increased, √√ concentration of nitric acid increased √√ **(Any two)** (4)

[20]

QUESTION 2

2.1 Clear pink solution turns blue√ (1)

2.2 Clear blue solution turns pink√ (1)

2.3 Clear blue solution turns opaque pink solution (pink with white ppt) √√ (2)

2.4.

Equilibrium disturbance	Observation
Addition of HCl	Pink to blue√
Cooling of solution	Blue to pink√
Addition of AgNO3	Blue to opaque pink√

(3)

2.5. Common ion effect √ (1)

2.6. Reverse reaction √ (1)

2.7. Exothermic √ (1)

2.8. The decrease in temperature favours the exothermic reaction√. The solution Went from blue to pink √→ forward reaction favoured. √ So forward reaction is exothermic√. (4)

2.9.1. Silver chloride √ (1)

2.9.2. Ag+ (aq)√+ Cl- (aq)√→ AgCl (s)√ (3)

2.9.3. Silver nitrate reacts with Cl- ions thus removing them from the solution. √The concentration of chloride ions decreases so the equilibrium shifts so as to accommodate that change. The forward reaction is thus favoured√. and the solution turns pink. √. (3)

[21]

QUESTION 3

3.1 Concentration of Pb^{2+}(1M) √; H^+(1M) √; pressure of O_2 1 atm√; Temperature 25°C√ (4)

3.2 Pb√√ (2)

3.3 $2Pb\ (s) \rightarrow 2Pb^{2+}\ (aq) + 4e^-$√√ (2)

3.4 $O_2 + 4H^+ + 4e^- \rightarrow 2\ H_2O$√√ (2)

3.5 $2Pb + O_2 + 4H^+ \rightarrow 2\ H_2O + 2Pb^{2+}$√√ (2)

3.6 $E^\theta_{cell} = E^\theta_{cathode} - E^\theta_{anode}$ √

$= 1{,}23$ √ $- (-0{,}13)$√

$E^\theta_{cell} = 1{,}36\ V$ √ (4)

[16]

SESSION 17

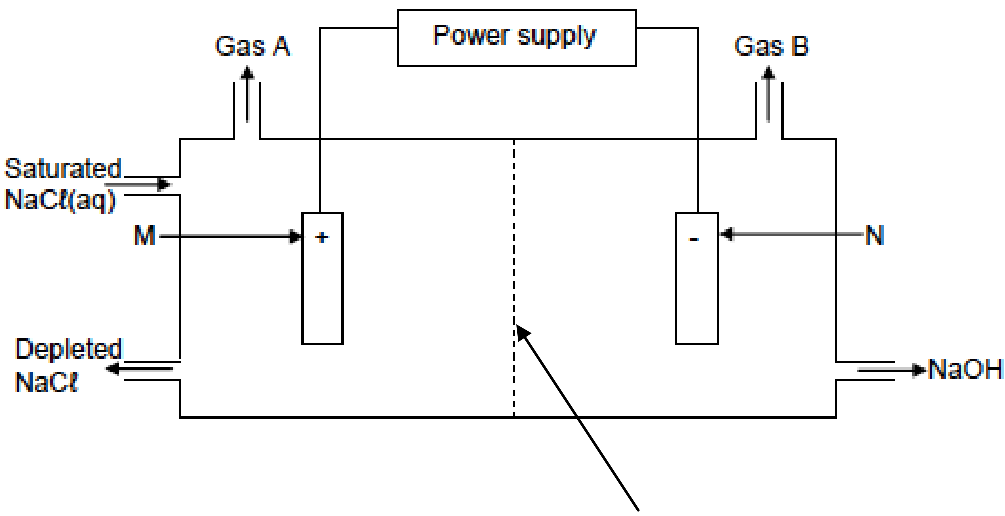
TOPIC 1: CHEMICAL CHANGE AND CHEMICAL SYSTEMS - EXTRACTION OF ALUMINIUM AND CHLORALKALI INDUSTRY

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 10 minutes

(Taken from the DoE Physical Sciences Additional Exemplar Paper 2 2008)

The diagram below shows a type of membrane cell used in the chloroalkali industry.



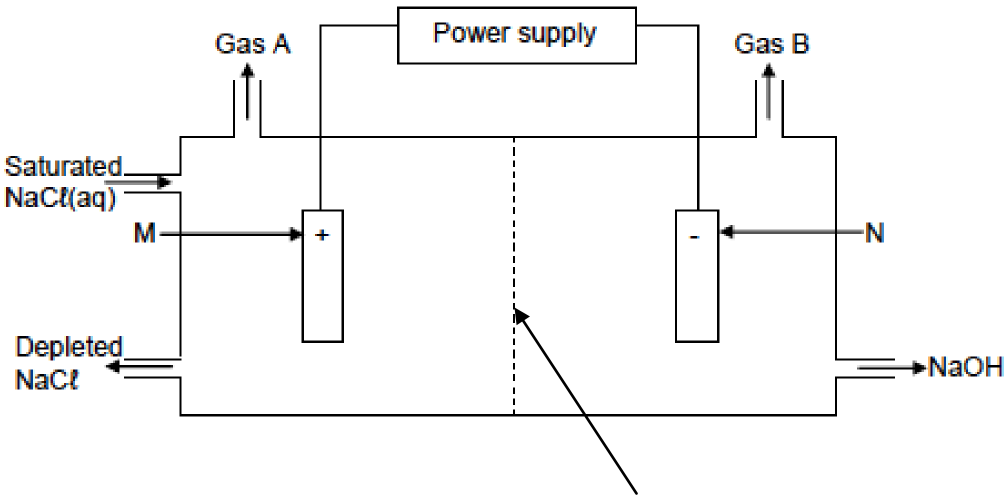
Cationic membrane

1.1	Name the gases A and B.	(2)
1.2	Why is the membrane called a cationic membrane?	(1)
1.3	Write down the half-reaction that takes place at electrode N.	(2)
1.4	Apart from its use in household products, name ONE industrial use of chlorine.	(1)
1.5	Explain why this electrolytic process cannot be done in one large container without a membrane.	(2)
		[8]

QUESTION 2: 15 minutes

(Taken from the DoE Physical Sciences Exemplar Paper 2 2008)

The chloralkali (also called 'chlorine-caustic') industry is one of the largest electrochemical technologies in the world. Chlorine is produced using three types of electrolytic cells. The simplified diagram on the following page shows a membrane cell. Gas A Power supply Gas B.



2.1 Give TWO reasons why the membrane cell is the preferred cell for the preparation of chlorine. (2)

2.2 Why do you think it is advisable to use inert electrodes in this process? (2)

2.3 Write down the equation for the half-reaction taking place at electrode M. (2)

2.4 Which gas is chlorine gas? Write down only Gas A or Gas B. (2)

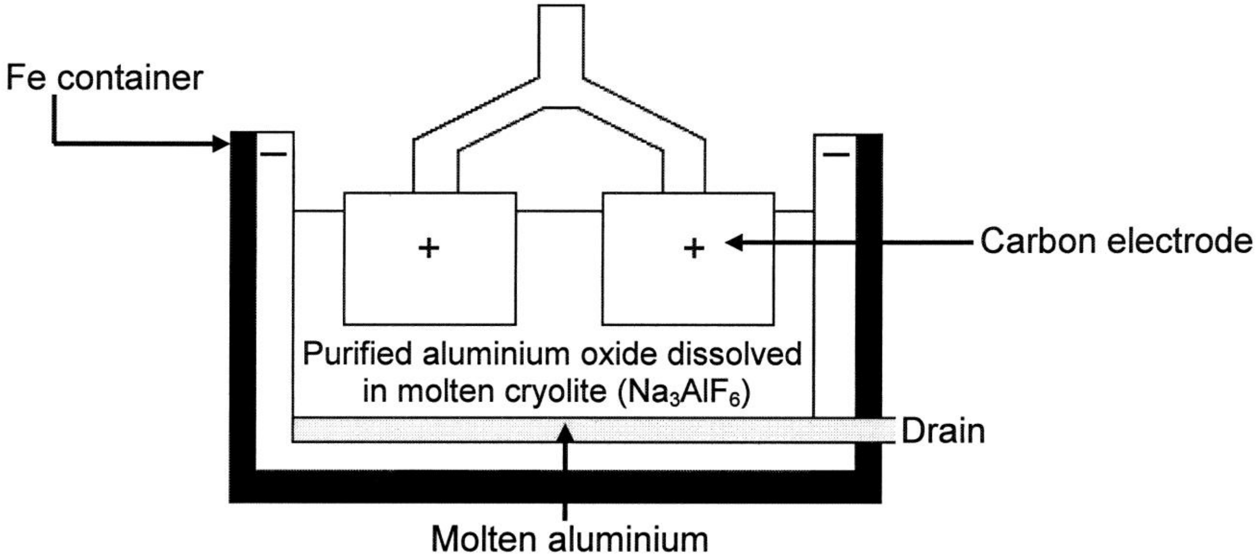
2.5 Briefly explain how sodium hydroxide forms in this cell. (3)
[11]

QUESTION 3: 15 minutes

(Taken from the DoE Physical Sciences NSC November Paper 2 2008)

Aluminium is one of the most abundant metals on earth, yet it is expensive – largely because of the amount of electricity needed to extract it. Aluminium ore is called bauxite. The bauxite is purified to yield a white powder, aluminium oxide, from which aluminium can be extracted.

The diagram below shows an electrolytic cell used for the extraction of aluminium at temperatures as high as 1000° C.



3.1 State the energy conversion that takes place in this electrolytic cell. (2)

3.2 Is aluminium formed at the positive or negative electrode? Write down POSITIVE or NEGATIVE only. (1)

3.3 Use the Table of Standard Reduction Potentials (Table 4A or 4B) to write down the half-reaction for the formation of aluminium. (2)

3.4 Explain why carbon dioxide gas is formed at one of the electrodes. (2)

3.5 Why should the carbon electrodes be replaced regularly? (2)

3.6 Write down TWO negative effects that the extraction of aluminium can have on the environment. (2)

[11]

QUESTION 4: 15 minutes

4.1. Which type of cell is most commonly used nowadays to produce chlorine?

A. Castner cell

B. Mercury cell

C. Diaphragm cell

D. Membrane cell

4.2. Which of the following are the final products of the electrolysis of sodium chloride?

A. hydrogen, chlorine and sodium hydroxide

B. mercury, sodium and chlorine

C. mercury and brine

D. sodium hydroxide and hydrogen chloride

4.3. Aluminium is refined from bauxite. What is bauxite?

A. Impure Aluminium

B. Aluminium oxide ore

C. Cryolite

D. Used aluminium available for recycling

4.4. Copper chloride can be decomposed into copper and chlorine using electrolysis. Which statement is true about this reaction.

