

Chapter 11

PHYSICAL SCIENCES

The following report should be read in conjunction with the Physical Sciences question papers of the November 2019 Examinations.

11.1 PERFORMANCE TRENDS (2015–2019)

The number of candidates who wrote the Physical Sciences examination in 2019 decreased by 7 841 in comparison to that of 2018. The performance of the candidates in 2018 reflects a slight improvement at the 30% level from 74,2% in 2018 to 75,5% and at the 40% level from 48,7% in 2018 to 51,7%.

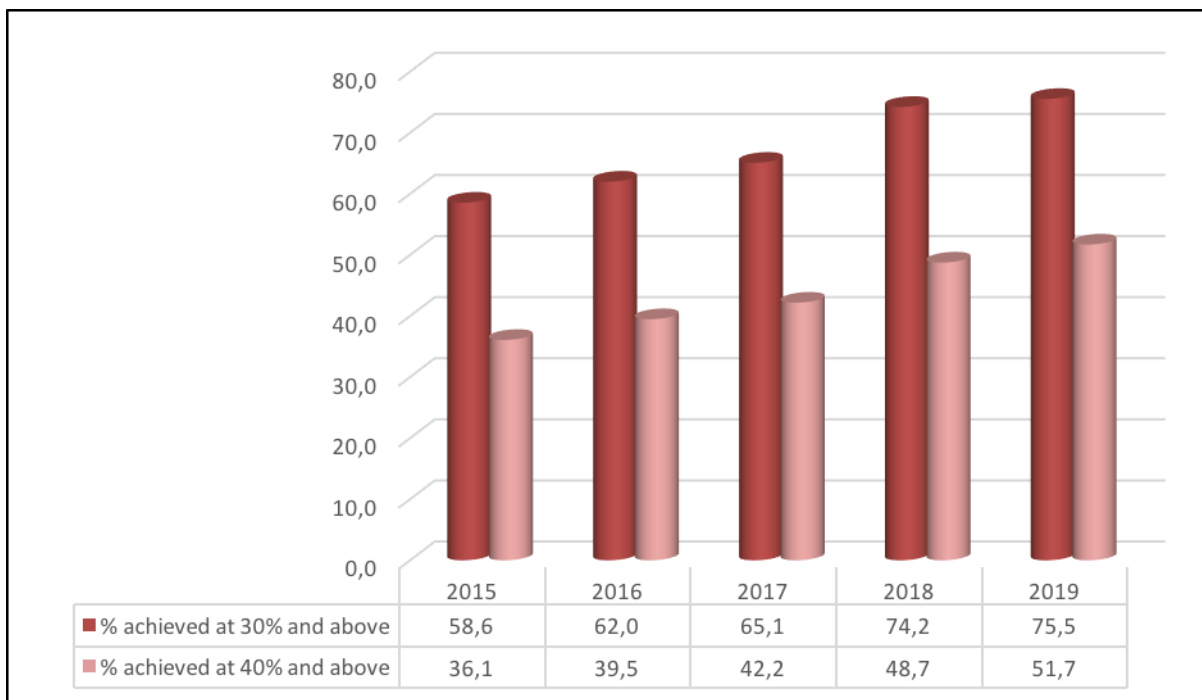
Table 11.1.1 Overall Achievement Rates in Physical Sciences

Year	No. wrote	No. achieved at 30% and above	% achieved at 30% and above	No. achieved at 40% and above	% achieved at 40% and above
2015	193 189	113 121	58,6	69 699	36,1
2016	192 710	119 467	62,0	76 068	39,5
2017	179 561	116 862	65,1	75 736	42,2
2018	172 319	127 919	74,2	84 002	48,7
2019	164 478	124 237	75,5	85 034	51,7

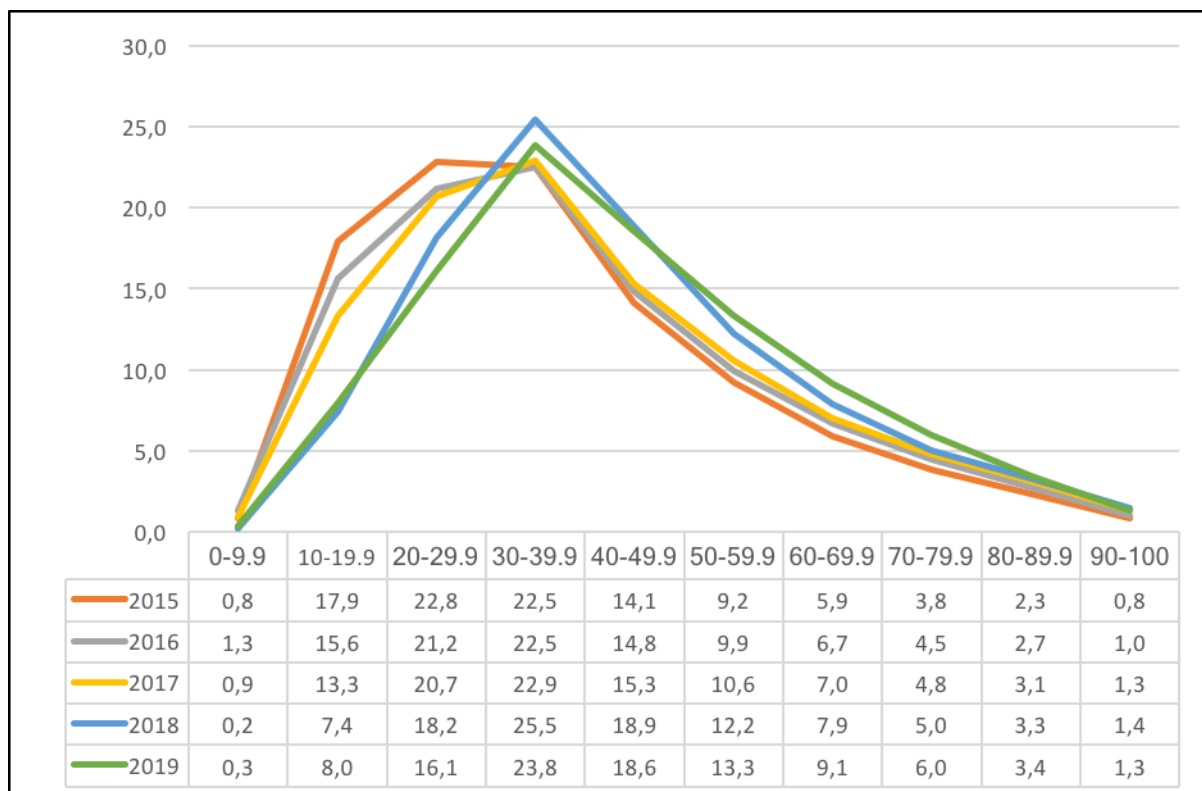
The slight improvement in performance of candidates in 2019 can be attributed to the stability in the curriculum and both teachers and candidates becoming familiar with the assessment style of the subject.

However, there is still room for improvement in the performance of the candidates if the challenges surrounding problem-solving skills, mathematical skills, conceptual understanding and integration of topics are addressed. In this regard, integrated problem-solving must become an integral part of teaching and learning.

Graph 11.1.1 Overall Achievement Rates in Physical Sciences (Percentage)



Graph 11.1.2 Performance Distribution Curves in Physical Sciences (Percentage)



