CHAPTER 11

PHYSICAL SCIENCES

The following report should be read in conjunction with the Physical Sciences Paper 1 and Paper 2 question papers of the NSC November 2021 examinations.

11.1   PERFORMANCE TRENDS (2017–2021)

The number of candidates who sat for the Physical Sciences examination in 2021 increased by 22 658 compared to that of 2020, i.e. 13% of the cohort.

The trend in pass rate reflected over the past five years reflected steady improvement in the period 2017–2019 followed by a decline in 2020. However, there was a pleasing improvement in the pass rate this year.
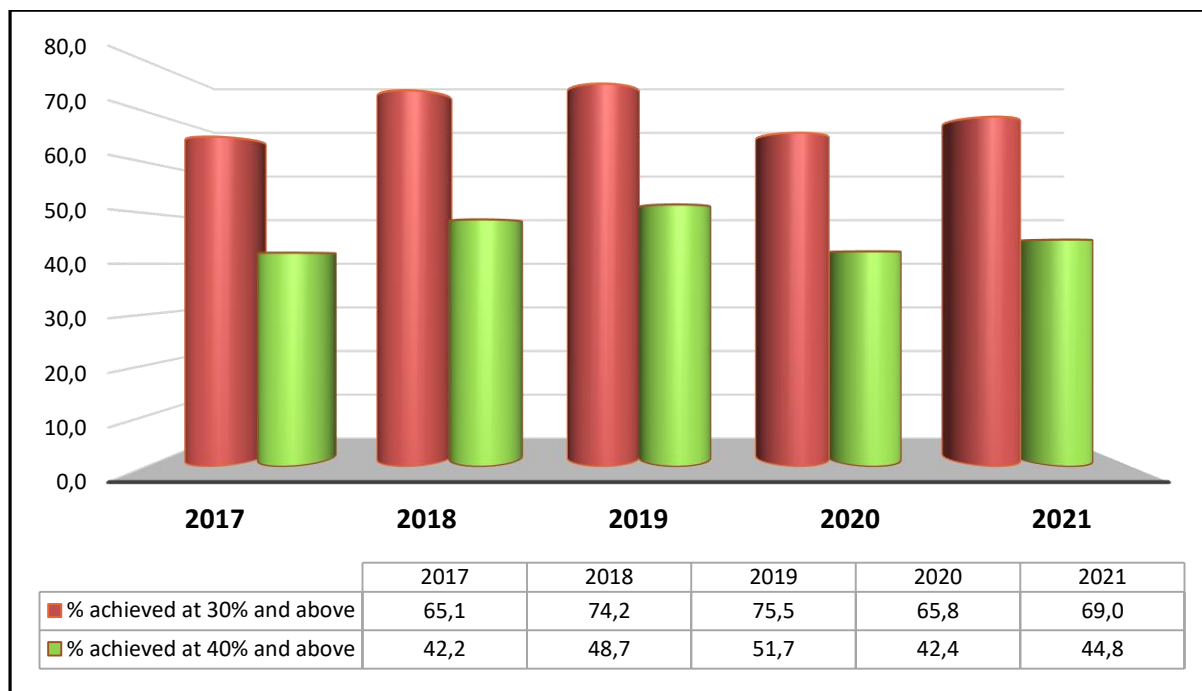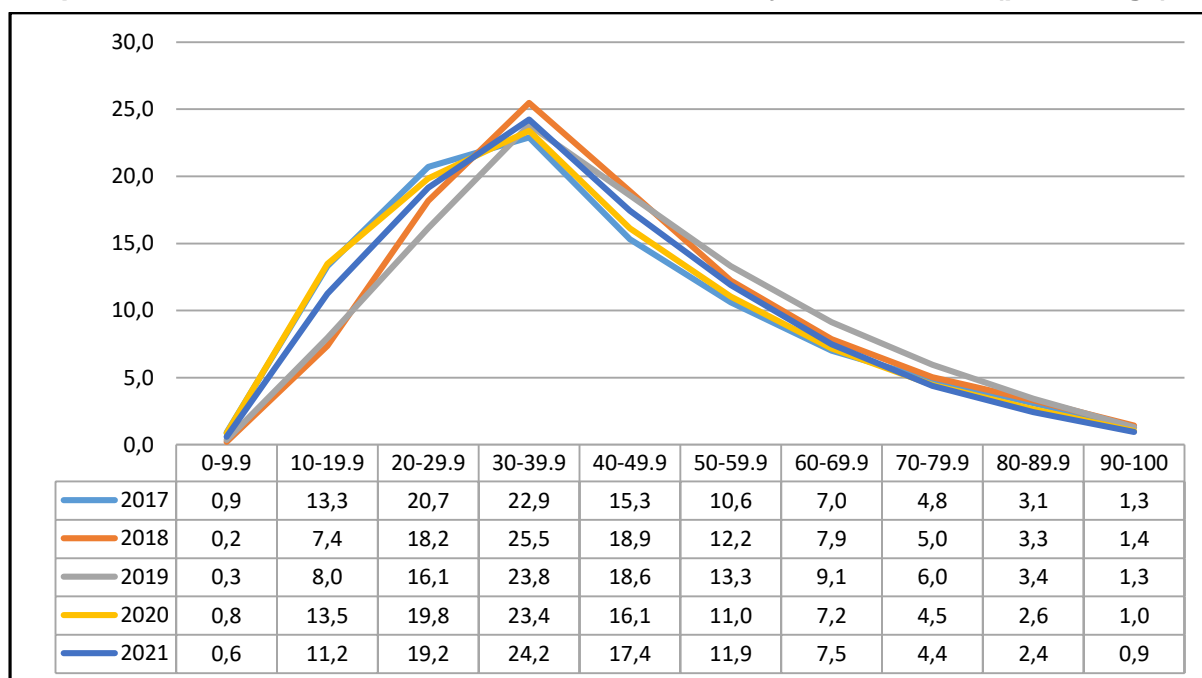
Candidates who passed at 30% (Level 2) improved from 65,8% in 2020 to 69,0% in 2021. There was a corresponding improvement at 40% (Level 3) from 42,4% to 44,8%. Given the increase in the size of the cohort, the number of passes increased considerably by 21 157 at 30% (Level 2) and by 14 182 at 40% (Level 3).