A. the reaction is endothermic

B. the reaction is exothermic

C. Only oxidation occurs in this reaction

D. Only reduction occurs in this reaction

4.5. In an electrolytic cell, it is always true to say:

A. reduction occurs at the anode

B. oxidation occurs at the cathode

C. ions conduct electricity in the electrolyte

D. electrons conduct electricity in the solution

4.6. Cryolite is added to the bauxite in the refining of aluminium to:

A. allow the electrolyte to conduct electricity

B. ensure that the anode and the cathode remain separate

C. lower the melting point of the Bauxite ore

D. prevent the carbon dioxide from escaping

4.7. Lead(II)bromide can be melted and decomposed using an electric current. Which combination is true of this half reaction

$$2\,Br^- \rightarrow Br_2 + 2e^-$$

A	Oxidation	Anode
B	Oxidation	Cathode
C	Reduction	Anode
D	reduction	Cathode

4.8. Where do you think you are most likely to find Chlorine production plants?

A. Inner cities

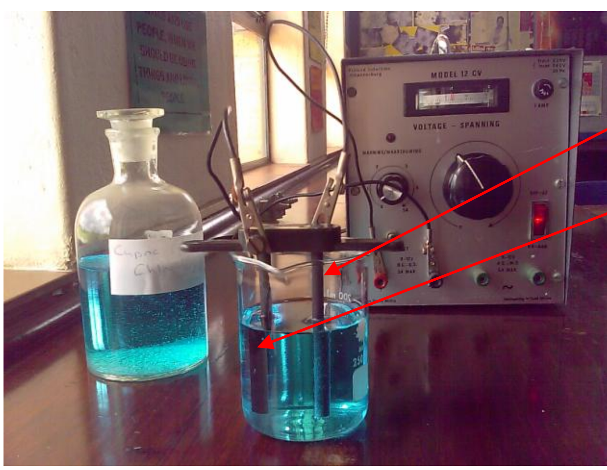
B. Remote mountainous areas

C. At the coast

D. In Gauteng's industrial areas (2 x 8) [16]

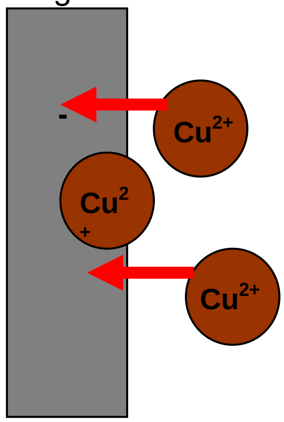
SECTION B: ADDITIONAL CONTENT NOTES

Electrolysis of a copper chloride solution

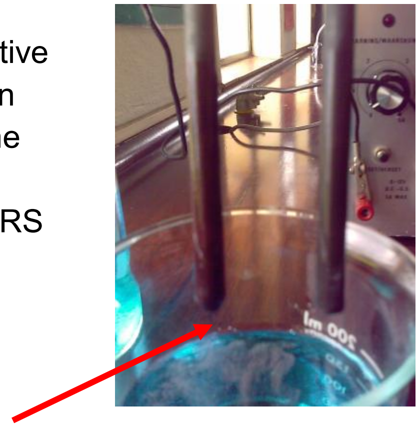


- Chloride ions lose electrons and form chlorine molecules (oxidation)
- Copper ions gain electrons and form copper metal (reduction)

Negative electrode

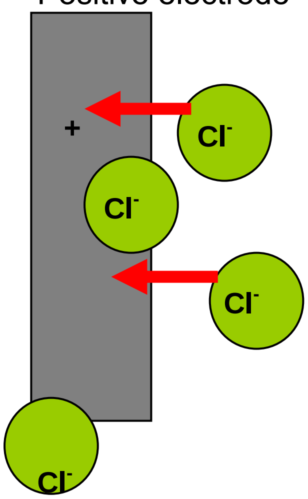


Positive cations are attracted to the negative cathode. Cations gain electrons and become neutral metal.
REDUCTION OCCURS AT THE CATHODE

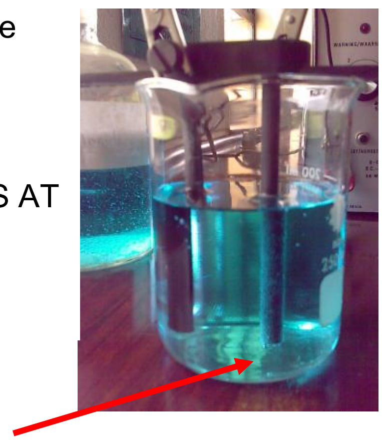


Copper ions reduce to copper metal

Positive electrode



Negative anions are attracted to the positive anode. Anions lose electrons and become neutral non metal.
OXIDATION OCCURS AT THE ANODE



Chloride ions oxidise to chlorine gas

PRACTICAL USE OF ELECTROLYSIS

- Electroplating (item to be plated acts as cathode)
- Purification of metals (e.g. copper)
- Refining of metals (e.g. aluminium)
- Production of chlorine

EXTRACTION OF ALUMINIUM FROM BAUXITE

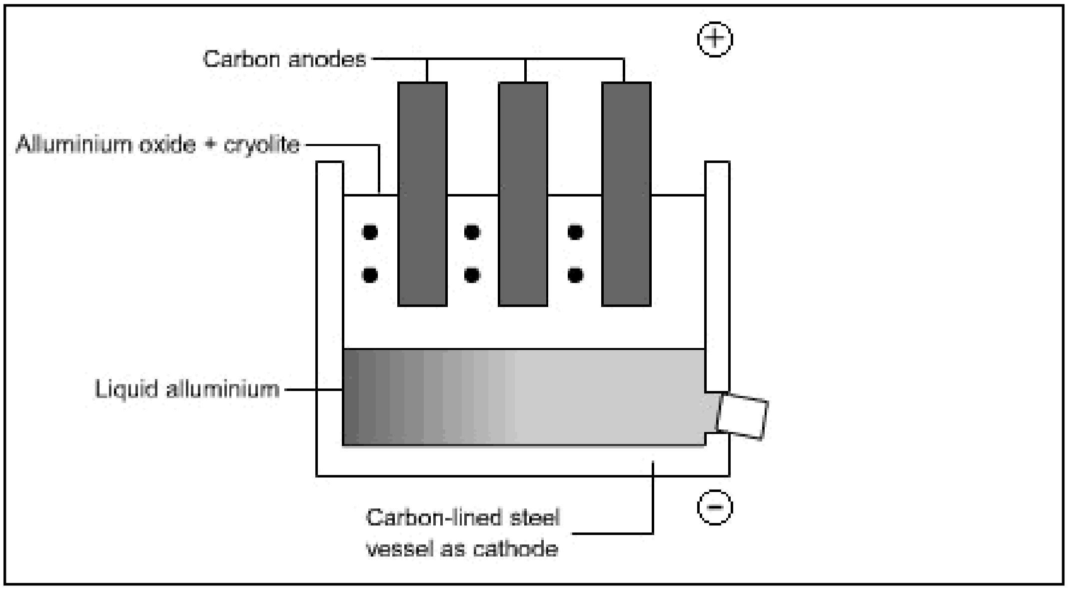


Image from: http://lgfl.skoool.co.uk

* Electrolysis of aluminium oxide dissolved in cryolite (Na_3AlF_6) results in harvesting of pure aluminium

At the cathode:

$$Al^{3+} + 3e^- \rightarrow Al_{(l)}$$

* The liquid aluminium forms a layer of molten aluminium at the bottom of the cell.

At the anode:

$$2O^{2-} \rightarrow O_{2(g)} + 4e^-$$

* Oxygen reacts with the carbon electrode to form carbon dioxide. The carbon electrodes therefore slowly erode and need to be replaced from time to time.

* Electrolysis of aluminium oxide is hugely environmentally un-friendly. The process uses a massive amount of electricity since the ore needs to be melted.
* The cryolite is added to lower the melting point of the ore.
* Electricity production in South Africa produces carbon dioxide as does the anode of the electrolytic cell. Carbon dioxide is a greenhouse gas and as a result contributes to global warming.
* Because South African electricity is cheaper than most places in the world, large quantities of Aluminium ore are sent to South Africa to be refined.

THE PRODUCTION OF CHLORINE

- Chlorine is manufactured by the electrolysis of brine (NaCl dissolved in water). There are 3 processes each with pros and cons.

$$2NaCl_{(aq)} + 2H_2O_{(l)} \dashrightarrow Cl_{2(g)} + H_{2(g)} + 2NaOH_{(aq)}$$

- Sodium hydroxide is produced at the same time as chlorine. We call this a by-product).
- Sodium hydroxide is then used in making soap

Mercury cell electrolysis

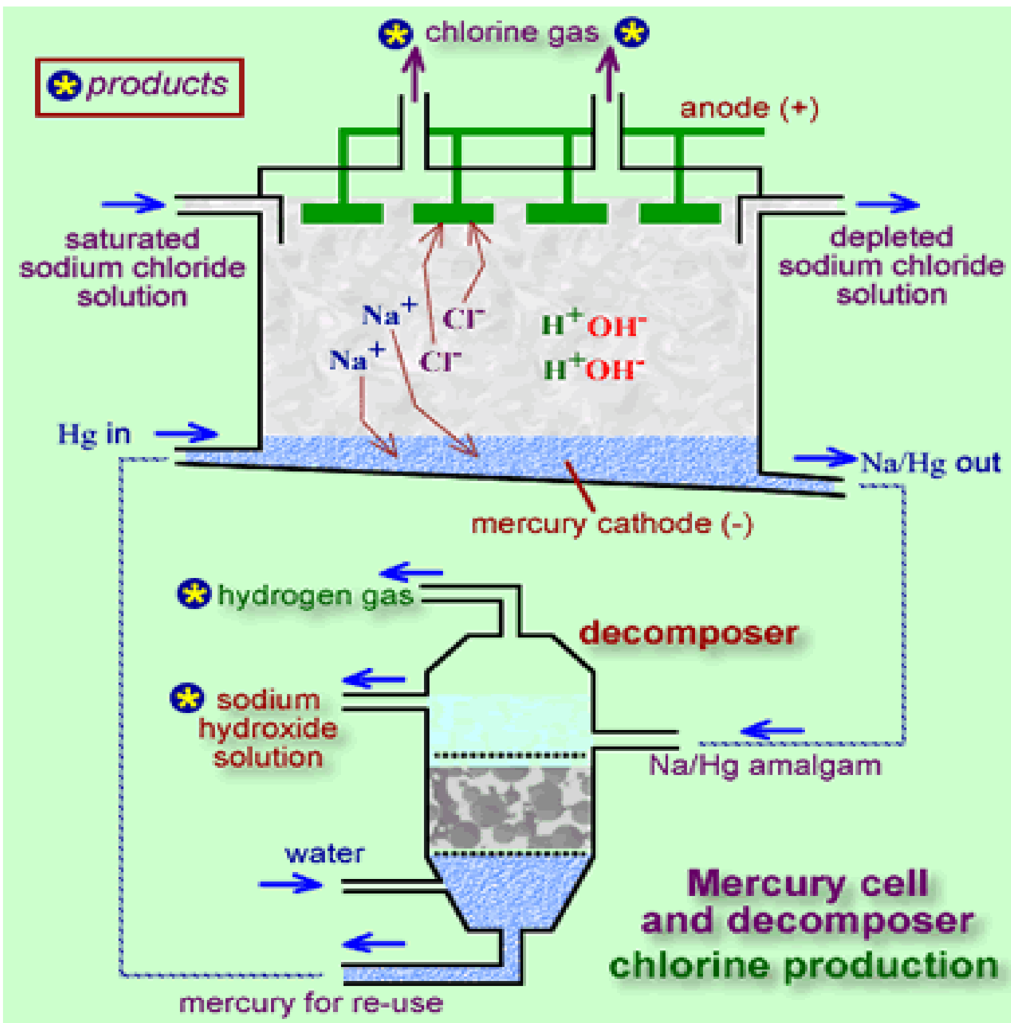


Image from: http://www.greener-industry.org

- Mercury cell electrolysis, also known as the Castner process, in which the "primary cell", titanium anodes are placed in a sodium (or potassium) chloride solution flowing over a liquid mercury cathode.
- When a potential difference is applied and current flows, chlorine is released at the titanium anode and sodium (or potassium) dissolves in the mercury cathode forming an amalgam.
- The mercury is then recycled to the primary cell.
- The mercury process uses the least energy of the three alternative cells.
- It is has the lowest yield of chlorine, of the three main technologies and there are also concerns about mercury emissions. Mercury is a cumulative heavy metal poison.