11.2 OVERVIEW OF LEARNER PERFORMANCE IN PAPER 1

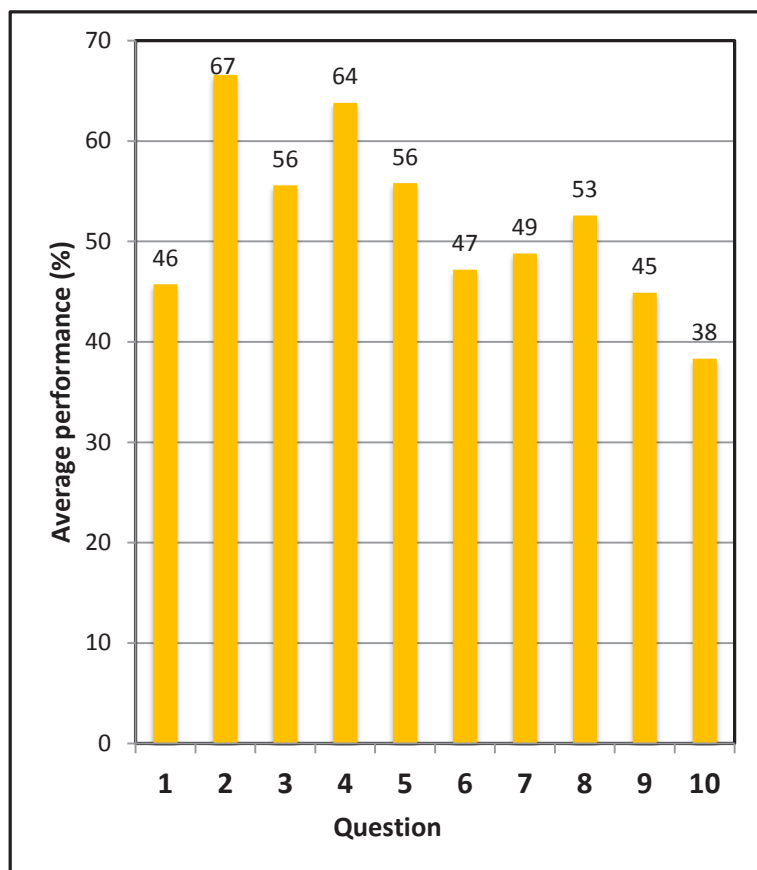
General Comments

- (a) The questions on Newton's Laws of Motion, Momentum, Work, Energy and Power Electrostatics and Electric Circuits (Q2, Q4, Q5, Q7 and Q8) were generally answered well.
- (b) Grade 10 work and Grade 11 work were poorly understood. This work should be integrated with the work done in Grade 12, especially in classwork, homework and tests.
- (c) Questions pertaining to pure recall of content were very poorly answered because keywords and phrases were omitted from definitions. Short informal assessment tasks relating to these issues will greatly assist in improving these shortcomings. This can be used to good effect in content relating to definitions and laws listed in the CAPS and the Examination Guidelines.
- (d) Learners are still struggling with drawing and labelling free-body diagrams correctly. The drawing of free-body diagrams is central to solving problems involving forces acting on objects. Teachers should therefore ensure that learners are able to draw free-body diagrams for such problems in classwork, homework and tests.
- (e) Interpretation of graphs is a challenge for many learners. Problem-solving exercises that involve graphs should be done in a variety of topics. Identification of the variables in relation to the equation describing the graph should be stressed. The scale of graphs, gradient, ordered pairs and x- and y-intercepts need to be emphasised within problem-solving in science contexts.
- (f) Some learners still cannot work correctly with scientific formulae. Teachers should emphasise the use of the relevant formula provided on the formula sheet, correct substitution and providing the answer with the correct unit and direction if required.
- (g) The application of mathematical principles is still a challenge for many learners. Learners should be given a variety of problem-solving activities that involve mathematical knowledge pertaining to simultaneous equations, quadratic equations, binomials, factorisation, trigonometry and graphs in classwork, homework, tests and examinations.
- (h) Problem-solving activities, where different knowledge areas are integrated, should be given to learners.
- (i) Teachers should include at least two conceptual questions on all topics in Physics in classwork and homework exercises each week. This will assist learners in having a deeper understanding of Physics concepts.
- (j) It is critical that learners understand the concept of a variable that is kept constant in a particular equation and to use this information to find relationships between variables in that equation.

11.3 DIAGNOSTIC QUESTION ANALYSIS OF PAPER 1

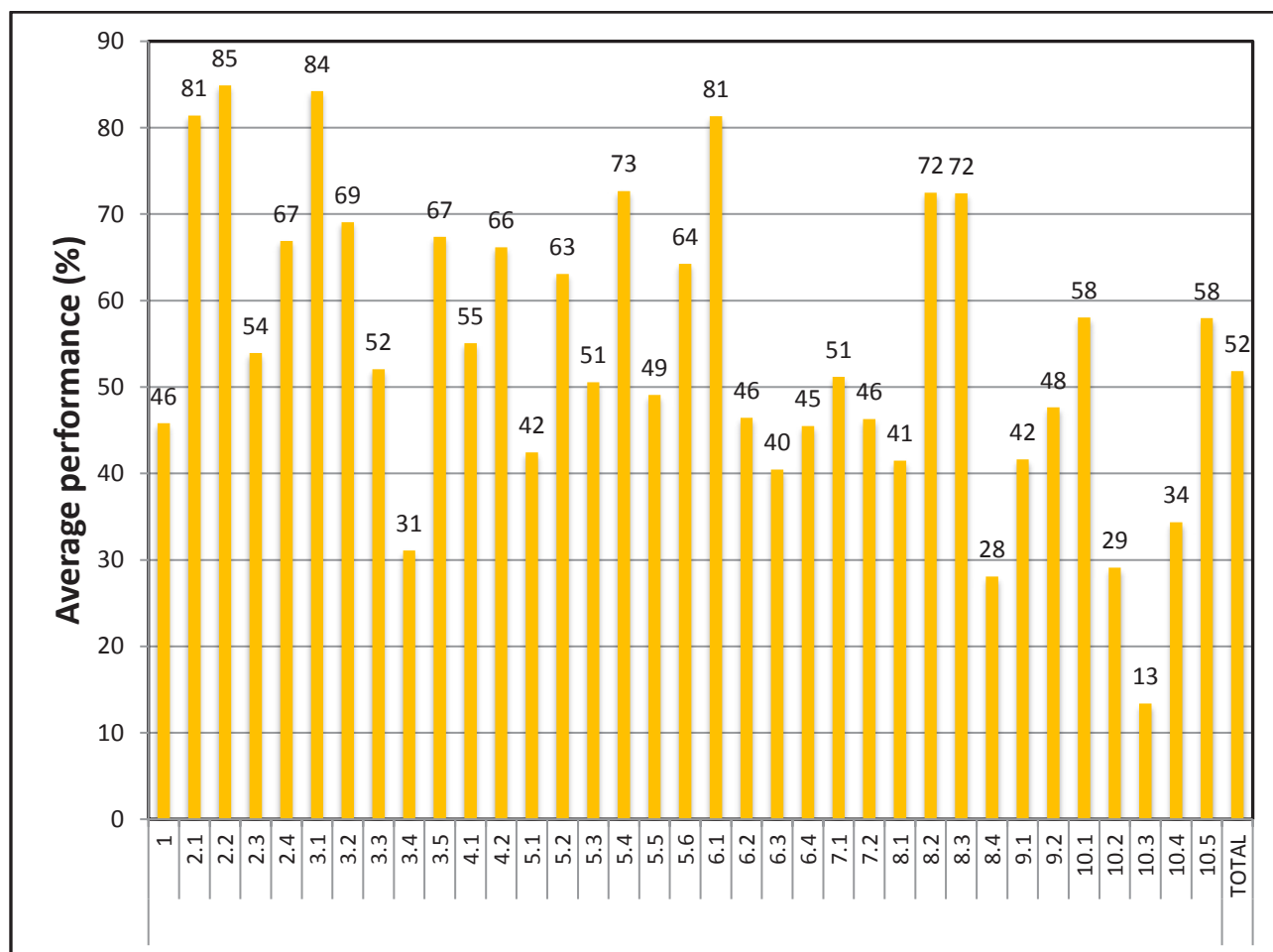
The following graph is based on data from a random sample of candidates. While this graph might not accurately reflect national averages, it is useful in assessing the relative degrees of challenge of each question as experienced by candidates.

Graph 11.3.1 Average Marks per Question as a Percentage in Paper 1



Q1	Multiple-choice questions - all topics
Q2	Newton's laws of motion
Q3	Vertical projectile motion
Q4	Momentum
Q5	Work, energy and power
Q6	Doppler effect
Q7	Electrostatics (Coulomb's Law and Electric Fields)
Q8	Electric circuits
Q9	Electrodynamics: motors, generators and alternating current
Q10	Photoelectric effect

Graph 11.3.2 Average Marks per Subquestion as a Percentage for Paper 1



11.4 ANALYSIS OF LEARNER PERFORMANCE IN EACH QUESTION IN PAPER 1

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Common Errors and Misconceptions

- In Q1.2 many candidates did not realise that the radius of the planet was R and that the new height above the centre of the planet is $3R$ instead of $2R$, as stated in the question.
- In Q1.5 candidates failed to integrate their mathematical skills with the scientific concepts, namely change in position (displacement), equations of motion, velocity and momentum.
- Most candidates failed to apply the law of conservation of charge in Q1.7, a topic dealt with in detail in Grade 10.
- Many candidates failed to associate the quantisation of light energy to the photoelectric effect.