The percentage of distinctions (over 80%; Level 7) declined marginally from 3,6% to 3,3%. This converts into an increase in the total number of distinctions from 6 275 in 2020 to 6 500 in 2021.

The results reflected above were despite the challenging circumstances brought about by the Covid-19 pandemic over the past two years which affected teaching and learning activities of the 2021 cohort. This appears to have been the result of creative intervention strategies by teachers and subject advisors as well as schools and provincial education departments. The resourcefulness and diligence of the above-average candidates also contributed to the overall performance in the subject.

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
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
2020	174 310	114 758	65,8	73 982	42,4
2021	196 968	135 915	69,0	88 164	44,8

Graph 11.1.1   Overall achievement rates in Physical Sciences (percentage)

	2017	2018	2019	2020	2021
■ % achieved at 30% and above	65,1	74,2	75,5	65,8	69,0
■ % achieved at 40% and above	42,2	48,7	51,7	42,4	44,8

Graph 11.1.2   Performance distribution curves in Physical Sciences (percentage)

	0-9.9	10-19.9	20-29.9	30-39.9	40-49.9	50-59.9	60-69.9	70-79.9	80-89.9	90-100
2017	0,9	13,3	20,7	22,9	15,3	10,6	7,0	4,8	3,1	1,3
2018	0,2	7,4	18,2	25,5	18,9	12,2	7,9	5,0	3,3	1,4
2019	0,3	8,0	16,1	23,8	18,6	13,3	9,1	6,0	3,4	1,3
2020	0,8	13,5	19,8	23,4	16,1	11,0	7,2	4,5	2,6	1,0
2021	0,6	11,2	19,2	24,2	17,4	11,9	7,5	4,4	2,4	0,9

General comments on Paper 1 and Paper 2

The question in Paper 1 on the Doppler effect and the multiple-choice questions were generally well answered. Performance pertaining to organic nomenclature and physical properties of organic compounds in Paper 2 was good. The questions on electrolytic cells in Paper 2 were very poorly answered.

Questions pertaining to pure recall of content were very poorly answered because key words 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*.

Interpretation of graphs is still 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. Practical work needs more attention in schools to ensure learners are able to apply practical skills, e.g. identification of variables, drawing of conclusions, interpretation of results and drawing and interpretation of graphs.

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.
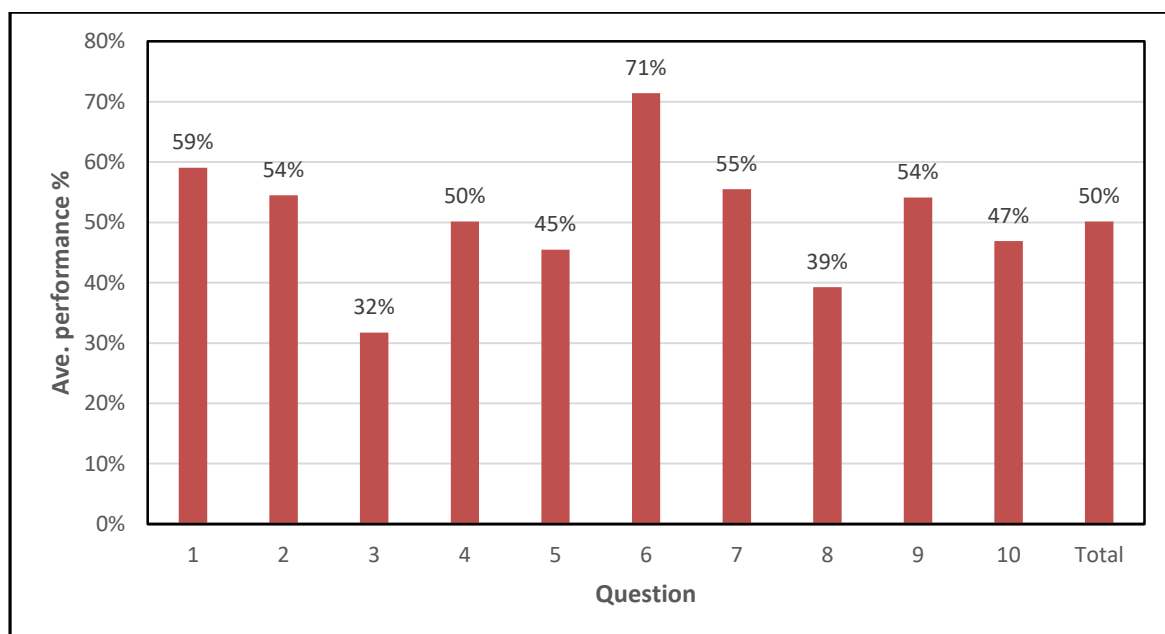
11.2   OVERVIEW OF CANDIDATES' PERFORMANCE IN PAPER 1

General comments

(a)   Question 1 (multiple-choice questions – ALL topics) and the question on the Doppler effect were generally well answered.