Diaphragm cell electrolysis

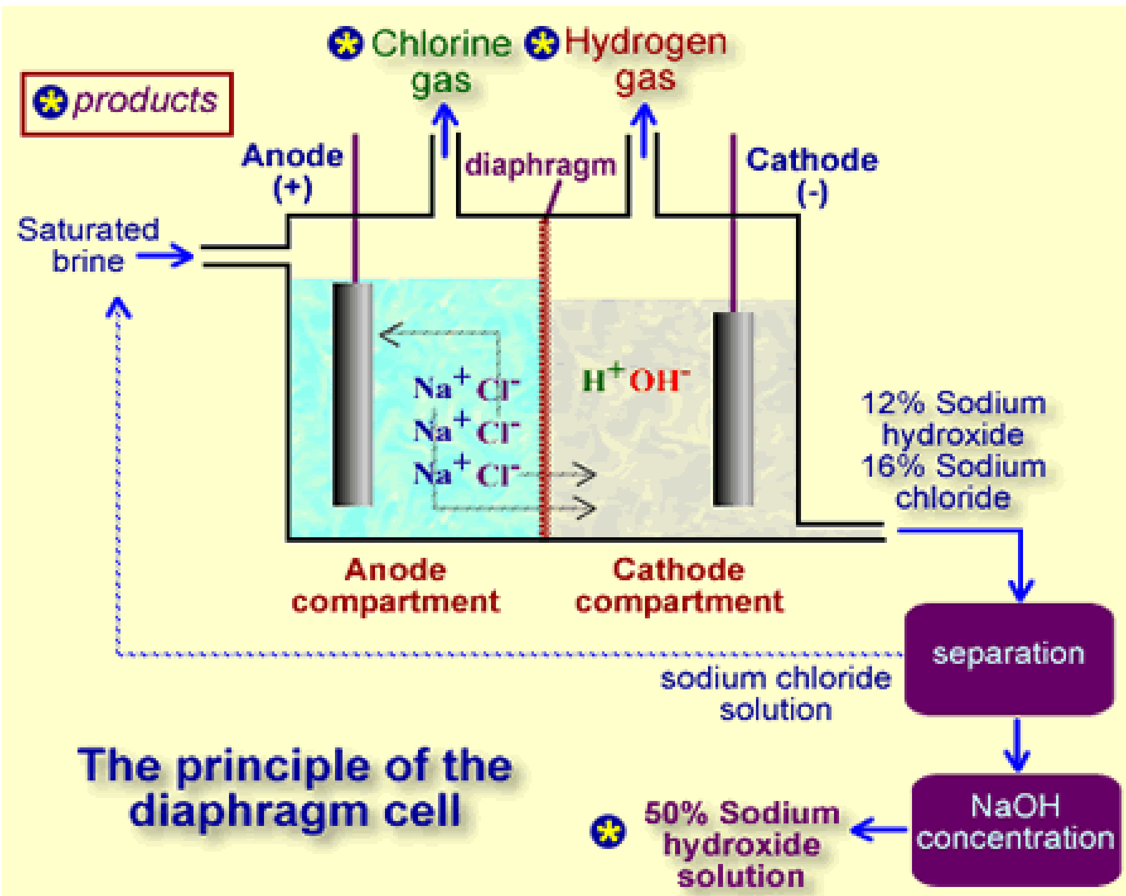


Image from: http://www.greener-industry.org

- In this process, a diaphragm separates cathode and anode, preventing the chlorine forming at the anode from re-mixing with the sodium hydroxide and the hydrogen formed at the cathode.
- The brine is continuously fed into the anode compartment and it flows through the diaphragm to the cathode compartment, where the sodium hydroxide is produced.
- This method produces alkali that is quite dilute (about 12%) but diaphragm cells do not have the problem of preventing mercury discharge into the environment.
- They also operate at a lower voltage, resulting in an energy savings but large amounts of steam are required if the sodium hydroxide has to be evaporated to the commercial concentration of 50%, so this then uses more electricity.

Membrane cell electrolysis

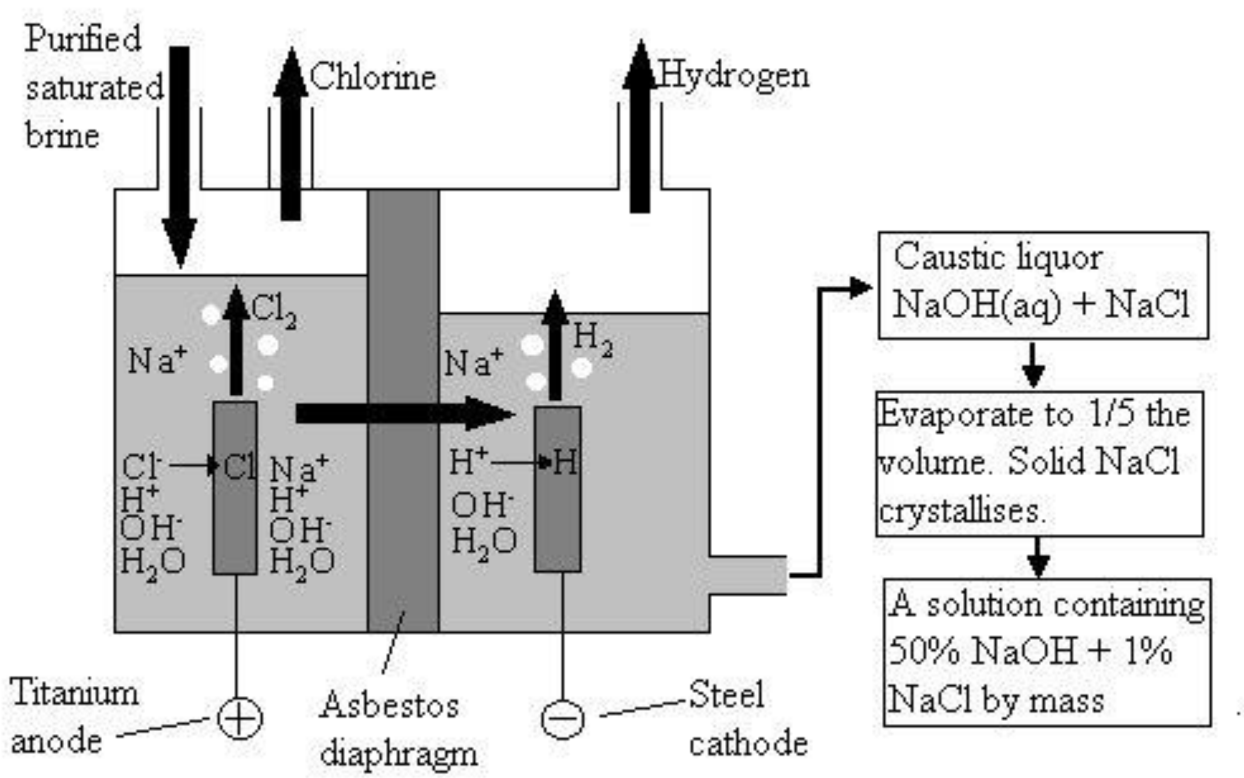


image from: http://www.drbateman.net

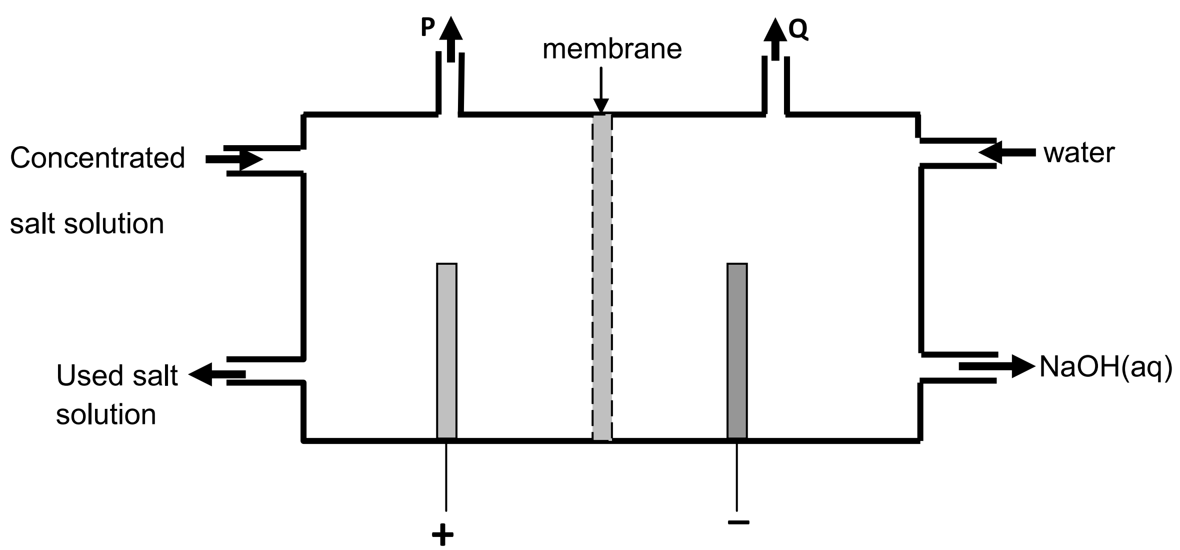
- The electrolysis cell is divided into two "rooms" by a cation permeable membrane acting as an ion exchanger.
- Saturated sodium (or potassium) chloride solution is passed through the anode compartment, leaving at a lower concentration.
- Sodium (or potassium) hydroxide solution is circulated through the cathode compartment, exiting at a higher concentration.
- A portion of the concentrated sodium hydroxide solution leaving the cell is diverted as product, while the remainder is diluted with deionised water and passed through the electrolyser again.
- This method is more efficient than the diaphragm cell and produces very pure sodium (or potassium) hydroxide at about 32% concentration, but requires very pure brine.

SECTION C: HOMEWORK

QUESTION 1: 12 minutes

(Taken from the DoE NSC Physical Sciences Supplementary February-March 2010 Paper 2)

The diagram below is a simplified version of a membrane cell, one of the electrolytic cells used in the chlor-alkali industry. The letters P and Q represent the two gases formed during this process.



1.1 Write down the letters P and Q. Next to each, write down the half-reaction that shows how gas P and gas Q are respectively formed. (4)

1.2 Water ($H_2O(\ell)$) and sodium ions ($Na^+(aq)$) are both present in the cathode side of the membrane cell. Explain why hydrogen gas, and not sodium metal, is formed in the membrane cell. Refer to the relative strengths of oxidising agents to explain your answer. (2)

1.3 State ONE function of the membrane. (1)

1.4 State TWO uses of chlorine. (2)

[9]

QUESTION 2: 13 minutes

(Taken from the DoE NSC Physical Sciences November 2010 Paper 2)

Industrially, chlorine gas is produced by the electrolysis of brine. In addition to chlorine gas, hydrogen gas and sodium hydroxide are also produced. $C\ell_2(g)$ is produced at the positive electrode and $H_2(g)$ is produced at the negative electrode.

2.1 Write the equation for the half-reaction that takes place at the cathode. (2)

2.2 Write the balanced overall (net) cell reaction, omitting spectator ions, for this electrolytic cell. (3)

2.3 State TWO functions of the membrane in the membrane cell. (2)

2.4 Use the relative strengths of oxidising agents present in a brine solution to explain why sodium metal is NOT one of the products in this process. (2)

2.5 Chlorine is used in many useful products such as plastics, drugs and disinfectants. Environmentalists are protesting against the large-scale production of chlorine. They base their argument on the negative impact of chlorine on humans.

Name ONE negative impact of chlorine on humans. (1)
[10]

SECTION D: SOLUTIONS TO SECTION A

QUESTION 1

1.1 A: chlorine √
B: hydrogen √ (2)

1.2. Allows only the cations (positive ions) to pass through it. √ (1)

1.3 $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ √√ (2)

1.4 Any one:

Manufacture of PVC √, paper, drugs, etc

Disinfectant of water (1)

1.5 In a single pot the chlorine will react with water to form chlorine water. √√ (2)

OR The chlorine will react with the OH^- ions to form bleach.

OR products formed will be contaminated. **[8]**

QUESTION 2

2.1 **Any two√√:**
There will be less pollution√ /
It is cheaper √ /
The product obtained will be more pure √. (2)

2.2 It does not react √ and thus it can be re-used. √ (2)

2.3 $2Cl^- \leftrightarrows Cl_2 + 2e^-$ √√ (2)

2.4 Gas A √√ (2)

2.5 Sodium ions migrate through the semi-permeable membrane to the cathode. √ Hydrogen ions produced from the water are reduced to hydrogen gas. The hydroxide ions form from the water. √ The sodium ions now combine with the hydroxide ions to form the sodium hydroxide product. √ (3)

[11]

QUESTION 3

3.1 Electrical energy √ is converted to chemical energy. √ (2)

3.2 negative √ (1)

3.3 $Aℓ^{3+} + 3e^- \rightarrow Aℓ$ √ √ (2)

3.4 Carbon will burn in/react with O_2 because of the high temperature to form CO_2 √ √
OR
C(s) + O2(g) → CO2(g)
OR
The carbon is oxidised according to the following half-reaction:
$C(s) + 2O_2\text{-}(g) \rightarrow CO_2(g) + 4\ e^-$ (2)

3.5 Carbon burns away/used up/oxidised / loses e- (and needs to be replenished) √ √ (2)

3.6 **Any two:** √ √
Ecological Impact
- Loss of landscape due to the size of the chemical plant needed
- Disposal of red mud (iron(III) oxide formed during extraction of aluminium oxide from bauxite) into lagoons causing them to become unsightly

Environmental Impact
- Carbon dioxide from the burning of the anodes contributes to the (enhanced) greenhouse effect (air pollution /global warming)
- Carbon monoxide is poisonous
- fluorine (and fluorine compounds) lost from the cryolite during the electrolysis process is poisonous
- Alkali of red mud dams can drain into soil and contaminate groundwater
- Pollution caused by power generation (for electrolytic process) using coal-fired plants leads to acid rain/enhanced (greenhouse effect)
- Noise pollution (2)

[11]

QUESTION 4

4.1. D √√

4.2. A √√

4.3. B √√

4.4. A √√

4.5. C √√

4.6. C √√

4.7. A √√

4.8. C √√

(2 x 8) **[16]**

SESSION 18

TOPIC 1: ELECTROSTATICS - GRADE 11 REVISION

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 10 minutes

(Taken from the DoE Physical Sciences Feb-March Paper 1 2010)

Capacitors are circuit devices used to store electrical energy. The capacitance of capacitors depends, amongst other factors, on the plate area. The larger the plate area, the more the energy that can be stored.