Suggestions for Improvement

- (a) Multiple-choice questions test learners' understanding of concepts, principles and laws and the relationship between the dependent, independent and constant variables that must be demonstrated through logical reasoning and not by engaging in lengthy calculations. During teaching and learning, carefully selected concrete examples must be worked out to demonstrate these concepts, laws and principles, followed by generalisations and making predictions.
- (b) Learners must also be encouraged to refer to the formula sheet because it gives the formulae of laws and principles, as well as the relationship between the variables.
- (c) Teachers must include the use of ICT when teaching the subject. Multimedia/Software, such as *PHET* and *Edukite*, as well as YouTube videos to be used to demonstrate the answers of multiple-choice questions through simulations (virtual experiments).
- (d) It is recommended that a booklet containing multiple-choice questions on different topics from different sources, such as previous NSC and provincial question papers and textbooks should be prepared. These booklets should also show and explain how the correct answer is obtained.

QUESTION 2: NEWTON'S LAWS OF MOTION

Common Errors and Misconceptions

- (a) In Q2.1 candidates omitted keywords in their definition, especially the word 'resultant/net'. Instead of 'net force' many of the candidates simply wrote 'force'.
- (b) A considerable number of candidates used the incorrect phrase: 'the net force is directly proportional to the acceleration and inversely proportional to the mass of the object'.
- (c) Many candidates labelled their free-body diagram incorrectly and also omitted arrows in the free-body diagrams.
- (d) Candidates swapped $\sin\theta$ with $\cos\theta$ when determining the components of the weight.
- (e) Candidates did not realise that the net force increased after the block started moving on a frictionless surface as a result of less forces opposing the motion of the block.

Suggestions for Improvement

- (a) Teachers should adhere to and emphasise the definitions in *CAPS* and the Examination Guidelines. Keywords must be emphasised in these definitions.
- (b) The importance of drawing free-body diagrams for each object correctly and their usefulness in problem-solving must be emphasised. Teachers must insist that Newton's Second Law be applied to each object, which will provide an equation for the motion of each object in a specific direction. A method of solving simultaneous equations can be used to solve for the unknown in the equation.

- (c) Teachers should emphasise that the net force acting on an object is the sum of all the forces acting on the object parallel to the direction of motion of the object.
- (d) Learners must be systematically exposed to different questions in which trigonometric relations must be applied.

QUESTION 3: VERTICAL PROJECTILE MOTION

Common Errors and Misconceptions

- (a) Many candidates omitted the keyword 'only' with regard to the gravitational force in their definition of free fall.
- (b) The candidates experienced problems with the signs of velocity and acceleration in their substitutions into the appropriate equations of motion.
- (c) Some of the candidates used $a = 0 \text{ m} \cdot \text{s}^{-2}$ at the maximum height.

Suggestions for Improvement

- (a) Learners must be advised to start every calculation in mechanics, especially vertical motion, by indicating the sign convention at the beginning of the problem. Teachers must emphasise that the direction of gravitational acceleration does not change in a question; it remains constant.
- (b) Learners must be taught the equations of motion in Physics and how these equations are related to the equations in Mathematics. Learners must be assisted in relating the relevant points of a position versus time graph to the corresponding points on a velocity versus time graph.

Straight-line graph (velocity-time graph)

$$y = mx + c$$

$$v_f = a\Delta t + v_i$$

Parabola (position-time graph)

$$y = ax^2 \quad (+ bx + c)$$

$$y_f = \frac{1}{2} a(\Delta t)^2 (+ v_i \Delta t + y_i)$$

Hyperbola

$$k = xy \quad y \text{ inversely proportional to } x, k \text{ is constant}$$

$$F_{\text{net}} = ma \quad a \text{ inversely proportional to } m, F_{\text{net}} \text{ is constant}$$

QUESTION 4: MOMENTUM

Common Errors and Misconceptions

- (a) In Q4.1 many candidates omitted the word 'external' in their definition of an isolated system as used in Physics. Once again keywords in the definitions should be emphasised.
- (b) Many candidates erroneously used the formula $\Sigma p_i = \Delta \Sigma p_f$ instead of $p = mv$.
- (c) Some candidates could not differentiate between the initial and final velocities in their substitution into the appropriate equation $F_{\text{net}} \Delta t = m \Delta v$.

Suggestions for Improvement

- (a) Expose learners to many different scenarios or problems that include the application of Newton's Third Law, the principle of conservation of linear momentum and the impulse-momentum theorem. Teachers should also integrate topics (as and when necessary) in their teaching rather than only teaching topics in isolation. Moreover, they should expose learners to problems that integrate the application of different concepts.
- (b) Use the data sheet and formula sheet throughout the year.
- (c) The difference between momentum and change in momentum should be made clear during teaching.

QUESTION 5: WORK, ENERGY AND POWER

Common Errors and Misconceptions

- (a) Some candidates could not properly define conservative force, while some omitted keywords in their definition, e.g. omitting the word 'work' and using 'force' instead of 'work'.
- (b) Many candidates could not differentiate between a conservative force and a non-conservative force acting on the object.
- (c) Many candidates wrote a direction for work done on an object, which is a misconception since work done is a scalar quantity.

Suggestions for Improvement

- (a) Carefully selected examples and assessment tasks must be used to facilitate the understanding of why certain forces are classified as conservative or non-conservative.
- (b) Use *PhET* simulations to assist learners in the identification of forces acting on objects.

- (c) Learners should know that work done by a force is always equal to a change in energy, e.g. $W_{\text{net}} = \Delta K$, $W_{\text{nc}} = \Delta U + \Delta K$, $W_g = -\Delta U$.
- (d) When using $W_{\text{nc}} = \Delta U + \Delta K$ or $W_{\text{net}} = \Delta K$, learners must draw a free-body diagram to identify the forces acting in the direction of motion to know how many forces are causing the net work to be done. Emphasise that Δ implies: final – initial.
- (e) Teachers should emphasise the frame of reference in calculating potential energy, i.e. what is the position at which the potential energy is given a zero value? Is the object's potential energy decreasing or increasing?

QUESTION 6: DOPPLER EFFECT

Common Errors and Misconceptions

- (a) A number of candidates could not interpret the graphs in terms of wavelength, period and frequency correctly.
- (b) Many candidates struggled to differentiate between the concepts 'period', 'frequency' and 'time'.
- (c) Many candidates used the equation $E = hf$ to calculate the frequency of the waves and also confused f_s with f_L .

Suggestions for Improvement

- (a) Teachers need to source and expose learners to a variety of questions relating to the Doppler effect equation, as the scope is very broad, given the number of variables in the equation.
- (b) Revise the use of the wave equation: $v = f\lambda$, and period equation $T = \frac{1}{f}$.
- (c) There is a need for teachers to emphasise the progression of knowledge. The work done in Grade 12 cannot be seen in isolation from work done in Grades 10 and 11.

QUESTION 7: ELECTROSTATICS (COULOMB'S LAW AND ELECTRIC FIELDS)

Common Errors and Misconceptions

- (a) Candidates failed to recall that 'like charges repel', hence the repelled sphere should have been positive.
- (b) Many candidates omitted the force of gravity in their free-body diagram.
- (c) Candidates also confused Coulomb's Law with Newton's Law of Universal Gravitation.

- (d) Candidates swapped/mixed the formulae for E and F; i.e. $E = \frac{F}{q}$ and $E = \frac{kQ}{r^2}$.
- (e) Many candidates failed to realise that the forces acting on the sphere are in equilibrium and a closed vector diagram would have assisted them in calculating the tension in the string.
- (f) Candidates did not use the absolute value of the charges when substituting in the formula of Coulomb's Law or the electric field at a point.

Suggestions for Improvement

- (a) Teachers need to emphasise that calculations of net electrostatic force and electric field are similar in terms of their vector considerations.
- (b) Teachers need to clarify the distinction between the two equations i.e. $E = \frac{F}{q}$ and $E = \frac{kQ}{r^2}$.

It is important that learners understand which charge 'q' and 'Q' refer to in each of these formulae.

- (c) Expose learners to vector diagrams (1D and 2D) and vector triangles when determining the resultant of forces (e.g. electrostatic, gravitational and tension) acting on a body and net electric fields.

QUESTION 8: ELECTRIC CIRCUITS

Common Errors and Misconceptions

- (a) Many candidates were not scientifically correct in defining the emf of a battery as keywords were omitted in their definitions.
- (b) Many candidates omitted the units in the final answer.
- (c) Candidates do not have a clear understanding of the relationship between potential difference V, current I, resistance in the circuit when using the equation $\varepsilon = Ir + IR = V_{\text{internal}} + V_{\text{external}}$.
- (d) The influence on V_{external} in the presence of r_i when there is a change in the total resistance in the circuit is still a problem for many candidates.
- (e) Learners are unable to substitute the correct values of R, V and I when applying the formula $R = \frac{V}{I}$ to the whole circuit or to parts of a circuit.