(b)   In many questions, candidates made the same errors and displayed the same poor conceptual understanding as in previous years. Provinces should mediate the effective implementation of the recommendations in this diagnostic report.

(c)   Questions pertaining to pure recall of content were very poorly answered because key words 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)   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.

(e)   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

There was an improvement in performance in five questions, viz. multiple-choice questions (Q1), Doppler effect (Q6), electrostatics (Q7), electrodynamics (Q9) and photoelectric effect (Q10) as compared to 2020. There was a decline in performance in each of the other five questions.

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 performance per question in Paper 1

Q	Topics	Q	Topics
1	Multiple-choice Questions	6	Doppler Effect
2	Newton's Laws of Motion	7	Electrostatics (Coulomb's Law & Electric Fields)
3	Vertical Projectile Motion	8	Electric Circuits
4	Momentum and Impulse	9	Electrodynamics: Motors, Generators & Alternating Current
5	Work, Energy and Power	10	Photoelectric Effect

Graph 11.3.2   Average performance per subquestion in Paper 1
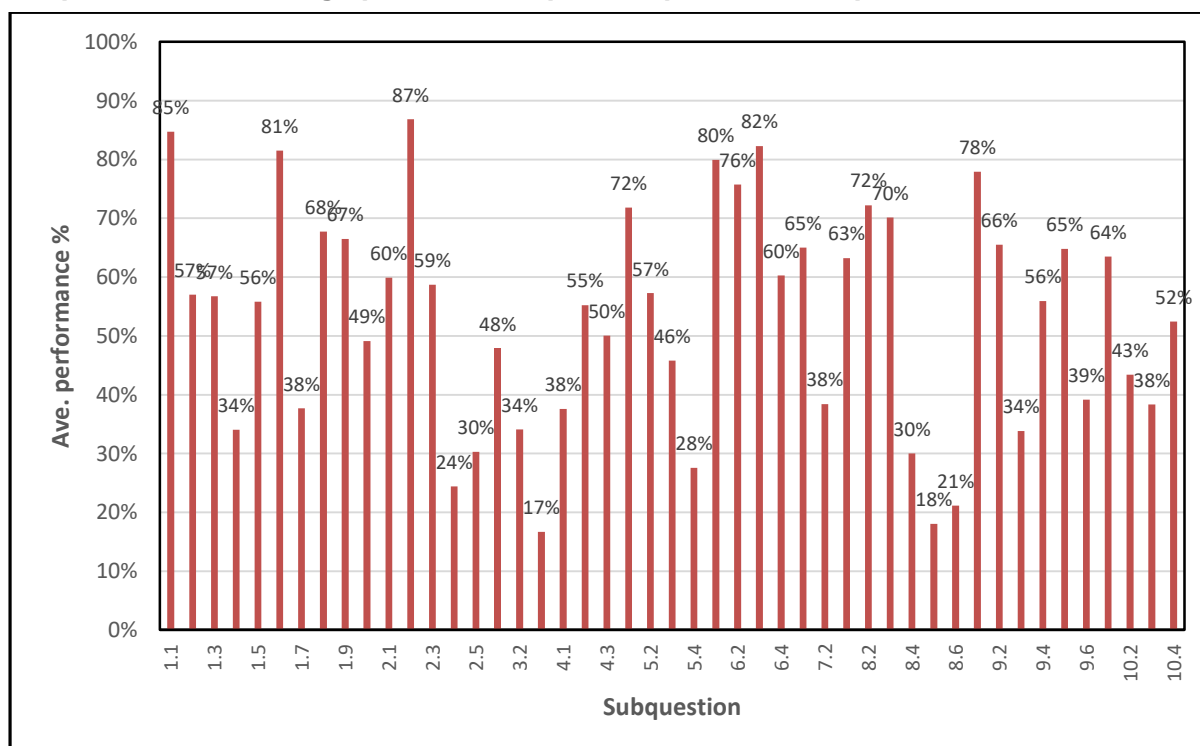
SubQ	Topic	SubQ	Topic
1.1	Normal force – definition	5.4	Calculating change in kinetic energy
1.2	Free fall	6.1	Wavelength of detected sound
1.3	Rate of change of momentum	6.2	Stating Doppler effect
1.4	Conservation of mechanical energy	6.3	Distance and frequency: wave fronts
1.5	Doppler shift	6.4	Calculating speed of ambulance
1.6	Electric field	7.1	Electrons & electric fields
1.7	Coulomb's law	7.2	Calculating the magnitude of charge
1.8	Electric circuits	8.1	Reading on V_1 and V_2
1.9	Electrodynamics	8.2	Defining term power
1.10	Emission and absorption spectra	8.3	Calculating resistance of resistor X
2.1	Definition: Newton's First Law of Motion	8.4	External resistance of circuit
2.2	Drawing a free-body diagram	8.5	Calculating reading on V_2
2.3	Calculating force: Newton's 2nd Law	8.6	Explaining how V_1 affected
2.4	Net force; when applied force removed	9.1	Component: AC and DC generator
2.5	Calculating distance between X and Y	9.2	Direction of current in coil
3.1	Identifying if balloon is in free fall	9.3	Defining rms potential difference
3.2	Calculating speed of hot-air balloon	9.4	Calculating rms current
3.3	Sketching position-time graph	9.5	Calculating power in 25 Ω resistor
4.1	Explaining term elastic collision	9.6	Sketching V vs Δt graph
4.2	Calculating velocity of Y	10.1	Defining threshold frequency
4.3	Calculating magnitude net force X exerts on Y	10.2	Comparing $E_{k(max)}$ for M and N
5.1	Defining mechanical energy	10.3	Calculating f_x
5.2	Calculating speed of box	10.4	Y-intercept, No. of photo electrons, $E_{k(max)}$
5.3	Calculating frictional force		

11.4 ANALYSIS OF CANDIDATES' PERFORMANCE IN EACH QUESTION IN PAPER 1

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Common errors and misconceptions

(a)   In Q1.3 many candidates did not realise that the net force is given by the gradient of the graph at different time intervals.