1.1 Apart from plate area, state TWO other factors that can influence the capacitance of a capacitor. (2)

1.2 A certain parallel plate capacitor consists of two plates, each having dimensions of 2cm by 10cm. The plates are 0,2mm apart and are held at a potential difference of 20V. The space between the plates is filled with air.

1.2.1 Sketch the electric field pattern between the two oppositely charged parallel plates of the capacitor. (3)

1.2.2 Calculate the capacitance of this capacitor. (5)

[10]

QUESTION 2: 30 minutes

(Taken from the GDE Preliminary Examination September 2009 Paper 1)

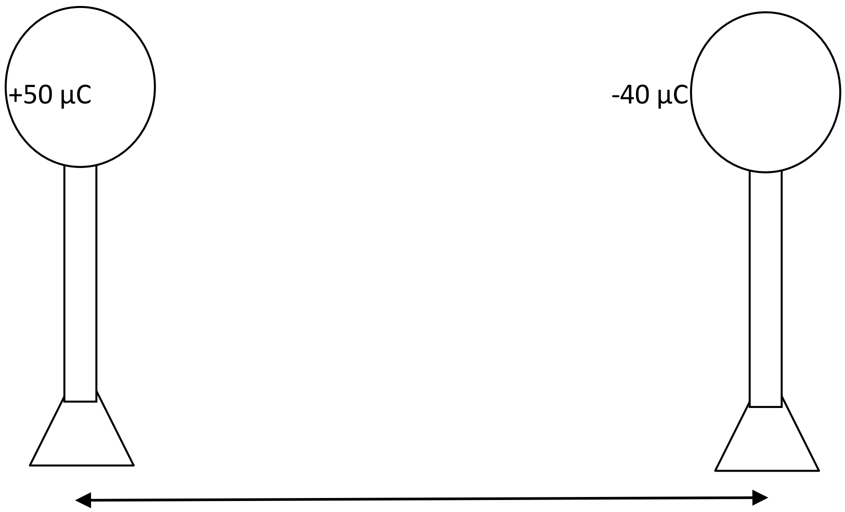
2.1 Capacitors are widely used in common household electrical appliances like television screens, computers, alarm systems etc.

2.1.1 What is the <u>function</u> of a capacitor in an electrical appliance. (2)

2.1.2 A specific capacitor stores a maximum of 30 nC of charge at a potential difference of 12 V across the ends. Calculate the capacitance of this capacitor. (3)

2.1.3 During an electrical thunderstorm the potential difference between the earth and the bottom of the clouds can be 35 000 kV. If the surface area of the clouds is 1 x 10^8 m^2 at a height of 1 200 m above the surface of the earth, calculate the capacitance of this gigantic “earth-cloud” capacitor. Take the permittivity of air to be the same as the permittivity of a vacuum. (4)

2.2 Two point charges with magnitudes of +50 μC and -40 μC respectively, are placed at a distance of 450 mm from each other on isolated stands as shown in the diagram below. The charges are allowed to touch each other and are then placed back at their original positions.



2.2.1 Calculate the magnitude and nature of each of the charges after they have touched each other, and have been moved back to their original positions. (2)

2.2.2 Draw a sketch of the electric field pattern which results after the two charges have touched each other. (4)

2.2.3 Determine the magnitude and direction of the force which the charges exert on each other after touching each other. (4)

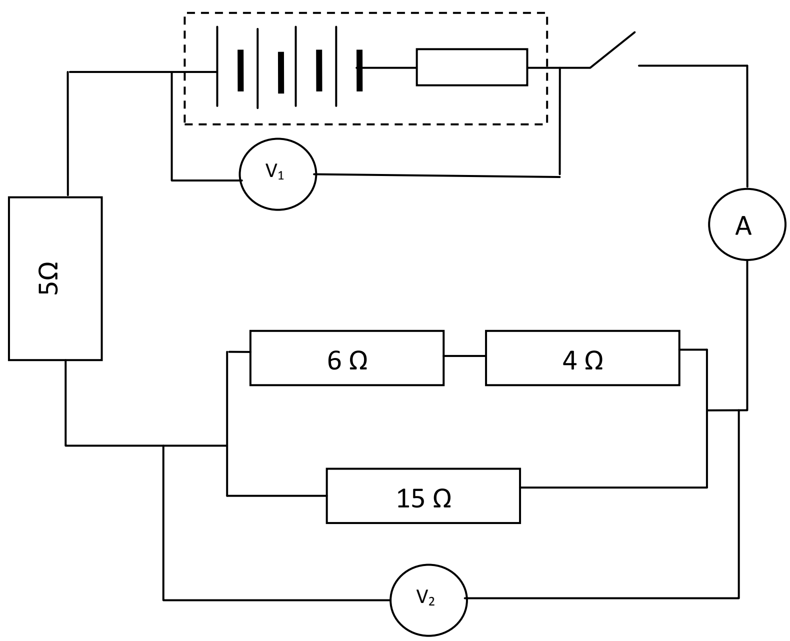
2.2.4 The original force which existed between the two charges before touching each other was 80 times greater than the final force between the two charges after touching. Explain why? (3)

[22]

TOPIC 2: ELECTRICITY - GRADE 11 REVISION

QUESTION 3: 25 minutes
(Taken from the GDE Preliminary Examination September 2009 Paper 1)

3.1 The circuit on the following page shows a battery consisting of four 1.5 V cells connected in series. An ammeter with negligible resistance is connected in series to the battery. The reading on the ammeter is 0.5 A when the switch is closed. The connectors have negligible resistance and the voltmeters have very high resistance. Voltmeter V_1 has a reading of 5.5 V when the switch is closed.



3.1.1 Calculate the value of the internal resistance of a single cell. (4)

3.1.2 Calculate the value of the resistance of the external circuit. (4)

3.1.3 Calculate the value of the reading on voltmeter V_2 (4)

3.2

3.2.1 A small submersible element takes a certain time to boil a single cup of water. If a similar element of lower resistance, plugged into the same plug, is also used to boil a single cup of water, it takes a shorter time. Explain, using electricity concepts (current, voltage, work done, heat and power), why the water boils faster when the resistance of the element is decreased. (3)

3.2.2 Two learners, namely Bongani and David, want to design an investigation to prove the assumption made in 3.2.1.

3.2.2.1 Design a method that they will be able to use. List the most important steps – at least five steps – that they need to carry out in order to end up with reliable results. Ensure that you mention in your steps at least one safety precaution that Bongani and David have to take. (3)

3.2.2.2 List the controlled variables, the dependant variable and independent variable that Bongani and David have to consider to ensure that the results to their investigation is valid. (2)

[20]

SECTION B: ADDITIONAL CONTENT NOTES

TOPIC 1: ELECTROSTATICS

Recall

There are two types of charges:

- Positive – when a substance has lost electrons.
- Negative – when a substance has gained electrons.

Electric Fields

- **an electric field** is a region in space in which an electric charge will experience a force represented by a pattern of field lines.
- An electric field line is a line drawn in such a way that at any point on the line a small positive point charge placed at that point will experience a force in the direction of the tangent of the line.

Conservation of charge

- The **Law of Conservation of Charge** states that charges cannot be created nor destroyed, but are merely transferred from one object to another, i.e. the amount of charges in a closed system remains the same.
- According to the law, when two charged spheres of the same size are brought into contact, electrons move from the more negative sphere to the less negative sphere till the charge is spread evenly over both spheres. On separation, each sphere carries half the total charge of the two spheres.

Coulomb's Law of Electrostatics

The law states that the force of attraction or repulsion between the two electric charges at rest is directly proportional to the product of the charges, and inversely proportional to the square of the distance between them.

$$F = \frac{KQ_1Q_2}{r^2}$$

Q = charge, unit: coulomb **(C)** r = distance between the charges, measured in **m**

k = Coulomb's constant = 9×10^9 $N{\cdot}m^2{\cdot}C^{-2}$

Electric Field Strength Introduction

- The measure of the force (attraction or repulsion) exerted on a charge placed at a point in the field.
- By definition:
  Electric Field strength is the force per unit charge which a positive charge will experience at that point i.e. force experienced by 1C of charge in an electric field.

Formula: $\text{Electric Field Strength (E)} = \dfrac{\text{Force (F)}}{\text{Charge (q)}}$

In symbols: $\mathbf{E = \dfrac{F}{q}}$

Units: Force – Newton (N), charge – coulomb (C), Field Strength – N/C

- Electric field strength is a vector.
- Therefore, the magnitude of the force exerted on a known charge in an electric field strength:
  F = QE

Electric Field Strength around a charged sphere

- Consider a small test charge ***q*** placed at distance ***r*** from the charge ***Q***.
- According to Coulomb's Law, the force ***F*** exerted on ***q*** is given by

$$F = \frac{kQq}{r^2}$$

- If the electric field strength due to ***Q***, at the point where ***q*** has been placed, is ***E***. the force ***F*** exerted on q by the field is

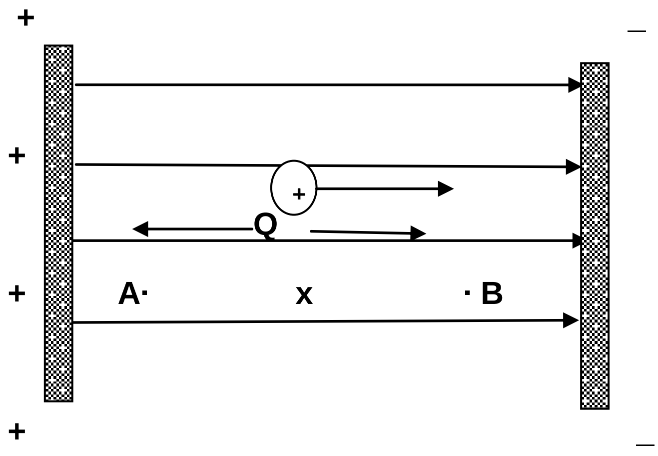
$$F = QE$$

- Combining the two equations: $\dfrac{k\cancel{Q}q}{r^2} = \cancel{Q}E$

- Therefore, $\mathbf{E = \dfrac{kQ}{r^2}}$

Work done in moving a charge in an electric field

Consider the following diagram



The point charge Q experiences a force F in the direction of the field E, and if Q is free to move, it will accelerate in the direction of the field.

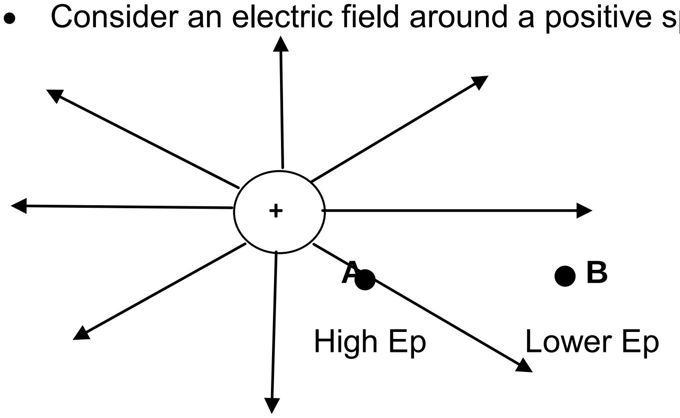
Field exerts a force on Q, causes it to move therefore work is done on Q.

W = F · x and **F = QE**

Therefore, **W = QEs**

Electrical Potential Difference

- A charge placed at any point in an electric field possesses potential energy.
- When it moves, it accelerates, so its potential is converted to kinetic energy.
- Consider an electric field around a positive sphere



- If a positive charge ***Q*** is placed at point A, it experiences a force of repulsion and moves to the right, gaining kinetic energy as it moves.

- At A the test charge has potential.
- Same charge placed at point B, has the same behaviour.
- To move the charge from B to A requires an external force, i.e. work must be done by an outside force.