Suggestions for Improvement

- (a) Although the principles of series and parallel circuits are taught from Grade 9, the basic principles have to be revised and practised constantly. The critical features of series and parallel circuits should be reinforced.
- (b) Use *PhET* simulations to demonstrate the relationship between V_{ext} and V_{int} , as well as the effect of adding resistors in series and parallel.

- (c) Teachers need to get learners to conduct practical work involving series and parallel circuits and to make observations and calculations regarding resistance, current, emf and potential difference regarding these circuits. These informal practical activities can be used as teaching tools for electric circuits.
- (d) Learners need to understand the formula $R = \frac{V}{I}$ and be able to substitute the correct values of R, V and I when applying the formula to the whole circuit or to parts of a circuit.

QUESTION 9: ELECTRODYNAMICS

Common Errors and Misconceptions

- (a) Many candidates had difficulty in explaining that for an emf to be induced, there must be a change in the magnetic flux linked to the coil.
- (b) Many candidates still omit the subscripts rms and ave in the equations:
 $P_{ave} = V_{rms} I_{rms}$, $P_{ave} = I_{rms}^2 R$, and $P_{ave} = \frac{V_{rms}^2}{R}$.
- (c) Candidates could not differentiate between a DC and an AC source.

Suggestions for Improvement

- (a) Emphasise the use of subscripts in the formulae when rms calculations are done.
- (b) Teachers should show learners the workings of an AC and DC generator using demonstration models of generators or also by allowing learners to build small generators that work.

QUESTION 10: PHOTOELECTRIC EFFECT

Common Errors and Misconceptions

- (a) Many candidates omitted keywords in the definition of the photoelectric effect.
- (b) Candidates did not realise that they had to use the graphing skills to determine the work function of the metal and the mass of the photo-electron, i.e. the y-intercept in the given graph is the work function and the gradient of the graph represented the mass of the photo-electron.
- (c) In Q10.4 the calculation of X was well attempted by many candidates. Common errors were:
- Omitting the subscript max in the formula: $E = W_0 + K_{max}$.
 - Incorrect mathematics in the calculation.

- (d) Most candidates did not know that a change in intensity of light will affect the number of photo-electrons emitted per unit time.

Suggestions for Improvement

- (a) Teachers should use computer simulations (e.g. *PhET*) when teaching the photoelectric effect. This will assist in improving learners' understanding of the concept.
- (b) Learners should be given a variety of problem-solving exercises at cognitive levels 3 and 4 for both classwork and homework.
- (c) Questions on new situations, where interpretation of graphs is required, should be compiled and provided to the learners on photoelectric effect. Also use graphs to highlight concepts, such as 'work function' and 'threshold frequency'.

11.5 OVERVIEW OF LEARNER PERFORMANCE IN PAPER 2

General Comments

- (a) Although the multiple-choice questions in Q1 were answered well in general, those pertaining to chemical equilibrium, acids and bases, galvanic cells and electrolytic cells were answered poorly.
- (b) Q9 on electrolytic cells and the use of the Table of Standard Reduction Potentials was answered poorly. Teachers are advised to give learners more tasks on how to use the table to determine the oxidising agent, reducing agent, oxidation and reduction in given redox reactions and how to explain their choice.
- (c) Most candidates had a poor understanding of Le Chatelier's principle, resulting in poor performance in Q6. Those who applied the principle correctly often failed to explain their choice correctly using the principle.
- (d) Questions pertaining to pure recall of content showed that learners memorise definitions without understanding resulting in using words haphazardly. Teachers are advised to use more short informal assessment tasks in order to reinforce basic concepts and principles, e.g. short speed tests (± 10 minutes). This can be used to good effect in content relating to definitions and laws listed in the CAPS and the Examination Guidelines.
- (e) Grade 11 work (Stoichiometry) is still poorly understood. Grade 11 work should be included in classwork, homework and tests in Grade 12.
- (f) The Table of Standard Reduction Potentials (Q8 and Q9) is still not well understood by most learners. Time should be spent in class to thoroughly explain how to use the table to determine relative strengths of oxidising and reducing agents to decide which substance will be oxidised and which one will be reduced. It is evident that candidates have a misconception that a weaker reducing agent is a strong oxidising agent. Teachers need to assist learners to understand that a weaker reducing agent is, in fact, not a strong oxidising agent.

- (g) Learners should be taught that, for example, Na can never be an oxidising agent because it cannot undergo reduction (gain electrons). Oxidising agents are listed on the left in the Table of Standard Reduction Potentials and reducing agents on the right (see the section of Table 4B below). Time should also be spent on the approach to follow when explaining in terms of relative strengths of reducing or oxidising agents

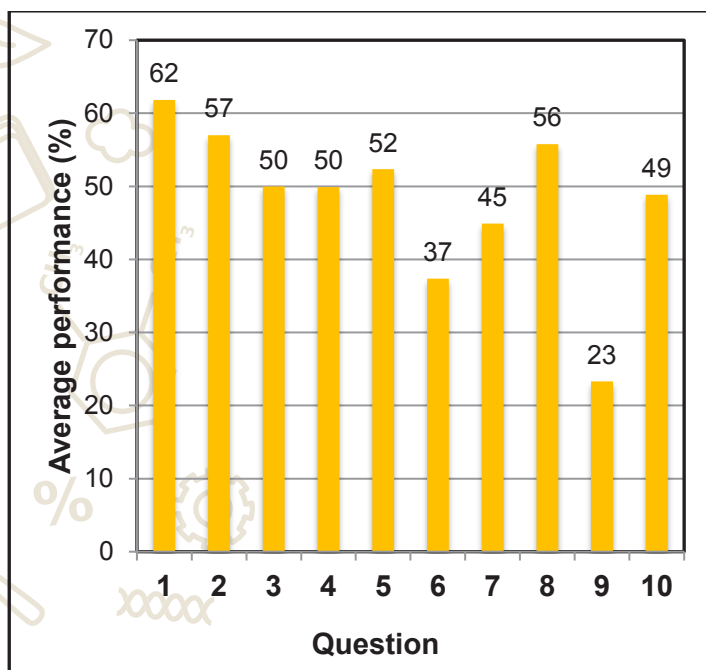
Section of the TABLE OF STANDARD REDUCTION POTENTIALS (4B)

Most negative reduction potential Weakest oxidising agent	$\text{Ni}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ni}$	-0,27	Most negative reduction potential Strongest reducing agent
	$\text{Sn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Sn}$	-0,14	
	$\text{Pb}^{2+} + 2\text{e}^- \rightleftharpoons \text{Pb}$	-0,13	
	$\text{Fe}^{3+} + 3\text{e}^- \rightleftharpoons \text{Fe}$	-0,06	
Most positive reduction potential Strongest oxidising agent	$2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0,00	Most positive reduction potential Weakest reducing
	$\text{S} + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2\text{S}(\text{g})$	+0,14	
	$\text{Sn}^{4+} + 2\text{e}^- \rightleftharpoons \text{Sn}^{2+}$	+0,15	
	$\text{Cu}^{2+} + \text{e}^- \rightleftharpoons \text{Cu}^+$	+0,16	
	$\text{SO}_4^{2-} + 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{SO}_2(\text{g}) + 2\text{H}_2\text{O}$	+0,17	
	$\text{Cu}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cu}$	+0,34	
	$2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^- \rightleftharpoons 4\text{OH}^-$	+0,40	
	$\text{SO}_2 + 4\text{H}^+ + 4\text{e}^- \rightleftharpoons \text{S} + 2\text{H}_2\text{O}$	+0,45	

11.6 DIAGNOSTIC QUESTION ANALYSIS OF PAPER 2

The following graph is based on data from a random sample of candidates. While this graph might not reflect national averages accurately, it is useful in assessing the relative degrees of challenge of each question as experienced by candidates.