(b)   In Q1.4 many candidates did not recall that the total mechanical energy is conserved in elastic collisions.

(c)   In Q1.7 candidates did not realise that when Coulomb's law is applied, the charges exert forces of equal magnitude on each other.

(d)   Candidates lacked an understanding of the basic concept of the *emission* and *absorption spectra* in Q1.10.

Suggestions for improvement

(a)   Multiple-choice questions test learners' understanding of concepts, principles, laws and the relationship between the dependent, independent and constant variables. This 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 the making of predictions.

(b)   Learners must also be encouraged to refer to the formula sheet because it gives the summaries of laws and principles as well as the relationship between the variables.

(c)   Teachers must include the use of ICT in the teaching of the subject. Multimedia/Software such as *PhET* and *Edukite* as well as YouTube videos should be used to demonstrate the answers for multiple-choice questions through simulations (virtual experiments).

(d)   It is recommended that a booklet containing multiple-choice questions from different topics, from different sources, such as previous NSC and provincial papers and text books, be prepared. The booklet should also have a step-by-step explanation of how to answer multiple-choice questions.

QUESTION 2: NEWTON'S LAWS OF MOTION

Common errors and misconceptions

(a)   In Q2.1 candidates omitted key words in their definition such as:
- Straight line when referring to constant speed
- Net when referring to force
- State of rest
- Motion at constant velocity

(b)   Many candidates labelled their free-body diagram incorrectly; they also omitted arrows and labels in the free-body diagrams and drew forces that were not in contact with the body.

(c)   Some candidates failed to realise that $F_{net} = 0$ at constant velocity, due to the fact that acceleration equals zero.

(d)   Many candidates did not realise that when the force F was removed, Newton's Second Law becomes applicable and the acceleration on the incline had to be calculated.

Suggestions for improvement

(a)   Teachers should adhere to and emphasise the definitions in the *Examination Guidelines* and *CAPS*. Key words 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. A method of solving simultaneous equations can be used to solve for the unknown in the equation and this method should be taught thoroughly in class. Encourage learners to use different problem-solving strategies to solve the same problem to ensure that they gain a greater understanding of the problem and their solutions.

(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) Once again, many candidates failed to realise that the balloon was moving upwards at a constant velocity and therefore $F_{net} = 0$ and not $F_{net} = mg$.

(b) Candidates did not realise that the initial velocity of both stone A and stone B is the same as that of the balloon and also applied incorrect sign conventions to the vector quantities.

(c) Many candidates failed to interpret the motion of stone A and the balloon and therefore could not sketch the graphs correctly. Common errors noted were:
- The graphs did not start at the same point.
- The graphs were not labelled.
- The gradient of the graph of the balloon is higher than that of the stone until it reaches maximum height.

Suggestions for improvement

(a) Learners must be advised to start every calculation in mechanics, including vertical projectile motion, by indicating the sign convention at the beginning of the problem. Emphasise that the direction of gravitational acceleration does not change in a question but remains constant. Learners should be advised to keep to ONE sign convention when solving a problem and not to change their chosen sign convention within a problem as this could lead to confusion.

(b) Teach learners skills of interpreting and sketching graphs especially for projectiles, e.g. to have reference points and collect all relevant data before calculating any quantity.

(c) Learners should be exposed to several questions involving different scenarios of projectile motion, including two or three objects as was asked in this question.

QUESTION 4: MOMENTUM AND IMPULSE

Common errors and misconceptions

(a) In Q4.1 many candidates could not explain the concept of an *elastic collision*.

(b) Some candidates could not differentiate between the initial and final velocities in their substitution into the equation $F_{net}\Delta t = m\Delta v$.

Suggestions for improvement

(a) Teachers should integrate topics (as and when necessary) in addition to teaching each topic in isolation. Moreover, they should expose learners to problems that integrate the application of different concepts.

(b) The vector nature of momentum and impulse should be emphasised during teaching.

QUESTION 5: WORK, ENERGY AND POWER

Common errors and misconceptions

(a)   The common error in stating the principle in Q5.1 was the omission of keys words 'total' and 'isolated'.

(b)   Many candidates made use of the equations of motion in Q5.2 even though it was stipulated that the principle of conservation of mechanical energy should be used. Equations of motion cannot be used in this question as the motion from P to Q is not in a straight line.

Suggestions for improvement

(a)   Use the statement $(E_p + E_k)_P = (E_p + E_k)_Q$ to demonstrate the principle of conservation of mechanical energy. If $W_{nc} = \Delta E_p + \Delta E_k$ make sure that learners realise that $W_{nc} = 0$ because of the absence of non-conservative forces.

(b)   Work done by a force is always equal to the change in energy:
e.g. $W_{net} = \Delta E_k$, $W_{nc} = \Delta E_p + \Delta E_k$, $W_w = -\Delta E_p$

(c)   When using $W_{nc} = \Delta E_p + \Delta E_k$ or $W_{net} = \Delta E_k$, the identification of forces acting on the object is very important and therefore the use of free-body diagrams is advised.

(d)   Use *PhET* simulations for the identification of forces acting on objects.