- This implies that ***Q*** has more potential energy at point a than at point B.
- Therefore A has a higher electrical potential energy than B and a difference in potential energy exists between these two points.
- *The **potential energy** in an electric field is defined as the work it takes to move a unit positive charge from the point at lower potential to the point at higher potential.*

$$\mathbf{V = \frac{W}{Q}}$$

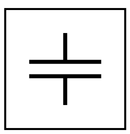
Units: V – volts (v), W – joule (J)

Electric Field Strength Between two charged parallel plates

- The electric field strength between 2 oppositely charged parallel plates is uniform, i.e. a charge placed anywhere between these plates will have a constant force acting on it.
- The potential difference between the plates is given by : **V = W/Q**
- Work done by the field is therefore: **W = QV**
- Work is also : **W = QEx**
- Therefore, $\boldsymbol{\cancel{Q}Ex = \cancel{Q}V}$
- The electric field strength **E = V/d** where d is the distance between the plates in **m.**

Capacitors

- A ***capacitor is a device that can store energy***. Like a cell, it has two terminals. Inside a capacitor the terminals connect to two metal plates that are separated by an insulating material called a ***dielectric***. The dielectric can be anything that does not conduct electricity readily and it keeps the plates from touching each other.
- The bigger the area of the plates, the more charge the capacitor can store.
- Symbol:



- When a capacitor is connected to a battery, the plate connected to the negative terminal of the battery accepts electrons from the cell and becomes negatively charged.
- The plate connected to the positive terminal loses electrons to the battery and becomes positively charged.
- Once fully charged, the capacitor has the same potential difference as the battery. The area of the metal plates determines how much charge the capacitor can hold, but the voltage depends on the voltage of the power supply that it is connected to.
- As the voltage decreases, the current and hence the rate of discharge, decreases.
- Four factors affect the ability of the capacitor to store electrical charge. These are
  - The potential difference between the plates
  - The area of the plates
  - The distance between the plates and
  - The insulating substance between the parallel plates.

Capacitance

- Capacitance is a measure of the ability of a capacitor to store charge.
- The capacitance (C) of a capacitor is the charge stored on its plates per volt of potential difference between the plates.
  C = Q/V
- The units for capacitance is coulomb per volt (C/V) called a **farad** (F).
- The farad is a very large unit. Typical capacitor are in
  - Microfarads, μF = 10^{-6}F
  - Nanofarads, nF = 10^{-9}F
  - Picofarads, pF = 10^{-12}F

Electrical Discharges: Spark plugs and Lightning

- Lightning flashed and spark plugs produce sparks of a very different size with very different voltages needed. Although they are different in nature, they all require air to be ionised.
- In a thunderstorm, charges build up in clouds due to different movements of air, raindrops and ice.
- When the potential difference between a collection of positive charges and one of negative charges becomes big enough, a lightning flash occurs. This can be between two clouds or between a cloud and the ground.
- A spark or a lightning flash (a very big spark) occurs when the force in the field or some other factor causes electrons to be released and ions formed.
- These then collide with other atoms, producing more positive ions and electrons. In a complex way, these form a conducting path, allowing the spark to happen.
- When lightning strikes in a particular place, the following also happens:
    - The lightning may cause a surge if current along good conducting paths nearby, such as cabling and wire fences. For example, if you are using a landline phone, this surge may cause problems.
    - It may also flash over and strike something nearby in addition to the main strike. For example, if you standing close to a tree and the lightning strikes the tree, you may get struck by the lightning as well.

Precautions

- ➢ Try to be indoors when a thunderstorm is approaching.
- ➢ Stay inside a car. It is safe because the metal of the car will mean that the charge can only go on the outside without affecting those inside the car.
- ➢ Stay away from a tree or tall objects that are out in the open.
- ➢ Use a lightning conductor on your home because it provides an easy passage for the lightning to follow.
- ➢ Avoid getting wet during a thunderstorm as any contact with water would make it easier to be struck by lightning.

TOPIC 2: ELECTRIC CIRCUITS

Resistance and Ohm's Law

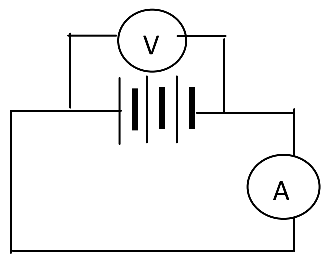
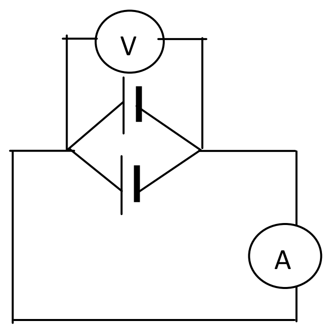
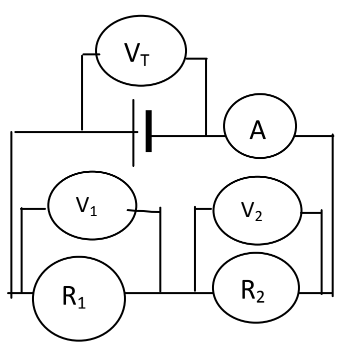
- Ohm's Law states that ***the current between any two points in a conductor is directly proportional to the potential difference between these points provided that the temperature of the conductor remains constant.***

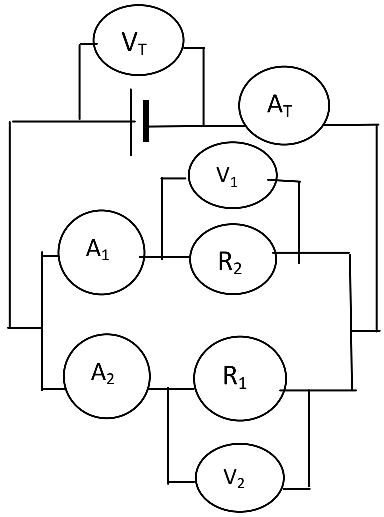
Equation: $\mathbf{R = \frac{V}{I}}$

Units : current – amperes (A), voltage – volts (V) and resistance – ohms (Ω)

- The resistance of the conductor depends on
  - The type of material used
  - The length of the conductor – the longer the conductor, the greater the resistance
  - The thickness of the conductor – the thicker the conductor, the smaller the resistance
  - The temperature of the conductor – the higher the temperature, the greater the resistance

Series and Parallel Connections

Components	Connection	Diagram	Effect on Current (A)	Effect on Potential Difference (V)
Cells	Series		Increases	Increases
Cells	Parallel		Remains the same	Remains the same
Resistors	Series $R_T = R_1 + R_2$		The current in a given series circuit is the same throughout the circuit. The more resistors in series, the greater the resistance, the current decreases.	Resistors in series are potential dividers i.e. $V_T = V_1 + V_2$

Resistors	Parallel $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$		Resistors in parallel in a given circuit split the current $A_T = A_1 + A_2$ (the more resistors in parallel, the greater the total current because the total resistance decreases)	Resistors in parallel have the same potential (in the absence of another resistor in series) $V_T = V_1 = V_2$

EMF and internal resistance

- The ***emf*** of a cell is the maximum amount of energy which the cell can supply.
- When the cell is delivering current, the terminal potential difference is less than the emf, the difference is called '**lost volts'** or internal volts .
- The passage of charge through the cell and the ***internal resistance*** of the cell, account for this loss of energy in the form of heat in the cell.
  Thus emf = terminal potential difference + "lost volts"

Emf = IR + Ir

OR **Emf = I(R + r)**

Therefore, $\mathbf{I = \frac{emf}{R + r}}$

Energy in an electric circuit

Electrical energy.

Potential difference in an electric field

- **Potential difference** = $\frac{\text{work done to move a charge}}{\text{Magnitude of the charge moved.}}$

  i.e. ***V = W / Q,*** therefore, ***W = Q V***

- **Quantity of charge** : formula for the quantity of charge is
  Q = I t Q = I Δ***t***

- **Work done by an electric field: *W = Q V***
  But ***Q = It*** , ***Q = I*** Δ***t*** therefore, ***W = V I t W = V I*** Δ***t***

- **Power:** the rate at which work is done
  Power = $\frac{\textit{work}}{\textit{Time}}$

  Units: watt (W)

  If ***P = W /*** Δ***t*** and ***W = V I*** Δ***t***

  $$P = \frac{V\ I\ \Delta t}{\Delta t}$$

  Therefore, ***P = V I***

Ohm's Law and Energy

The formula ***P = VI*** gives the power at which electric energy is 'used' by a device or at which it is supplied by a source.

In summary:

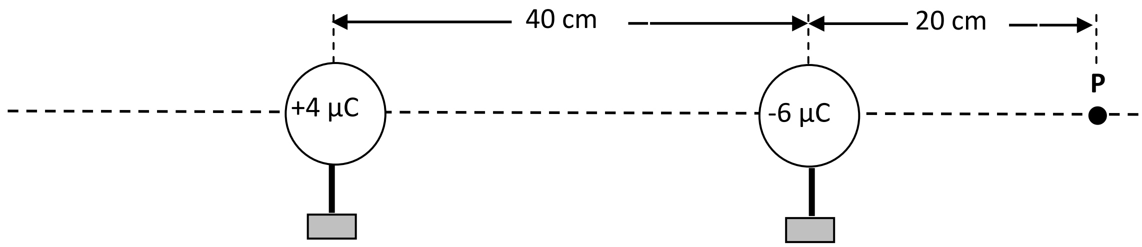
Total amount of work	Power
W = V I t	**P = VI**
But V = I R (Ohm's Law)	
W = I^2R t	**P = I^2R**
1.1 Or if I = V/R	
W = V^2 t / R	**P = V^2 / R**

SECTION C: HOMEWORK

TOPIC 1

QUESTION 1: 15 minutes
(Taken from the DoE Physical Sciences November Paper 1 2009)

Two metal spheres on insulated stands carry charges of +4 μC and -6 μC respectively. The spheres are arranged with their centres 40 cm apart, as shown below.



1.1 Calculate the magnitude of the force exerted by each sphere on the other. (4)

1.2 By what factor will the magnitude of the force in QUESTION 10.1 change if the distance between the spheres is halved? (Do not calculate the new value of the force.) (1)

1.3 Calculate the net electric field at point P as shown in the diagram above. (6)

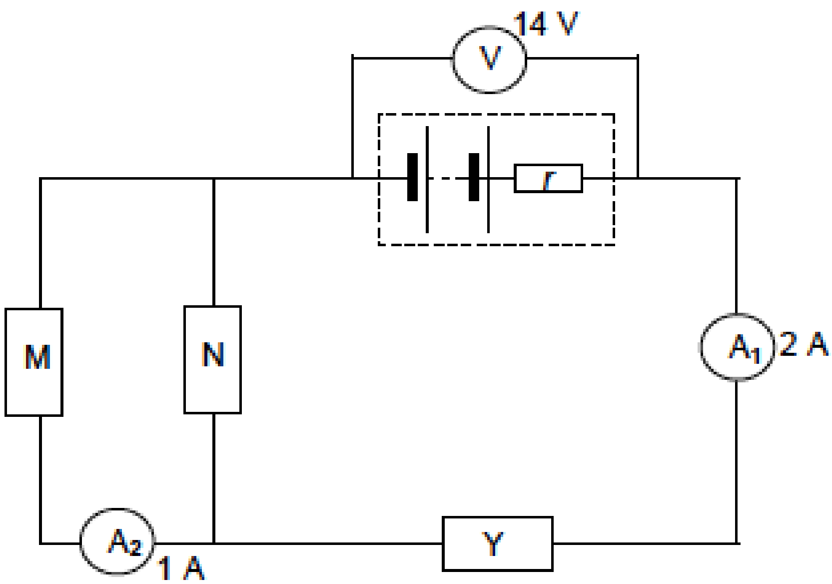
1.4 The spheres are now brought into contact with each other and then returned to their original positions. Now calculate the potential energy of the system of two charges. (5)
[16]

TOPIC 2

QUESTION 2: 15 minutes

(Taken from the DoE Physical Sciences Feb – March Paper 1 2010)

The circuit diagram below shows a battery with an internal resistance *r,* connected to three resistors, M, N na Y. The resistance of N is 2Ω and the reading on voltmeter V is 14V. The reading on ammeter A_1 is 2A, and the reading on ammeter A_2 is 1A. (The resistance of the ammeters and the connecting wires may be ignored.)