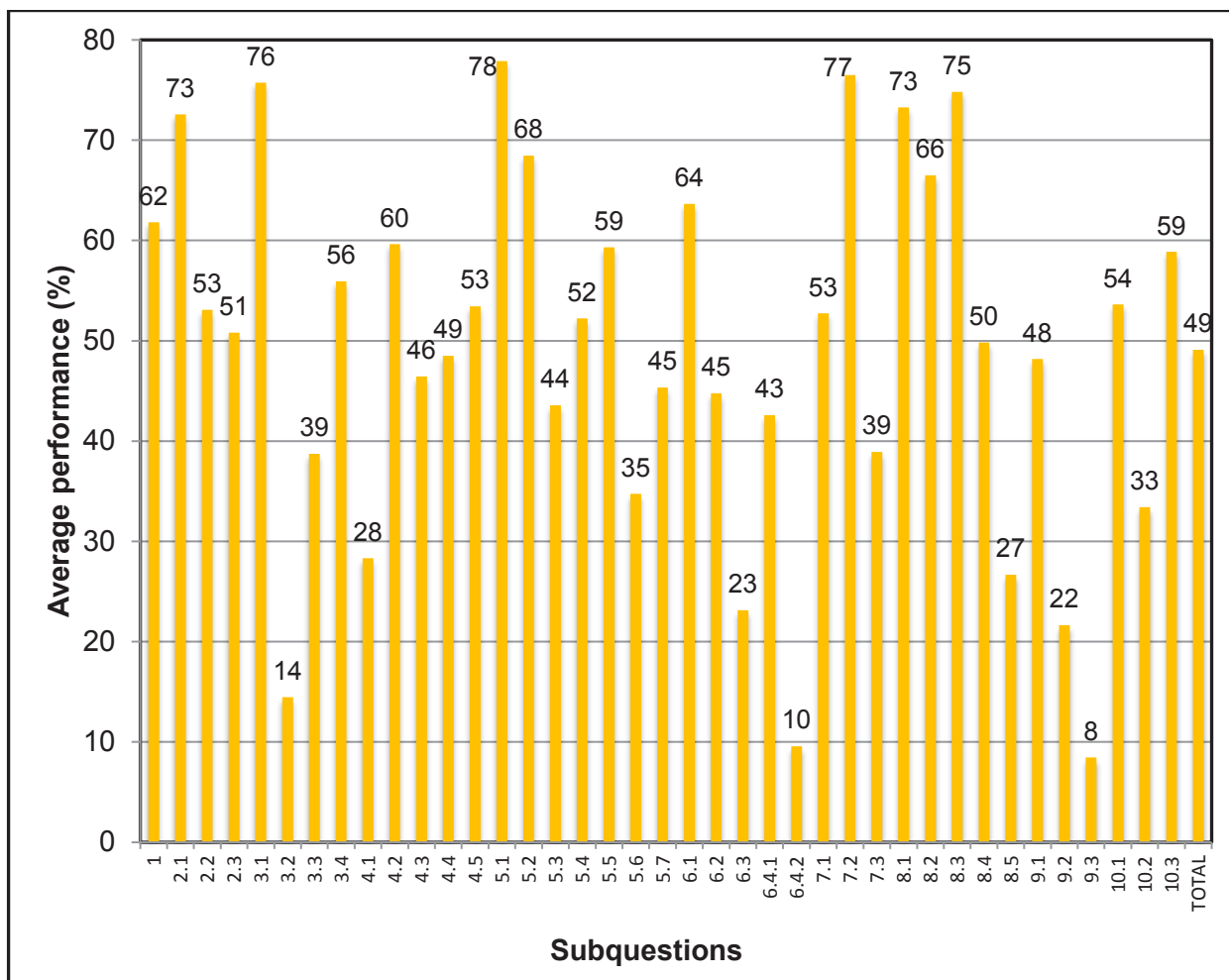
Graph 11.6.1 Average Marks per Question as a Percentage: Paper 2



Q1	Multiple-choice questions – all topics
Q2	Nomenclature of organic compounds
Q3	Physical properties of organic compounds
Q4	Reactions of organic compounds
Q5	Reaction rate and stoichiometry
Q6	Chemical equilibrium
Q7	Acids and bases and stoichiometry
Q8	Galvanic cells
Q9	Electrolytic cells
Q10	Fertilisers

There was an improvement in performance in five questions, namely multiple-choice questions (Q1), nomenclature of organic compounds (Q2), rates of reaction (Q5), galvanic cells (Q8) and fertilisers (Q10) as compared to 2018.

Graph 11.6.2 Average Marks per Subquestion as a Percentage: Paper 2



11.7 ANALYSIS OF LEARNER PERFORMANCE IN EACH QUESTION IN PAPER 2

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Common Errors and Misconceptions

- Most candidates incorrectly thought that distractor B ($E_a = 50 \text{ kJ}\cdot\text{mol}^{-1}$ & $\Delta H = +100 \text{ kJ}\cdot\text{mol}^{-1}$) is the correct answer in Q1.4.
- In Q1.5 many candidates thought that a catalyst increases the reaction rate as well as the yield of a reaction and chose A as answer.
- Candidates showed poor understanding of the application of Le Chatelier's principle and the effect of equilibrium conditions on the K_c value (Q1.6). The most common incorrect answer was C, which shows that most candidates did not know that a change in pressure at constant temperature will have no effect on the K_c value.
- Although most candidates could identify hydrochloric acid as a strong acid (Q1.7) and will, for the same concentration, have a higher $[\text{H}_3\text{O}^+(\text{aq})]$ than ethanoic acid, they failed to link a high $[\text{H}_3\text{O}^+(\text{aq})]$ to a low pH value and chose A as the answer.

- (e) In Q1.8 many candidates did not know how to use the given E^\ominus values to determine which one of the two half-reactions will be the oxidation and which one the reduction.
- (f) In both Q1.8 and Q1.9 candidates showed poor understanding of the concepts 'reduction', 'oxidation', 'reducing agent' and 'oxidising agent' and aspects specific to galvanic and electrolytic cells. In Q1.9 many candidates did not know that the anode is always the positive electrode in any electrolytic cell.

Suggestions for Improvement

- (a) The answering of multiple-choice questions is a skill that needs to be developed. Learners must be guided to eliminate the wrong answers through regular practice and assessment. Multiple-choice questions should be assessed on a regular basis on all topics covered.
- (b) It is advisable to compile a workbook containing multiple-choice questions from previous years per topic. These can also be used for regular short tests after completion of a topic and during review, teachers can explain how learners must approach these questions.
- (c) Learners should be taught that only a change in temperature can result in a change in the K_c value for a particular reaction. If the forward reaction is exothermic, a decrease in temperature will result in an increase in the K_c value. If the forward reaction is endothermic, an increase in temperature will result in an increase in the K_c value.
- (d) The concepts pertaining to redox reactions should be thoroughly explained and learners should be exposed to sufficient problem-solving in the use of these concepts. Oxidation and reduction are reactions, while oxidising agents and reducing agents are substances. Avoid using the words 'oxidised' and 'reduced' as one adds more confusing vocabulary. Rather limit terminology to 'oxidation', 'reduction', 'reducing agent' and 'oxidising agent'.
- (e) The meaning of reduction potentials (E^\ominus values in Tables 4A and 4B) needs more attention in class. Learners should be taught that the values listed are reduction potentials applicable to each reduction half-reaction and gives a comparative indication of the strength of oxidising agents listed in the table. When two half-reactions are compared, the one with the more positive value has the greater tendency to be a reduction and the substance undergoing reduction is the stronger oxidising agent.

QUESTION 2: NOMENCLATURE OF ORGANIC COMPOUNDS

Common Errors and Misconceptions

- (a) Many candidates were unable to differentiate between a general formula, a structural formula and a molecular formula (Q2.1.1) and gave the structural formula or molecular formula of the alkyne as the answer. Some candidates gave the structural formula of the functional group as the answer. Many got confused with the subscripts and common incorrect answers were: CH_{2n-2} ; C_nH_{2-2} ; C_nH_{2n} ; $\text{C}_n\text{H}_{2n+1}$.