QUESTION 6: DOPPLER EFFECT

Common errors and misconceptions

(a)   Candidates used the equation for the speed of light ($c = f\lambda$) instead of the equation for the speed of sound in air ($v = f\lambda$) to calculate the wavelength of the detected sound.

(b)   Several candidates omitted key words, i.e. 'change' and 'relative motion' in the definition of the Doppler effect.

(c)   Candidates did not realise that they had to subtract the 0,05 m from the wavelength of the emitted sound (0,5 m) in order to calculate the frequency of the detected sound. Instead, they used the 0,05 m as the wavelength of the detected sound.

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: $v = f\lambda$,

(c)   Teachers must emphasise the progression of knowledge since the work done in Grade 12 cannot be seen in isolation from work done in Grade 10 and Grade 11.

(d)   Expose learners to *PHET* simulations, YouTube videos and the *Ten Fold* app to demonstrate the Doppler effect.

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

Common errors and misconceptions

(a)   Candidates described an electric field instead of defining the 'electric field at a point'.

(b)   Candidates were not able to establish the superposition of electrostatic forces when there is a net electrostatic force.

(c)   Candidates swopped/mixed the formulae for E and F as follows: $F = k\frac{Q}{r^2}$ and $E = k\frac{Q_1Q_2}{r^2}$.

(d)   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 to learners 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 $E=\frac{kQ}{r^2}$ and explain to learners what charge the 'q' in $E=\frac{F}{q}$ represents and what charge the 'Q' in $E=\frac{kQ}{r^2}$ represents.

(c)   Teachers should emphasise the difference between electrostatic force and electric field as well as the equations thereof.

(d)   Teachers should emphasise the application of the principle of superposition of electric fields and electrostatic forces.

QUESTION 8: ELECTRIC CIRCUITS

Common errors and misconceptions

(a)   Many candidates had difficulty interpreting the circuit. They failed to identify which resistors were in series and which were in parallel and therefore could not apply the relevant principles of resistors in series and parallel.

(b)   Many candidates failed to identify the series-parallel network in the circuit and calculated R_{ext} as: $R_{ext} = (\frac{1}{6}+\frac{1}{6})^{-1}+2,4+4 = 9,4\ \Omega$

Suggestions for improvement

(a)   Although the principles of series and parallel circuits are taught from Grade 9, the basic principles should be revisited and practised constantly. The critical features of series and parallel circuits with and without internal resistance must be emphasised.

(b)   The effect of any short circuit or bridging of resistors in a circuit is:
A decrease in total resistance in the circuit, an increase in total current in the circuit and therefore an increase in $V_{internal}$.

(c)   Use *PhET* simulations to demonstrate the relationship between V_{ext} and V_{int} and the effect of adding resistors or removing resistors in series and parallel can also be demonstrated.

QUESTION 9: ELECTRODYNAMICS

Common errors and misconceptions

(a)   Many candidates had difficulty in defining the term 'rms potential difference'.

(b)   Many candidates still omit the subscripts 'rms' and 'ave' in the equations $P_{ave} = V_{rms}I_{rms}$, $P_{ave} = I^2_{rms}R$ and $P_{ave} = \dfrac{V^2_{rms}}{R}$.

(c)   Many candidates failed to recognise that doubling the speed of rotation of the coil would double the frequency (2f) and hence halve the period of the wave (½T) and double the output voltage.

Suggestions for improvement

(a)   The Grade 11 work on electromagnetic induction must be revised in Grade 12 when motors and generators are discussed.

(b)   Emphasis should be placed on the use of subscripts in the formulae when rms calculations are done.

(c)   The differences and similarities between V_{rms} and V_{max}, I_{rms} and I_{max}, P_{ave} and P_{max} must be explained clearly and sufficient application type questions must be given to learners.

(d)   Khan Academy, *PhET* and *Edukite* are also very useful resources for teachers especially for topics that have many practical aspects.

QUESTION 10: PHOTOELECTRIC EFFECT

Common errors and misconceptions

(a)   Many candidates could not relate the straight-line graph to the equation:
$hf = W_0 + E_{k(max)}$ and could not interpret f_x as the frequency of the incident light.

(b)   Many candidates failed to realise that the intensity of light has no influence on the maximum kinetic energy of the emitted photoelectrons.

(c)   Many candidates omitted the subscript 'max' in the equation: $E = W_0 + E_{k(max)}$.

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)   Teachers must emphasise and ensure that learners understand what causes a change in the number of photoelectrons per unit time and the maximum kinetic energy of the emitted photoelectrons.

(c)   Questions on new situations where an interpretation of graphs is required should be compiled and provided to the learners on the photoelectric effect. Also use graphs to highlight concepts such as work function and threshold frequency.

(d)   The formula $hf = hf_0 + E_{k(max)}$ should be related to the equation of a straight line, $y = mx + c$. Dividing the whole equation by h yields $f = f_0 + \dfrac{E_{k(max)}}{h}$ where $\dfrac{1}{h}$ is the gradient of the straight line and f_0 is the threshold frequency (y-intercept of the straight line).

11.5   OVERVIEW OF CANDIDATES' PERFORMANCE IN PAPER 2

General comments

(a)   As in previous years' performance pertaining to organic nomenclature and physical properties of organic compounds, (Q2, Q3) was good.

(b)   The performance in the question pertaining to acids and bases (Q7) improved from previous years' performances.

(c)   The questions on organic reactions (Q4), reaction rate (Q5) and electrolytic cells (Q9) were very poorly answered.