2.1 State Ohm's law in words. (2)

2.2 How does the resistance of M compare with that of N? Explain how you arrived at the answer. (2)

2.3 If the emf of the battery is 17V, calculate the internal resistance of the battery. (5)

2.4 Calculate the potential difference across resistor N. (3)

2.5 Calculate the resistance of Y. (4)

[16]

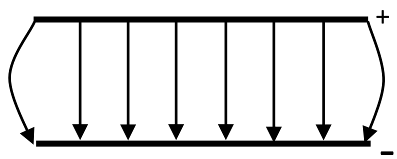
SECTION D: SOLUTIONS AND HINTS TO SECTION A

TOPIC 1

QUESTION 1

1.1 Dielectric ✓
Distance between plates ✓ (2)

1.2.1



Checklist	Mark
Evenly spaced field lines.	✓
Direction of field lines from positive to negative.	✓
Field lines curved at the ends.	✓

(3)

1.2.2

$$C = \frac{\varepsilon_0 A}{d} \checkmark = \frac{(8{,}85\times10^{-12})\overset{\checkmark}{}(2\times10^{-2})(10\times10^{-2})\overset{\checkmark}{}}{0{,}2\times10^{-3}\ \checkmark}$$

$= 8{,}85 \times 10^{-11}$ F ✓ (5)

[10]

QUESTION 2

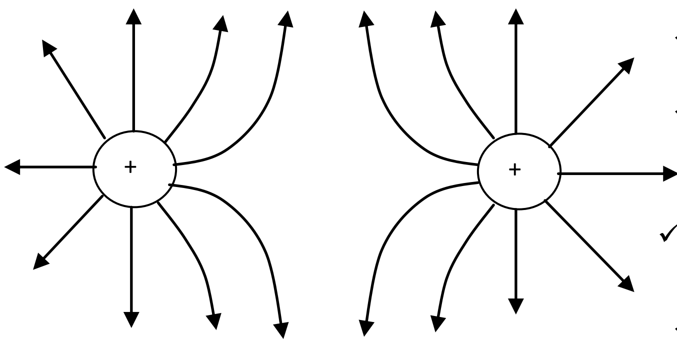
2.1.1 It stores electrical charge **OR** electric potential energy ✓✓ (2)

2.1.2 $C = \overset{\checkmark}{\frac{Q}{V}} = \frac{30\times10^{-9}}{12} \overset{\checkmark}{=} 2.5\times10^{-9}\,F(=2.5nF)\checkmark$ (3)

2.1.3 $C = \frac{\varepsilon_0 A}{d}\checkmark = \frac{(8.85\times10^{-12})\checkmark(1\times10^{8})}{1200\ \checkmark} = 1.06F$ ✓ (4)

2.2.1 New charge = $\frac{(+50\mu C)+(-40\mu C)}{2} = +5\mu C$ ✓✓ (2)

2.2.2



✓direction of lines

✓shape of lines on outside

✓ shape of lines on inside

✓symmetry of lines

(4)

2.2.3 $F = \frac{kQ^2}{r^2} = \frac{(9\times10^9)(5\times10^{-6})^2}{(0.45)^2} = 1.11\,N$ ✓ ✓ ✓ repulsion ✓ (4)

2.2.4 Charges of +50 μC and -40 μC became smaller by factors of 10 and 8 respectively. As F α Q_1Q_2 ✓, it means that the ✓original force was 10 x 8 = 80 larger than the final force. ✓ (3)

[22]

TOPIC 2

QUESTION 3

3.1.1

$$r_{battery} = \frac{V_{usedinbattery}}{I_{total}} = \frac{0.5}{0.5} = 1\Omega$$ ✓ ✓ thus each cell = 1Ω/4 = 0.25Ω ✓ ✓ (4)

3.1.2 $\frac{1}{R_p} = \frac{1}{6+4} + \frac{1}{15} = \frac{1}{6}$ ✓ so R_p = 6Ω ✓ and

$R_{external} = r_1 + r_2 = 5 + 6 = 11\ \Omega$ ✓ ✓

OR

$$R_{external} = \frac{V_{external}}{I_{total}} = \frac{5.5}{0.5} = 11\Omega$$ ✓ ✓ ✓ ✓ (4)

3.1.3

$V_{5\Omega} \overset{\checkmark}{=} IR = 0.\overset{\checkmark}{5}(5) = 2.5V$ thus

$V_2 = 5.5 - \overset{\checkmark}{2.5} = 3$ V ✓

OR

$V_2 = I_{total} \overset{\checkmark}{R_p} = 0.\overset{\checkmark}{5}(6) \overset{\checkmark}{=} 3V$ ✓ (4)

3.2.1 $W = \dfrac{V^2 t}{R}$ The same potential difference is applied so that V stays constant. The same amount of water is boiled so the energy W stays the same. This means that R α t. It means that if the resistance decreases ✓ then the time to boil the water decreases and the water boils faster. ✓

OR

$P = \dfrac{V^2}{R}$ The same potential difference ✓ is applied so that V stays constant. This means that P α !/R. ✓ If R decreases then P increases and the time taken to boil the water is less. ✓ (3)

3.2.2.1

- Measure identical amounts of water, and place in identical containers at identical temperatures.
- Place the first submersible element into one of the containers, taking care that there are no open wires in contact with water
- Start the current and the stopwatch at the same time
- Note the time it takes to boil the water.
- Make sure that you handle the hot container with suitable tongs or gloves.
- Place the second element into the second container of water
- Start the current and the stopwatch at the same time
- Note the time it takes to boil the water.
- Compare the times

✓	Identical amounts of water, Initial temperature the same
✓	Name one safety measure
✓	Measure the time to boil

(3)

3.2.2.2 Controlled variables:

- Amount of water
- Same initial temperature
- Same voltage eg plug into 220 V
- Same type of container to control the heating area as well as the conduction of heat.
- Water needs to reach boiling point

Independent variable: The type of element

Any two ✓ ✓

Dependant variable: Time it takes to boil the water (2)

[20]

SESSION 19

TOPIC: ELECTRODYNAMICS - MOTORS AND GENERATORS AND ALTERNATING CURRENT

SECTION A: TYPICAL EXAM QUESTIONS

QUESTION 1: 13 minutes

(Taken from the DoE Physical Sciences Preparatory Examination Paper 1 2008)

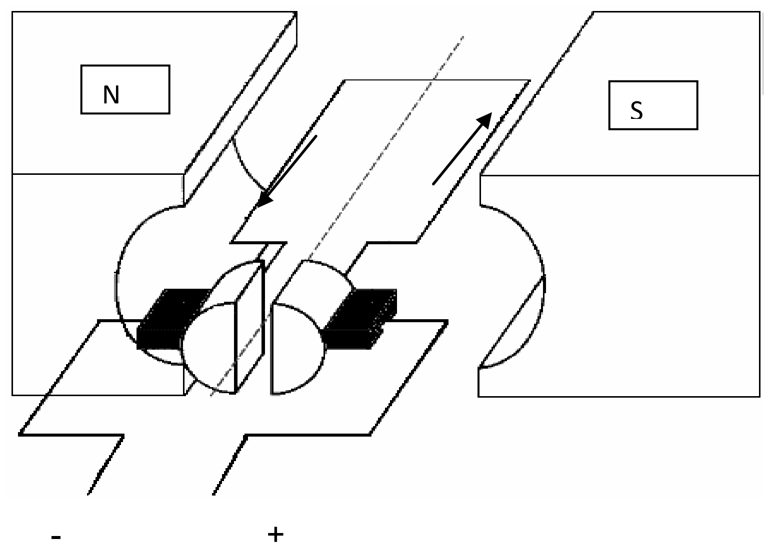
Electric motors are important components of many modern electrical appliances. AC motors are used in washing machines and vacuum cleaners, and DC motors are used in toys and tools.

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)

1.3 List THREE ways in which the efficiency of the motor can be improved. (3)

1.4 Consider the diagram below. The conventional current flows in the direction indicated by the arrows.



● position A

1.4.1 In which direction (clockwise or anti-clockwise), as seen from position A, will the coiled armature rotate if the switch is closed? (1)

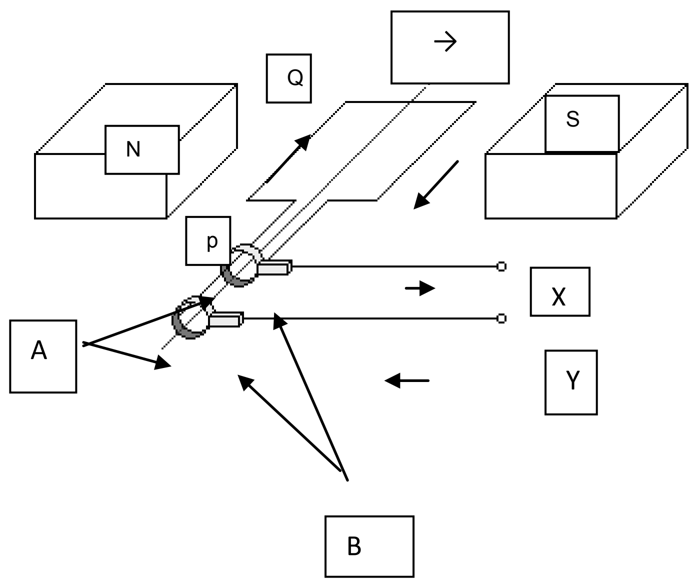
1.4.2 Why does the armature continue moving in the same direction once it has reached the vertical position? (2)

[10]

QUESTION 2: 10 minutes

(Taken from the DoE Physical Sciences Exemplar Paper 1 2008)

The simplified sketch below shows the principle of operation of the alternating current (AC) generator.



2.1 Name the parts labelled A and B respectively. (2)

2.2 In which direction does segment PQ of the coil have to be rotated in order to cause the current direction as shown in the diagram? Write down only clockwise or anticlockwise. (1)

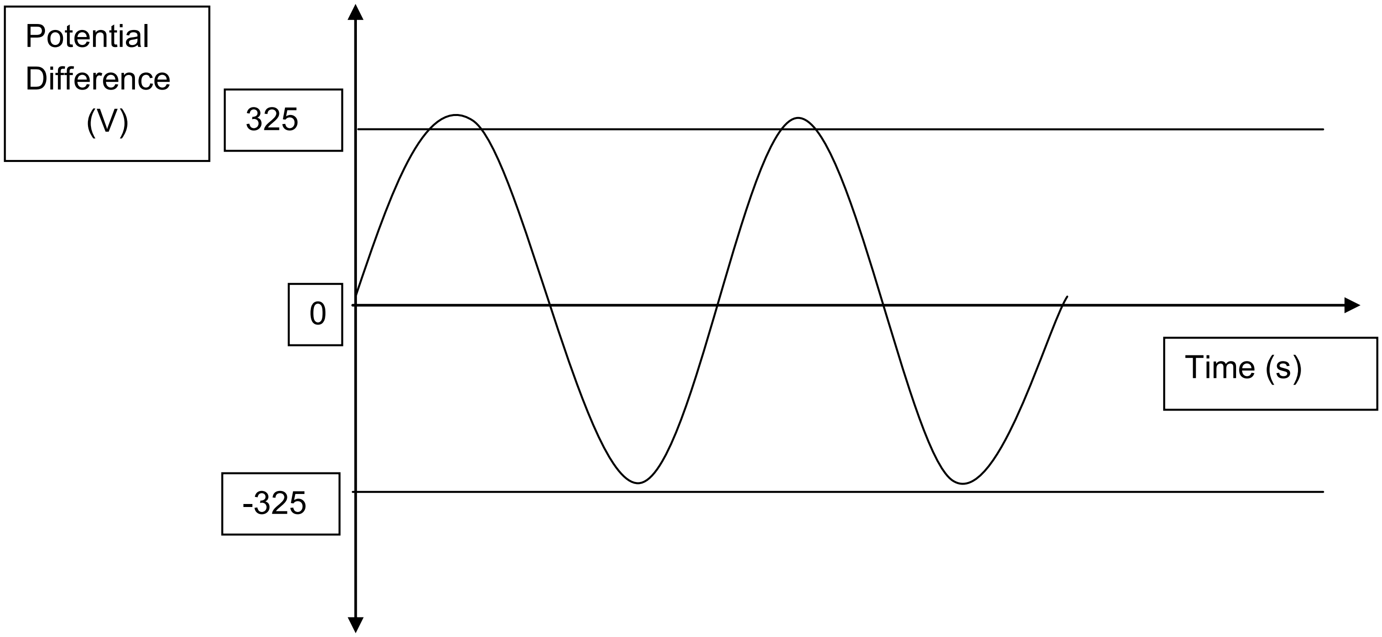
2.3 Write down TWO changes that can be brought about to improve the output of the generator. (2)