- (b) When drawing the structural formula of the alkyne (Q2.1.2), many placed the triple bond between C1 and C2 instead of between C2 and C3. Other common errors were:
- More than four bonds on the C atoms of the triple bond
 - Omitting H atoms
 - Omitting bond lines between atoms in the structure
 - Drawing condensed structural formulae for the methyl groups of the structural formula
- (c) The definition of the 'positional isomer' (Q2.2.1) was poorly answered in comparison to application-type questions. Some candidates forfeit the first mark due to the use of the words 'molecular structure' or 'general formula' or 'molecular mass' instead of 'molecular formula'. Many candidates forfeited the second mark because they did not specify that the 'functional group/substituent' will be in a different position and therefore 'same molecular formula but different positions' was a common half-correct response.
- (d) The term 'positional isomer' (Q2.2.2) was poorly understood. Many candidates wrote the IUPAC name of the compound given, i.e. 'pentan-2-one' instead of 'pentan-3-one'. Another error that frequently occurred was writing of the IUPAC name as 'pent-3-one' instead of 'pentan-3-one'.
- (e) Many candidates wrote the structural formula of another ketone (Q2.2.3) instead of that of the aldehyde. Such candidates did not understand the term 'functional isomer'.
- (f) Although most candidates could identify the alcohol as being a tertiary alcohol (Q2.3.1), many failed to give a correct reason. Common incorrect reasons were:
- The -OH group is bonded to three C atoms.
 - The functional group is bonded to the third C atom.
 - The C atom is bonded between three other C atoms (no reference to the functional group/-OH group).
- (g) Hyphens and commas are still not used correctly in IUPAC names (Q2.3.2 & Q2.3.3). Commas were used between numbers and words instead of between numbers only.
- (h) When writing the IUPAC name of the alcohol in Q2.3.2, many omitted the 'an' in butan-2-ol and a common incorrect answer was 2-methylbut-2-ol.
- (i) In Q2.3.3 many candidates could not identify the major product formed correctly and gave the IUPAC name of the minor product, 2-methylbut-1-ene, as the answer. Many did not know that the product of the elimination reaction is an alkene. The IUPAC name of an alkane (2-methylbutane) or an alkyne (2-methylbut-2-yne) were common incorrect answers. Some candidates added '-an' in the correct name, i.e. '2-methylbutan-2-ene' and forfeited one mark.

Suggestions for Improvement

- (a) The different types of formulae, i.e. structural, condensed structural, condensed and molecular, should be revised and assessed regularly so that learners are able to distinguish between them and to interpret given formulae.

- (b) Learners should be exposed to many exercises to practise the writing of IUPAC names and/or structural formulae of positional, functional and chain isomers of given compounds to ensure they can distinguish between the different types of structural isomers.
- (c) When writing IUPAC names, the correct use of hyphens and commas should be emphasised. The use of 'an' in, for example, IUPAC names of ketones and alcohols, but not in the IUPAC names of, for example, alkenes, should be emphasised to ensure learners do not forfeit marks unnecessarily.
- (d) When drawing structural formulae, learners should be encouraged to count the number of bonds drawn around atoms to eliminate unnecessary errors, e.g. a C atom has a valence of four and should always form four bonds to other atoms.

QUESTION 3: PHYSICAL PROPERTIES OF ORGANIC COMPOUNDS

Common Errors and Misconceptions

- (a) Candidates who did not obtain full marks for Q3.1 forfeited a mark for 'temperature'. Such candidates only stated that 'it is the point (instead of temperature) when the vapour pressure of a substance equals atmospheric pressure'. Other incorrect definitions were:
- The temperature where a liquid boils
 - The temperature when a vapour is in equilibrium with its liquid
- (b) Most candidates failed to give a reason why the comparison of boiling points of the three chain isomers is fair (Q3.2). The most common incorrect reasons were that 'the compounds are all alkanes or belong to the same homologous series' without mentioning that 'they have the same number of C atoms and H atoms'.
- (c) Linking the three chain isomers to the boiling points (Q3.3) was poorly attempted. Most candidates gave incomplete explanations and compared only two of the three isomers. For a full explanation, all three isomers should be compared. Common errors were:
- Making a general statement, e.g. 'the longer the chain length, the higher the boiling point', without referring to any of the compound Q, R and S.
 - Referring to 'energy needed to break the bonds' (instead of 'intermolecular forces') or 'energy needed to break the intermolecular forces' between atoms (instead of 'molecules').
 - Only comparing the structural differences between the three isomers without comparing 'the strength of the intermolecular forces' and 'the energy needed to overcome the intermolecular forces in each'.
- (d) Many candidates incorrectly chose the alcohol, T, as the compound having the higher vapour pressure (Q3.4.1), but explained in Q3.4.2 that the alcohol has the stronger intermolecular forces, due to hydrogen bonding. The concept 'vapour pressure' and its relationship with the strength of intermolecular forces was therefore not well understood.

In their explanations, many candidates referred to one of the weaker types of intermolecular forces present between molecules of alcohols and molecules of aldehydes and omitted the strongest intermolecular force responsible for the uniqueness of each compound. An example of such an explanation is that 'alcohols have dipole-dipole forces and aldehydes have London forces'. The forces responsible for their unique physical properties are hydrogen bonding in alcohols and dipole-dipole forces in aldehydes.

Suggestions for Improvement

- (a) The relationship between strength of intermolecular forces and vapour pressure should be emphasised. Vapour pressure decreases as the strength of intermolecular forces increases.
- (b) When dealing with variables, it should be emphasised that any investigation should have only one independent variable. All other variables should be controlled (kept constant) to ensure a fair comparison.
- (c) In explanations of differences in boiling points, melting points and vapour pressure, the strongest intermolecular force in each of the compounds concerned should be mentioned to explain differences. For example, both alkanes and alcohols have London forces, but the intermolecular forces causing the difference in their boiling points is hydrogen bonding in alcohols and London forces in alkanes. The strongest intermolecular force in a particular compound is mainly responsible for its physical properties.

QUESTION 4: REACTIONS OF ORGANIC COMPOUNDS

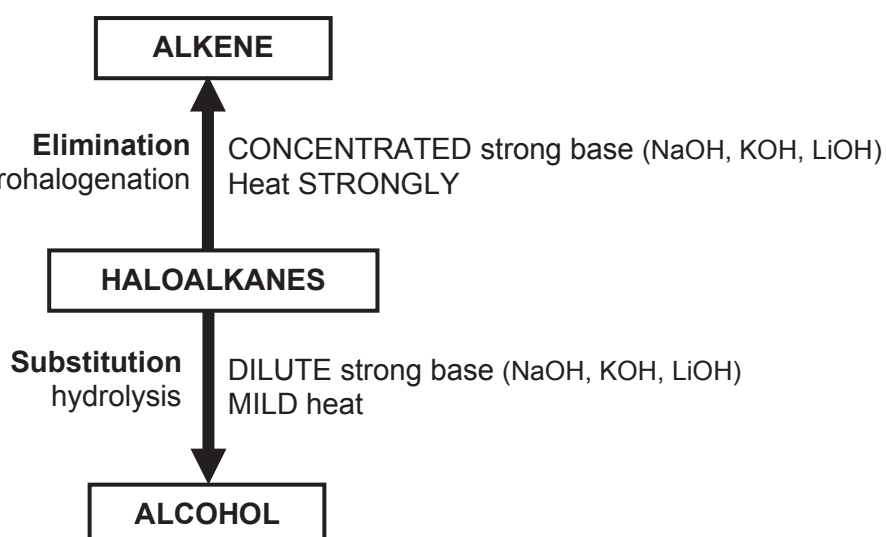
Common Errors and Misconceptions

- (a) Most candidates failed to interpret the flow diagram to identify the homologous series to which the unknown compound belongs as a 'haloalkane' (Q4.1). The most common incorrect response was 'alkanes'. Candidates therefore failed to use the products and the reaction conditions to work backwards to identify the unknown compound.
- (b) Although well answered, the analysis of the flow diagram to identify types of reactions (Q4.2) was a challenge to some candidates. Many candidates failed to recognise the esterification (Q4.2.3) from the information given.
- (c) Differentiation between the conditions for substitution (hydrolysis) and elimination (concentrated strong base), as shown in the flow diagram, was a challenge to many candidates. Although most candidates knew a concentrated base should be used to prepare the alcohol (Q4.3.1), they only stated that a 'strong base' is needed instead of a 'dilute strong base' or 'water'.

- (d) Identification of the primary alcohol (Q4.3.2) was a challenge to most candidates. They failed to use the alkene given in the flow diagram to determine that the alcohol should have three C atoms. Therefore, 'butan-1-ol' and 'pentan-1-ol' were common incorrect responses. Some of those who knew that the alcohol should have three C atoms, made one of the following mistakes:
- Omitting the position of the functional group e.g. 'propanol'
 - Incorrect functional group, e.g. 'propan-2-ol'
 - Omitting 'an', e.g. 'prop-1-ol'
- (e) Many candidates drew the structural formula of propan-1-ol instead of that of propan-2-ol in Q4.4. They did not apply the rule that during hydration of an alkene, the H atom bonds to the C atom of the alkene already having the most H atoms. Therefore, the -OH group should bond to the second C atom in this example. Other errors were:
- Omitting some of the H atoms in the structure
 - Attaching the -OH group incorrectly to the C atom so that the H atom of the -OH group is bonded to the C atom.
- (f) Instead of the structural formula of the ester (Q4.5.1), many candidates drew the structural formula of a carboxylic acid, such as pentanoic acid or the structural formula of a ketone. Others drew the structural formula of ethyl propanoate instead of that of propyl ethanoate.