(d)   Many candidates struggled to use their calculators correctly and failed to get the correct answer when calculating the acid concentration from the pH (Q7) and when performing calculations where small numbers are written in scientific notation (Q6).

(e)   From the performance in Q5 it is evident that practical skills did not receive much attention in 2021. Candidates had trouble in interpreting the given graph.

(f)   Lack of knowledge and skills to answer questions involving stoichiometry contributed to poor performance in Q5, Q6, Q7 and Q9.

(g)   The writing of definitions correctly is a challenge to many candidates. Key words were often omitted or words in definitions were replaced with their own wording or explanations, resulting in partially correct definitions.

(h)   Most candidates did not know how to use the Table of Standard Reduction Potentials correctly, which caused the poor performance in some of the subquestions in Q8.

(i)   Rounding off answers to two decimal places in each step of a multistep calculation led to some candidates obtaining final answers that were different from the accepted ranges in those questions. Rounding off to two decimal places should only be done in the final answer to a subquestion.

(j)   There is still a high percentage of candidates who performed poorly due to common consistent mistakes that can be avoided if they prepare well for the examination. These mistakes have no bearing on the difficulty level or the content tested. Many candidates

lost valuable marks due to these avoidable errors. This must be resolved through proper teaching and learning. Examples of mistakes are:
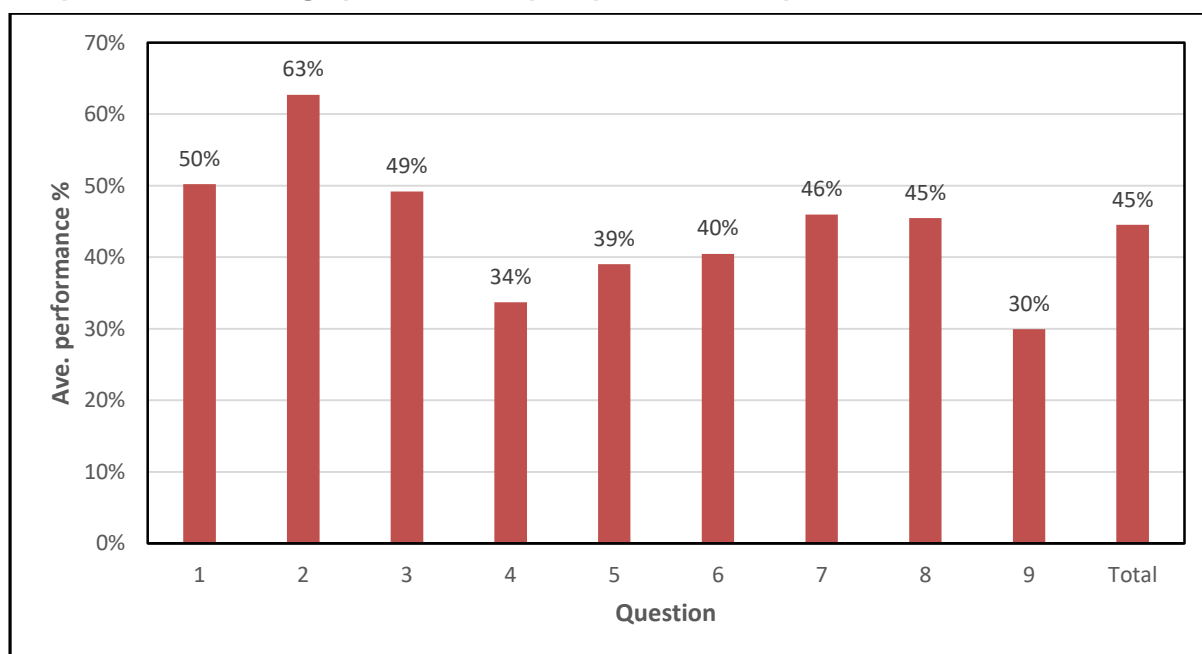
- Incorrect numbering of questions
- In calculations, using values incorrectly copied from the question paper
- Incorrect copying of formulae from the data sheet
- Substituting values different from those supplied on the periodic table or constant tables
- No units provided in final answers
- Omitting the minus sign in unit for concentration (mol·dm3 instead of mol·dm-3) or including a minus sign when writing unit of volume (cm-3 instead of cm3)
- Omitting H atoms and/or bond lines when drawing structural formulae of organic compounds.

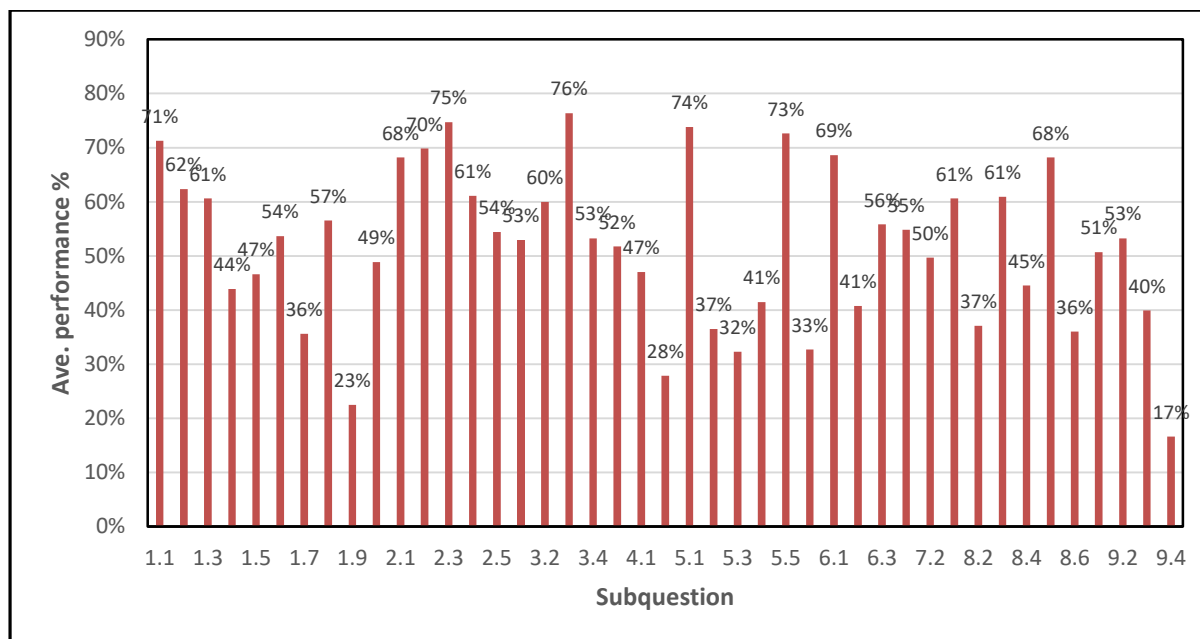## 11.6 DIAGNOSTIC QUESTION ANALYSIS OF PAPER 2