2.4 What changes must be made to the AC generator to make it function as a DC motor? (2)
[7]

QUESTION 3: 10 minutes

(Taken from the DoE Physical Sciences Preparatory Examination Paper 1 2008)

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

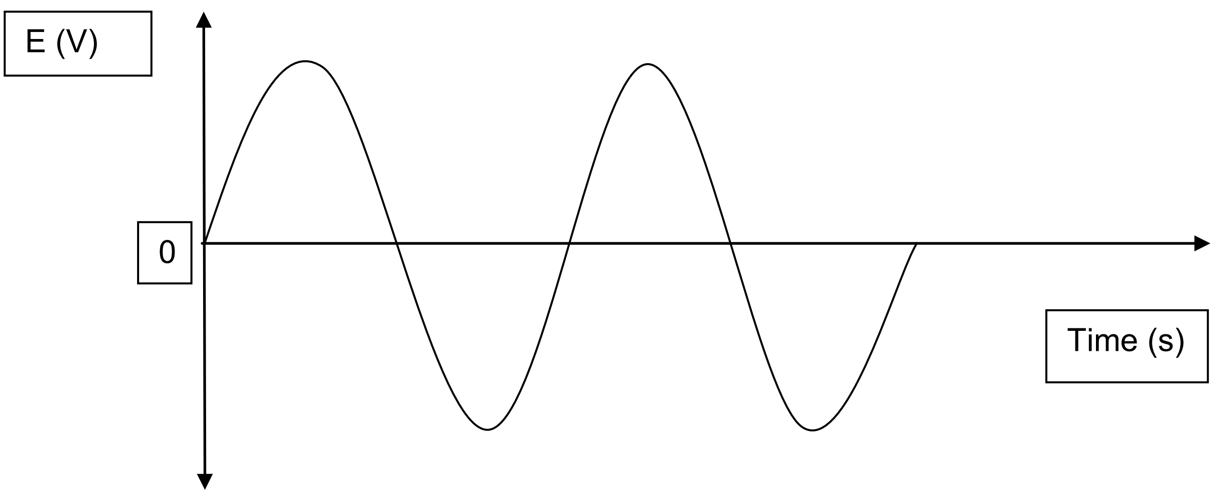


3.1 Explain the advantage of using alternating current at power stations. (2)

3.2 Calculate the average power dissipated by this generator if the rms current produced is 13A. (5)
[7]

QUESTION 4: 7 minutes
(Taken from the DoE Physical Sciences Exemplar Paper 1 2008)

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



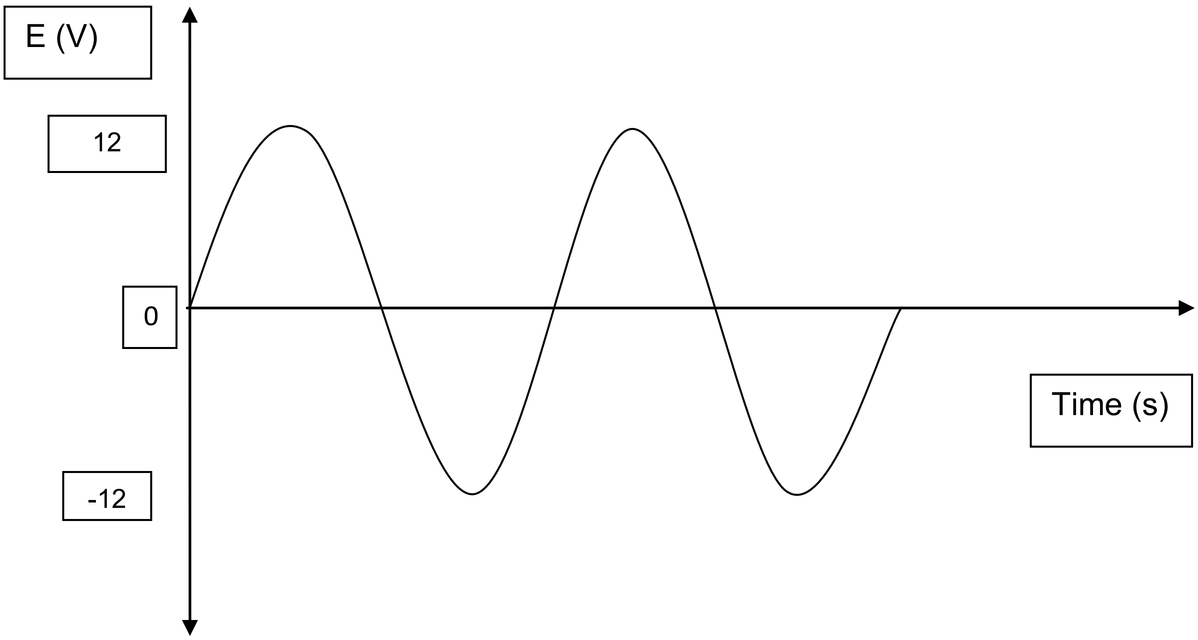
4.1 Sketch a graph to show how the above waveform changes, if at all, after changing this generator into a DC generator. (2)

4.2 State TWO advantages of using AC over DC for the long-distance transmission of electrical power. (2)
[4]

QUESTION 5: 15 minutes

(Taken from the DoE Physical Sciences Additional Exemplar Paper 1 2008)

The average power of a lamp is 15W. This lamp can be used with either an AC supply or a DC supply. The graph below shows the AC potential difference.



5.1 Calculate the potential difference of a DC supply that will produce the same brightness of the lamp. (3)

5.2 Calculate the peak current through the lamp when connected to a 12V AC supply. (4)

5.3 Draw a sketch graph of current through the lamp against time when connected to the AC supply. Indicate the value of the peak current on the graph. (3)

[10]

SECTION B: ADDITIONAL CONTENT NOTES

The Electric Motor

In order to realise the motor effect, the following components are necessary:

A current needs to be flowing in a magnetic field. This combination of force fields causes movement

Electrical energy is converted into kinetic energy.

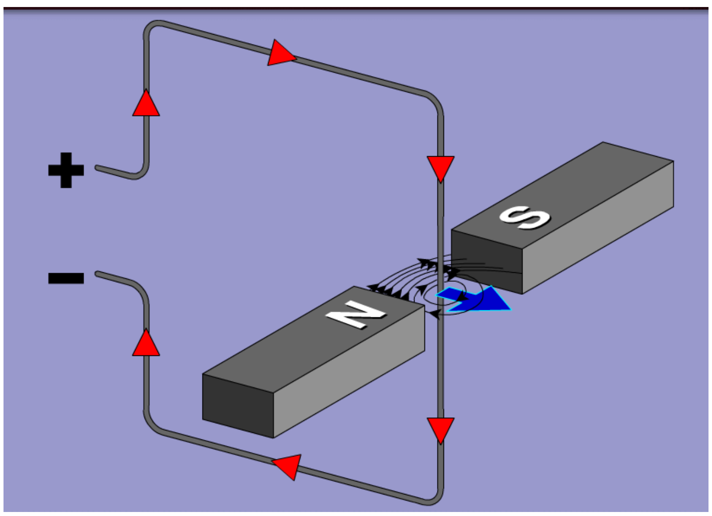


Image taken from Plato Multimedia Science School Simulations 11-16 – Physics – Electric Motor

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.

Electric current supplied through the commutator.

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

The brushes on the commutator allow for the free rotation of the coil.

The left hand rule can be applied to each arm of the rotating coil in order to determine the direction of rotation.

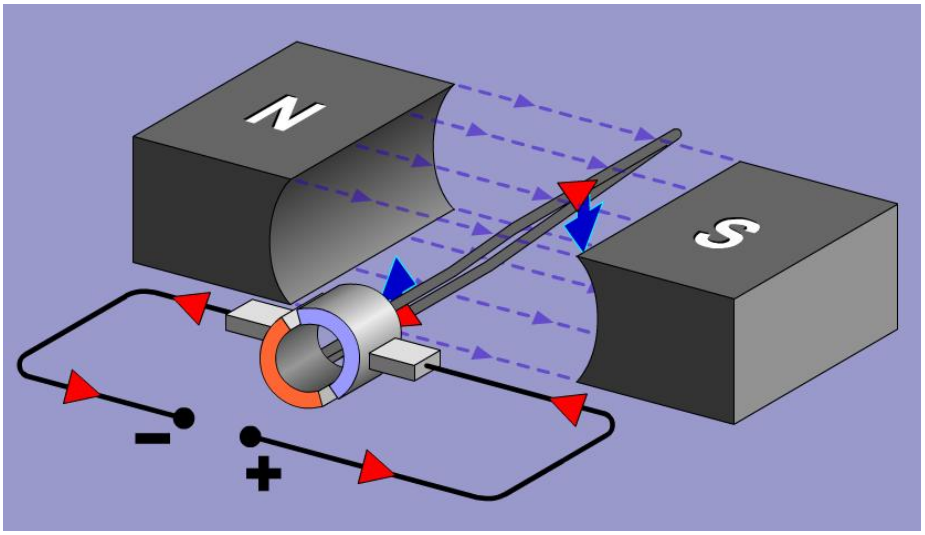


Image taken from Plato Multimedia Science School Simulations 11-16 – Physics – Electric motor

If we want to maximise the force created by the motor effect we can:

- Make the current stronger
- Increase the strength of the magnetic field
- Make sure that the angle between the magnetic field direction and the direction of the current is as close to 90º as possible, since the maximum effect is when the current flows at 90º to the magnetic field lines.

Faraday's Law of Induction

The induced emf in a conductor is directly proportional to the rate of change of the magnetic flux through the conductor.

Lenz's Law

The polarity of the induced emf is such that it produces a current whose magnetic field opposes the change which produces it.

The Dynamo

If a metallic coil is moved in a magnetic field an electric current is induced (created).

An emf is induced across the ends of a coil by a changing magnetic flux, which in turn causes a current to flow.

Kinetic energy is converted into electrical energy

A DC Dynamo with a split ring and brushes

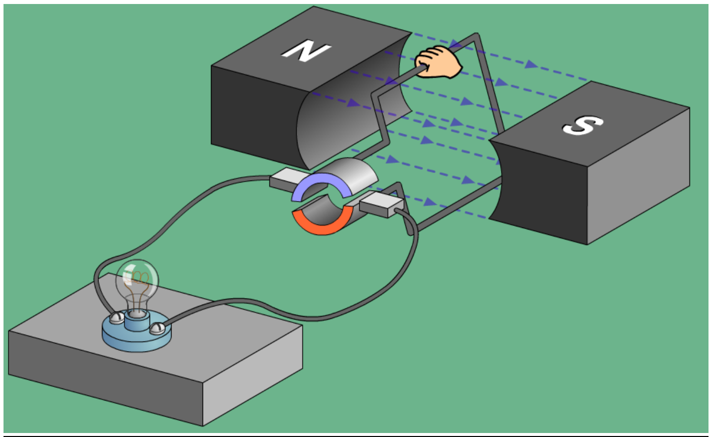


Image taken from Plato Multimedia Science School Simulations 11-16 – Physics – Electric Generator

An AC Dynamo with slip rings

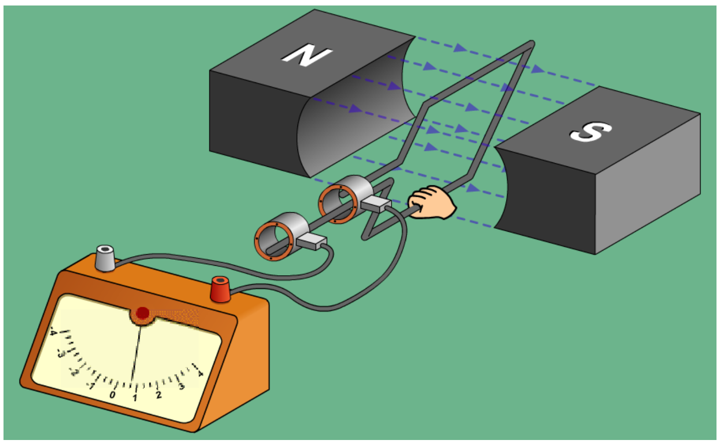
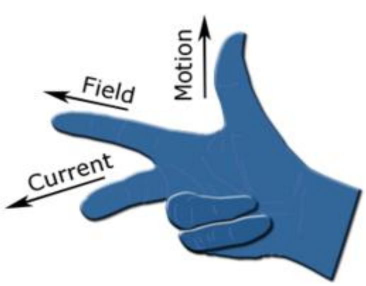


Image taken from Plato Multimedia Science School Simulations 11-16 – Physics – Electric Generator



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

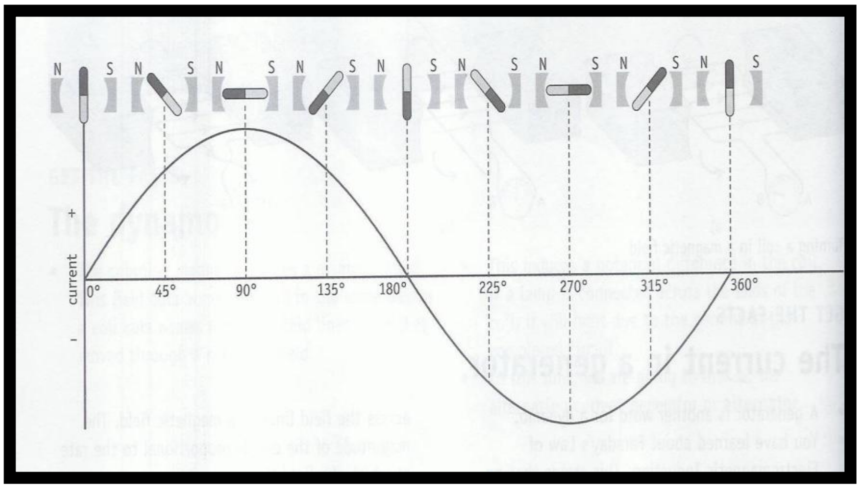
Using the RIGHT HAND:

- 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.