Suggestions for Improvement

- (a) The differences and similarities in the conditions for the substitution and elimination reactions of haloalkanes should be emphasised.



QUESTION 5: REACTION RATE

Common Errors and Misconceptions

- (a) The mark allocation contributed to the good performance in Q5.2. However, the following errors (not always penalised) occurred:
- Swapping the initial and final masses when calculating the change in mass (should be $0,25 - 2 = -1,75$ g)
 - Leaving the final answer as $-0,06 \text{ g}\cdot\text{s}^{-1}$ (reaction rate cannot be negative)
- (b) Very few candidates obtained full marks for the stoichiometric calculation (Q5.3). Many candidates forfeited marks for one or more of the following errors:
- Using the mass of two antacid tablets (4 g) instead of that of one tablet (2 g)
 - Omitting the calculation of the mass of CaCO_3 using 40% of the mass of the antacid tablet
 - Using the ratio between CO_2 and HCl (1:2) instead of that between CaCO_3 and CO_2 (1:1)
 - Using dm^{-3} or $\text{mol}\cdot\text{dm}^{-3}$ as the unit of volume in the final answer.
- (c) Many candidates thought that temperature is the controlled variable (Q5.4). These candidates did not interpret the graph correctly. It is clear from the graph that temperature is the independent variable.
- (d) The conclusion that can be drawn from the graph (Q5.5) was answered well. However, several candidates stated that 'as the time increases, temperature increases', whereas the graph shows the relationship between the 'inverse of time' and 'temperature'. Many candidates did not interpret $\frac{1}{t}$ as being reaction rate.
- (e) The use of the collision theory to explain the conclusion from the graph (Q5.6) was not answered well. Most candidates forfeited marks for one or more of the following reasons:
- Stating that at a higher temperature, molecules will have higher energy instead of higher kinetic energy.
 - Stating that 'molecules have higher kinetic energy' instead of 'more molecules have sufficient kinetic energy'.
 - Stating that 'more effective collisions take place' instead of 'more effective collisions per unit time'.
 - Stating that 'effective collisions take place per unit time' instead of 'more effective collisions per unit time'.
- (f) When drawing the curve that will be obtained for a higher concentration of acid (Q5.7), the following errors occurred:
- Starting curve Y at the same point on the y-axis as the original curve
 - Drawing a curve with an initial constant gradient before the gradient increases
 - Allowing the curves to cross (curve Y should always be above the original curve)
 - Drawing the two curves without labelling curve Y

Suggestions for Improvement

- (a) When calculating reaction rate for a reaction using the concentration of reactants, the following expression should be used: Average rate = $-\frac{\Delta c}{\Delta t} = -\left(\frac{c_f - c_i}{t_f - t_i}\right)$
- (b) The concentration of reactants decreases because reactants are used and therefore $c_f - c_i$ will be negative. The minus sign ensures that a positive value is obtained for reaction rate. The concentration can be substituted by number of moles (n) or mass (m) depending on the question.
- (c) When calculating reaction rate for a reaction using the concentration of products, the following expression should be used: Average rate = $\frac{\Delta c}{\Delta t} = \frac{c_f - c_i}{t_f - t_i}$.
- (d) The concentration of products increases because products are formed and $c_f - c_i$ will be positive. The concentration can be substituted by number of moles (n) or mass (m) depending on the question.

QUESTION 6: CHEMICAL EQUILIBRIUM

Common Errors and Misconceptions

- (a) When stating the definition of chemical equilibrium (Q6.1), many candidates omitted the word 'rate' and therefore stated that 'the forward reaction is equal to the reverse reaction'. No marks were allocated for such a statement. Other errors were:
- Chemical equilibrium is when the reactants and products are constant.
 - Chemical equilibrium is when the reactants are equal to the products.
 - It is when the concentrations of the reactants and products are equal.
- (b) The K_c calculation (Q6.2.1) was better answered than expected. However, the way of allocating marks could have contributed to good performance in this question. Common errors were:
- No K_c expression (Note that $\frac{[\text{products}]}{[\text{reactants}]}$ is NOT a K_c expression.)
 - Incorrect K_c expression, e.g. including the solid in the expression $K_c = \frac{[\text{CO}]^2}{[\text{C}][\text{CO}]}$
 - Using the mass of $\text{CO}_2(\text{g})$ given as the number of moles of $\text{CO}_2(\text{g})$
 - Using the given equilibrium concentration of $\text{CO}_2(\text{g})$ as the number of moles of $\text{CO}_2(\text{g})$ at equilibrium and, instead of multiplying by 3 dm^3 to obtain the equilibrium number of moles, dividing it by 3 dm^3
 - Ignoring the given concentration of $\text{CO}_2(\text{g})$ and calculating a concentration using any other value
 - Adding a unit to the K_c value calculated
- (c) Calculation of the minimum mass of $\text{C}(\text{s})$ (Q6.2.2) was answered poorly. Most candidates used the number of moles of $\text{CO}_2(\text{g})$ at equilibrium to derive the number of moles of $\text{C}(\text{s})$ needed. Very few candidates used the change in the number of moles of $\text{CO}_2(\text{g})$ that has reacted to calculate the mass of $\text{C}(\text{s})$ needed.

- (d) In Q6.3.1 most candidates did not know that the addition of more solid to an equilibrium mixture will not influence the equilibrium position/amount of products.
- (e) The explanation using Le Chatelier's principle (Q6.3.2) was answered poorly. Some candidates did not make reference to a choice when answering the question and therefore no marks could be allocated for their explanation. Some stated Le Chatelier's principle instead of applying the principle to the given scenario. Most candidates stated in their explanation that when pressure increases, the reaction that leads to the smaller number of moles will be favoured instead of the smaller number of moles of 'gas'.
- (f) When explaining why the reaction is endothermic (Q6.4.1), many candidates omitted mentioning that 'an increase in temperature favours an endothermic reaction'. Some candidates did not make reference to a choice when answering the question and therefore no marks could be allocated for their explanation.
- (g) Q6.4.2 was answered extremely poorly. Most candidates did not attempt the question. Some of those who answered this question, calculated a percentage from the values given in the table or added values in the table and then calculated a percentage there-of.

Suggestions for Improvement

- (a) Place more emphasis on explanations requiring Le Chatelier's principle. Learners struggle to express themselves when explaining in terms of Le Chatelier's principle. They should be exposed to more exercises to practise such explanations.
- (b) When explaining the effect of a change in temperature on the equilibrium position of a reaction, the first step should be to state how the change in temperature influences either an exothermic or an endothermic reaction. For example, if the percentage of products increases with an increase in temperature, candidates should state that 'an increase in temperature favours an endothermic reaction' to conclude that the forward reaction is endothermic.
- (c) Teachers should avoid the use of $K_c = \frac{[\text{products}]}{[\text{reactants}]}$ in class. Use chemical equations to teach the writing of K_c expressions.
- (d) Teachers should remind learners to write down their choice of option when asked to do so in a question, e.g. Q6.3.2 and Q6.4.1.

QUESTION 7: ACIDS AND BASES

Common Errors and Misconceptions

- (a) Many candidates thought that HBr is a weak acid (Q7.1). Most of those who identified HBr as a strong acid stated the definition of a strong acid (completely ionised) as the reason for the answer. No reference was made to the K_a value, which is greater than 1, giving the impression that they guessed the answer. A common incorrect reason given by some was that 'HBr is a strong acid because it is incompletely ionised'.

- (b) Although Q7.2 was answered well, some candidates forfeited marks due to the omission of the charge of Br^- .