Performance improved in only three questions, namely multiple-choice questions (Q1) nomenclature of organic compounds (Q2) and acids and bases (Q7), as compared to 2020. Whilst there was a significant improvement in the performance of Q7 (acids and bases), the performance in Q4 (organic reactions) showed a decline of more than 10%. Performance in electrolytic cells (Q9) is similar as in 2020.

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 performance per question in Paper 2

Q	Topic	Q	Topic
1	Multiple-choice Questions	6	Chemical Equilibrium
2	Organic Nomenclature and Structures	7	Acids and Bases
3	Physical Properties of Organic Molecules	8	Galvanic Cells
4	Organic Reactions	9	Electrolytic Cells
5	Rates of Reaction		

Graph 11.6.2   Average performance per subquestion in Paper 2

SubQ.	Topic	SubQ	Topic
1.1	Defining condensed structural formula	5.1	Definition of reaction rate
1.2	Hydrogen bonding	5.2	Interpreting gradient of the graph
1.3	IUPAC name of a ketone	5.3	Explanation in terms of graph
1.4	Limiting reactants; effect on yield	5.4	Stoichiometric calculation, percentage purity
1.5	Boltzmann distribution curve	5.5	Effect of impurities on reaction rate
1.6	K_c expression	5.6	Effect of impurities on rate, collision theory
1.7	pH, rate, neutralisation	6.1	Definition of chemical equilibrium
1.8	Conjugate acid-base pairs	6.2	Le Chatelier's principle and K_c calculation
1.9	Migration of ions in the galvanic cell	6.3	Effect of reactant on yield of reaction
1.10	Refining of copper	7.1	Lowry-Brønsted theory, conductivity, K_a values
2.1	Definition of unsaturated compounds	7.2	Concentration from pH; Stoichiometric calculation
2.2	Ketones, chain isomer, IUPAC name	8.1	Energy conversion in a galvanic cell
2.3	Definition of functional isomers	8.2	Standard concentration of electrolyte
2.4	Ethanoic acid; functional isomer of ethanoic acid	8.3	Definition of a reducing agent
2.5	Dehydration of an alcohol	8.4	Reducing agent and cell reaction
3.1	Definition of melting point	8.5	Calculation of initial emf
3.2	Drawing a conclusion	8.6	Effect of change in concentration of emf
3.3	Type of intermolecular force	9.1	Definition of an electrolyte
3.4	Data to determine phases of compounds	9.2	Identify the cathode
3.5	Molecular mass and boiling point of two isomers	9.3	Half-reaction taking place at object to be plated
4.1	Products formed, NaOH, reaction of alkene & HBr	9.4	Total charge transferred
4.2	Synthesis of 1,2-dibromopropane		

11.7   ANALYSIS OF CANDIDATES' PERFORMANCE IN EACH QUESTION IN PAPER 2

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Common errors and misconceptions

(a)   Q1.1 was the subquestion answered best. Most candidates were familiar with the term *condensed structural formula*.

(b)   In Q1.2 many candidates failed to identify the alcohol from its molecular formula as the compound with hydrogen bonds between molecules. The most common incorrect answer was *C*. Such candidates most probably thought that $CH_3COOCH_2CH_3$ is a carboxylic acid.

(c)   The most common incorrect answer in Q1.3 was *B*. These candidates, after identifying the position of the functional group, failed to number such that the substituent obtains the lowest number.

(d)   Most candidates did not know that the yield (amount) of product formed (Q1.4) is determined by the limiting reagent which is magnesium and not the acid which is in excess. Many chose *D* as the answer, thinking that a higher acid concentration will increase yield. The difference between yield (how much) and rate (how fast) was not well understood.

(e)   Those who got Q1.5 wrong, mainly chose *B* (increase in temperature) as the answer. Many candidates failed to link *more particles* shown on the *y*-axis to a *higher concentration*.

(f)   In Q1.6 some candidates chose options that include pure liquids or solids in the K_c expression.

(g)   Most candidates failed to relate the strength of acids to ion concentration and the effect on reaction rate in Q1.7. Of the two acids in question, the stronger acid has more particles per unit volume and will therefore react at the faster rate.

(h)   In Q1.8 some candidates did not know that the conjugate base can be obtained by removing H^+ from the given ion. The most common incorrect answer was *C* which represents the conjugate acid, obtained by adding H^+ from the given ion instead.