Alternating current

An AC dynamo produces alternating current. Our power stations produce alternating current and the current that we get from the plug points in our homes is AC.

How does the current vary?



The current changes direction every half revolution, and is changing strength continually. This has the advantage of changing the magnetic field in transformers on the national power grid.

Notice the similarity with sine curve.

The frequency of alternating current in South Africa is 50Hz.

The current has a constant potential difference of 220V.

The actual potential difference varies between 0V and 311V. This has the same effect as a constant value of 220V.

$$V_{RMS} = V_{max} / \sqrt{2}$$

The current fluctuates with time, in step with the fluctuating potential difference.

$$I_{RMS} = I_{max} / \sqrt{2}$$

The average power in an AC circuit is calculated by using:

$P_{ave} = V_{RMS} I_{RMS}$

$P_{ave} = I^2_{RMS} R$

$P_{ave} = V^2_{RMS} / R$

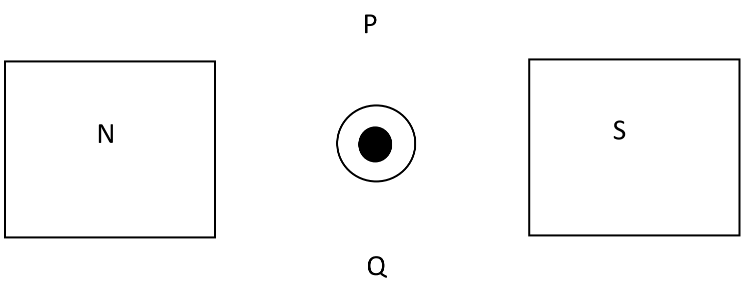
SECTION C: HOMEWORK

QUESTION 1: 7 minutes

1.1 Conventional current flows from:

A. North to South
B. South to North
C. Positive to negative
D. Negative to positive

1.2 Referring to the below aerial sketch of a section of a motor, predict the direction of movement of the conducting wire.

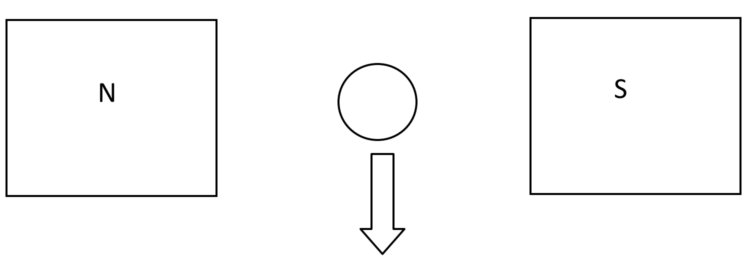


A. Towards P
B. Towards Q
C. Into the page
D. Out of the page

1.3 Which of the following is not a function of the commutator?

A. Supplies electric current
B. Reverses the current each half turn.
C. Stops the current for a split second to allow the coil to rotate.
D. Converts the current into AC

1.4 Referring to the aerial sketch of a section of a dynamo below, predict the direction of conventional current in the conducting wire. The arrow represents the applied force.



A. Towards North
B. Towards South
C. Into the page
D. Out of the page

1.5 Which of the following energy conversion combinations is correct?

	Motor	Dynamo
A	Electrical to kinetic	Electrical to kinetic
B	Kinetic to electrical	Electrical to kinetic
C	Electrical to kinetic	Kinetic to electrical
D	Kinetic to electrical	Kinetic to electrical

(5 x 2) [10]

QUESTION 2: 13 minutes

2.1 What is the advantage of using more than one coil in the rotor of any motor? (2)

2.2 In any motor, what is the function of:

2.2.1 commutators? (1)

2.2.2 brushes? (1)

2.3 Can the speed of a motor be changed without making changes to the motor itself? Explain your answer. (2)

2.4 Explain the basic difference between a motor and a generator. (2)

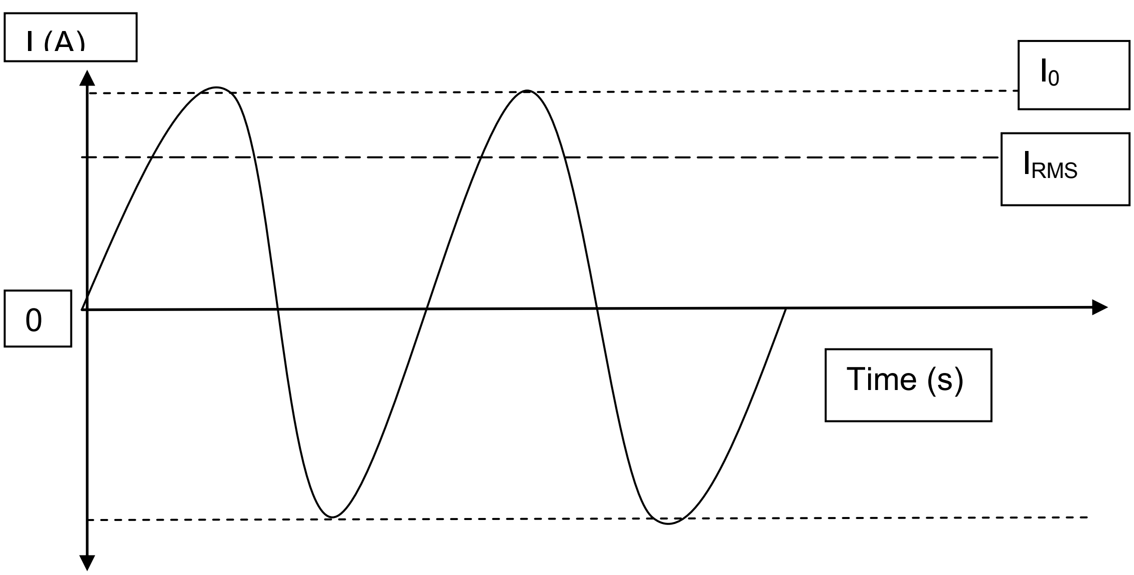
2.5 How does Faraday's Law apply to a generator? (2)

[10]

QUESTION 3: 10 minutes

(Taken from the DoE Physical Sciences Exemplar Paper 1 2008)

The sine wavefront shown below represents the variation of current (I) with time (t) for a generator used by a man to light his home. The current alternates between a maximum and a minimum.



In the diagram, I_0 = the peak current, I_{RMS} = root mean square current, $I_{AVERAGE}$ = average value of the current

3.1 Write down an expression for the instantaneous current in terms of the frequency of the source and the time. (2)

3.2 Write down a formula which represents the relationship between the maximum peak current (I_0) and the root mean square current (I_{RMS}). (2)

3.3 The frequency of the AC generated by ESKOM is 50Hz. A sub-station supplies 240V (RMS) to a house. Calculate the peak voltage at a wall socket. (3)

3.4 Explain why it is of greater value to use RMS current than the average. (2)
[9]

SECTION D: SOLUTIONS AND HINTS TO SECTION A

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)

1.3 Increase the number of turns on each coil/increased number of coils √
Stronger magnets √
Bigger current √ (3)

1.4.1 Clockwise √ (1)

1.4.2 Its own momentum, √ split ring commutator changes direction √ of current, every time the coil reaches the vertical position. (2)
[10]

QUESTION 2

2.1 A = slip rings √
B = brushes √ (2)

2.2 anti-clockwise √ (1)

2.3 Any two:
Increase the number of turns of the coil √
Increase the magnetic field strength (stronger magnets) √
Increase speed of rotation
Use horse-shoe magnet –***(it helps to concentrate the field)*** (2)

2.5 Use split ring commutators instead of slip rings. √
Add a battery to provide electrical energy to drive motor. √ (2)
[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)

3.2. $V_{RMS} = V_{max} / \sqrt{2}$ √

$= 325/\sqrt{2}$ √

$= 0{,}707\ (325) = 230\ V$

$P_{ave} = V_{RMS}\ I_{RMS}$ √

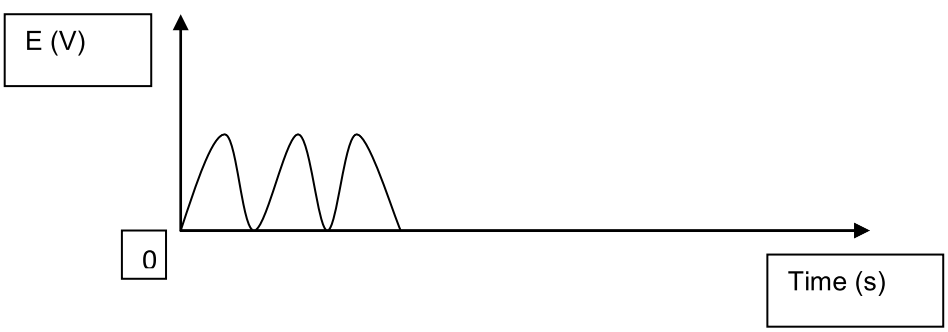
$= 230 \times 13$ √

$= 2990W$ √ (5)

[7]

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]

QUESTION 5

5.1 $V_{RMS} = V_{max} / \sqrt{2}$ √

$= 12/\sqrt{2}$ √

$= 8,49$ V √ (3)

5.2 $P_{ave} = V_{RMS} I_{RMS}$ √

$15 = 8,49 \times I_{RMS}$ √

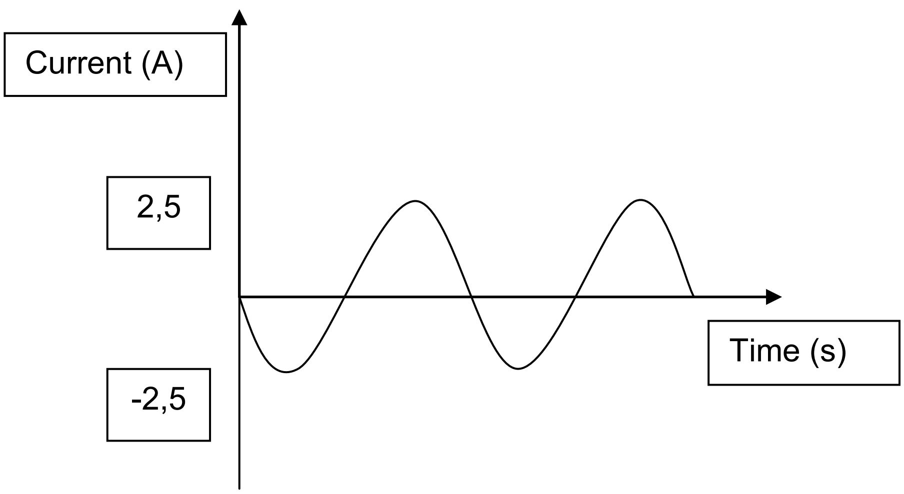
$I_{RMS} = 1,77$ A

$I_{RMS} = I_{max} / \sqrt{2}$

$I_{max} = 1,77\sqrt{2}$ √

$= 2,5$ A √ (4)

5.3



Checklist	Marks
Axes drawn and correctly labelled	√
Shape of graph as indicated	√
Peak current correctly indicated on y-axis	√

(3)
[10]