Common errors made in the pH calculation (Q7.3) were:

- Incorrect conversion from cm^3 to dm^3 .
- Using an incorrect ratio, e.g. $n(\text{HBr}) = 2n(\text{NaOH})$
- Mixing the pH and pOH formulae, e.g. $\text{pH} = -\log[\text{OH}^-]$ or $\text{pH} = -\log[\text{H}_3\text{O}^+]$ or $\text{pH} = -\log(\text{H}_3\text{O}^+)$
- Writing the pH formula as $\text{pH} = -\log[\text{HBr}]$
- Omitting the pH formula and just starting with $\text{pH} = -\log(0,092)$
- Using $K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14}$ to calculate $[\text{H}_3\text{O}^+]$ after substituting the concentration of NaOH as $[\text{OH}^-]$

- (c) Many candidates did not attempt Q7.4, while very few of those who answered the question obtained full marks. Most candidates calculated the initial number of moles of HBr and then equated that to the number of moles of $\text{Zn}(\text{OH})_2$ that has reacted. The step in which the number of moles of HBr that reacted with the $\text{Zn}(\text{OH})_2$ had to be calculated, i.e. $n(\text{HBr})_{\text{reacted}} = n(\text{HBr})_{\text{initial}} - n(\text{HBr})_{\text{reacted with NaOH}}$, was omitted and such candidates forfeited two marks for this step as well as the mark for the answer. Other errors were:

- Using an incorrect molar mass for $\text{Zn}(\text{OH})_2$
- Using an incorrect formula e.g. $n = \frac{c}{V}$ or using n when calculating $n = \frac{V}{V_M}$
- Incorrect or no conversion from cm^3 to dm^3 when substituting volumes into $C = \frac{n}{V}$

Suggestions for Improvement

- (a) Although HCl , H_2SO_4 and HNO_3 are listed as examples of strong acids, candidates should be made aware that there are other strong acids as well. Candidates should be taught how to use given K_a values to determine whether an acid is strong or weak.
- (b) Candidates should be taught to copy formulae from the data sheet. It is inexcusable to forfeit three marks due to an incorrect pH formula.
- (c) Ensure that stoichiometric calculations are taught properly in Grade 11. Expose candidates to stoichiometric calculations involving limiting reagents from the beginning of their Grade 12 year to give them enough practice.

QUESTION 8: REDOX REACTIONS AND GALVANIC CELLS

Common Errors and Misconceptions

- (a) Although Q8.1 was answered well, some candidates thought that 'chemical energy is transferred to mechanical energy', while others stated the energy conversion in an electrolytic cell, i.e. 'electrical energy to chemical energy'.

- (b) A common error made when writing the function of the salt (Q8.2) was stating that 'the salt bridge completes the cell', or 'the salt bridge is a pathway for the electrons to move'. Candidates also refer to the salt bridge as 'maintaining neutrality of the electrons'.
- (c) The calculation of the cell potential (Q8.3) was answered well in comparison to the other subquestions. Many learners identified metal **X** as Pb^{2+} , which is an ion of the metal. Others identified metal **X** as $\text{Pb} \rightarrow \text{Pb}^{2+} + 2\text{e}^-$ or $\text{Pb}^{2+} + 2\text{e}^- \rightarrow \text{Pb}$ instead of Pb. Common errors when doing the calculation were:
- Using abbreviations in the formula, e.g. $E_{\text{cell}} = E_{\text{red}} - E_{\text{ox}}$ or $E_{\text{cell}} = E_{\text{oxidising}} - E_{\text{reducing}}$
 - Using $E = \text{cathode} - \text{anode}$ as formula
 - Swapping the reduction potential of the anode with that of the cathode when substituting
 - Using Pt as the active electrode in the cathode half-cell and thus substituting the reduction potential of the Pt^{2+}/Pt half-reaction instead of that of the Cl_2/Cl^- half-reaction as E_{cathode}
- (d) In Q8.5.1 many candidates reasoned that 'the reactants are used up' or 'the cell is flat' or 'the rates of the oxidation and reduction half-reactions become zero' instead of stating that 'the cell reaction reached equilibrium'.
- (e) Although many candidates knew that the voltmeter reading will increase when $\text{AgNO}_3(\text{aq})$ is added to the chlorine half-cell (Q8.5.2), they failed to use Le Chatelier's principle to provide an explanation for the increase in voltmeter reading. Many merely stated Le Chatelier's principle instead of using the principle.

Suggestions for Improvement

- (a) Concepts such as 'reducing agent', 'oxidation', 'oxidising agent' and 'reduction' should not only be memorised, but learners should have a thorough understanding of these concepts and be able to identify, for example, the reducing agent in a particular reaction. Regular assessment on this identification is needed to ensure that learners fully understand these concepts.
- (b) Learners should be taught how to use the Table of Standard Reduction Potentials to identify the reducing agent, oxidising agent, reduction half-reaction and oxidation half-reaction in a galvanic cell. Regular assessment on this identification is needed to ensure learners understand the use of the Table of Standard Reduction Potentials.

QUESTION 9: ELECTROLYTIC CELLS

Common Errors and Misconceptions

- (a) In Q9.1 candidates did not know the difference between 'electrolysis', an 'electrolytic cell' and an 'electrolyte'. Some candidates wrote that electrolysis is a solution in which electrical energy is converted to chemical energy.

- (b) Very few candidates obtained full marks for the reduction half-reaction that takes place at the cathode during the electrolysis of a concentrated sodium chloride solution (Q9.2.1). A variety of incorrect reduction half-reactions were used of which the most common were $2\text{Cl}^- + 2\text{e}^- \rightarrow \text{Cl}_2$ and $\text{H}_2\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightarrow 2\text{H}_2\text{O}$. Many used a double arrow in the correct half-reaction.
- (c) Identification of the oxidising agent (Q9.2.2) was answered poorly. Many identified H_2 as the oxidising agent.
- (d) The use of the Table of Standard Reduction Potentials to explain why sodium ions will not be reduced during electrolysis (Q9.3) was a challenge to most candidates. They had a poor understanding of concepts such as 'oxidising agent', 'reducing agent', 'oxidation' and 'reduction'. Common errors were:
- Na^+ is a stronger reducing agent than H_2O and will be oxidised.
 - Na^+ ions are spectator ions.
 - Na^+ cannot be reduced because its E^\ominus value is below zero.
 - Comparing Na or Na^+ to Cl^- instead of to H_2O .
 - Rewriting the statement in the question paper, i.e. Na^+ ions will not be reduced.

Suggestions for Improvement

- (a) The difference between the definitions of 'electrolysis', an 'electrolytic cell' and an 'electrolyte' should be emphasised. Although there is a similarity in that the definition of both electrolysis and an electrolytic cell contains 'electrical energy is converted to chemical energy', there is a difference in that electrolysis is a process, while an electrolytic cell is a cell in which the energy change takes place. An electrolyte is a solution that conducts electricity through the movement of ions.
- (b) Candidates should be supplied with a summary of the five different types of electrolytic cells prescribed. Ensure that learners understand the reactions at the electrodes in these cells. The five types are: electrolysis of concentrated NaCl , electrolysis of concentrated CuCl_2 , the aluminium cell, an example of a cell used for electroplating and the purification of copper.
- (c) When copying either the oxidation or the reduction half-reaction from the Table of Standard Reduction Potentials, single arrows should be used to represent either the oxidation or the reduction.

QUESTION 10: FERTILISERS

Common Errors and Misconceptions

- (a) The interpretation of the flow diagram to identify gas X (Q10.1.1), acid Q (Q10.1.2) and gas Y (Q10.1.2) was poorly attempted. In Q10.1.2 'nitrogen oxide' instead of 'nitrogen monoxide' was a common incorrect answer.
- (b) Identification of the type of reaction (Q10.2.1) was answered poorly. The 'catalytic oxidation of ammonia' is a specific reaction in the Ostwald process and the question is actually a recall question. Incorrect answers were 'addition', 'substitution', 'elimination' and 'combustion'.

- (c) The balanced equation (Q10.2.2) for the reaction of ammonia (compound P) and HNO_3 (acid Q) was answered poorly, possibly because candidates failed to identify compound P and acid Q in the flow diagram.
- (d) In the calculation in Q10.3.2, many candidates omitted one of the steps to arrive at the mass of P in each bag. Common errors were:
- Incorrect use of the NPK ratio e.g. $\frac{3}{21}$ or $\frac{4}{8}$ instead of $\frac{3}{8}$
 - Drawing a conclusion based on percentage of phosphorous in each bag without taking into account the masses of the bags, e.g. $\frac{3}{8} \times 21 = 7,9\%$ and $\frac{3}{8} \times 27 = 10,1\%$, therefore bag B has the most phosphorous

Suggestions for Improvement

- (a) More attention should be given to fertilisers as a topic. Learners should be encouraged to study the topic, as they can obtain marks easily if they know their work.
- (b) Ensure learners understand the meaning of numbers given on a fertiliser bag and how to use them in calculations to prevent them from substituting those numbers haphazardly.