(i)   Q1.9 was the poorest answered multiple-choice question. Most candidates showed a poor understanding of the migration of ions between the half-cells and the salt bridge in a galvanic cell.

(j)   Most candidates (Q1.10) failed to link the impure copper to oxidation and chose *C* as answer. The process of refining of copper is poorly understood.

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 used in assessments on a regular basis for all topics covered.

(b)   Subject advisors should compile a booklet of multiple-choice questions arranged according to topics for schools. These questions can be used for weekly assessments. Through discussions, learners can then be shown how to approach such questions.

(c)   Learners should be taught how to determine the conjugate base or conjugate acid from a given species:
Conjugate acid: ADD H^+ to the given compound or ion
Example: Conjugate acid of $H_2PO_4^-$: $H_2PO_4^- + H^+ \rightarrow H_3PO_4$
Conjugate base: REMOVE H^+ from the given compound or ion
Example: Conjugate base of $H_2PO_4^-$: $H_2PO_4^- - H^+ \rightarrow HPO_4^{2-}$

(d)   The migration of ion in a galvanic cell must be explained to learners:
The concentration of positive ions (cations) increases in the anode half-cell due to oxidation and therefore negative ions must migrate towards the anode half-cell to balance the excess positive charge.

The concentration of negative ions (anions) increases in the cathode half-cell due to reduction and therefore positve ions must migrate towards the cathode half-cell, as illustrated below, to balance the excess negative charge. When the solution in the salt bridge is saturated, ions will move from the salt bridge into the half-cells and not the other way round.
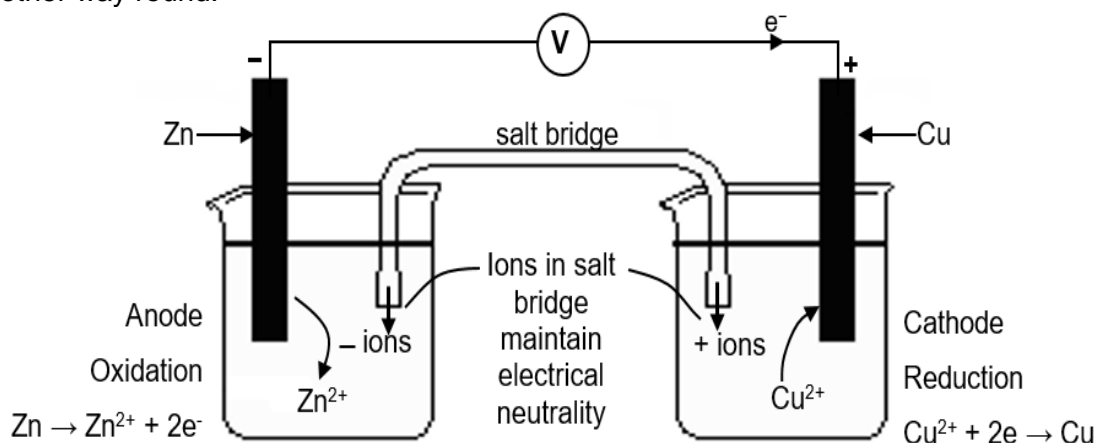
(e)   Learners should be exposed to the different types of electrolytic cells prescribed for Grade 12. The functioning of each type of cell should be well explained to ensure that learners can apply their knowledge to unfamiliar situations. The types of electrolytic cells are:
- Electrolysis of a concentrated sodium chloride solution (inactive electrodes)
- Electrolysis of a concentrated copper (II) chloride solution (inactive electrodes)
- Refining of copper – electrolysis of a concentrated copper (II) chloride solution (active electrodes)
- Electroplating

QUESTION 2: ORGANIC NOMENCLATURE

Common errors and misconceptions

(a)   Some candidates wrote that the *multiple bonds or double bonds are between carbon and hydrogen* atoms and forfeited both marks in Q2.1.1. Other common incorrect answers were:
- *Compounds with one or more bonds*
- *Compounds with no single bonds*
- *Compounds with triple, double and single bonds*

(b)   In Q2.2.2 many candidates confused the name of the functional group (carbonyl group) with the name of the homologous series (ketones). Others identified compound C as a carboxylic acid and consequently gave the incorrect name for the functional group.

(c)   Although Q2.2.4 was well answered, the naming of haloalkanes is still a challenge. Incorrect sequencing of substituents and/or omission or incorrect use of commas and

hyphens were often found in answers of candidates. Some candidates did not write substituents in alphabetical order and 3-methyl-2,5-dichlorohexane was a common incorrect answer. Another common error was the use of *chloro* instead of *dichloro* in the IUPAC name. Some candidates used *dichlorine* or *dichloride* instead of *dichloro*.

(d)   Q2.2.5 was well answered but some mistakes were C_nH_{2n+2} or C_nH_n.

(e)   When writing the definition of functional isomers in Q2.3, many candidates forfeited marks due to the use of incorrect words or terms. For example, *general formula* instead of *molecular formula* or *different positions of the functional group* instead of *different functional groups* were often found.

(f)   Although Q2.4.1 was well answered, some candidates omitted the word *acids* and only wrote *carboxylic*. A few candidates wrote *carboxyl acid* instead of *carboxylic acid*.

(g)   In Q2.4.2 many candidates did not know that carboxylic acids and esters are functional isomers. Many did not understand what functional isomers are, even though they know the definition.

(h)   Some candidates wrote the structural formula of the functional group of esters instead of the structural formula of methyl methanoate.

(i)   Most candidates knew that the answer is ethanol (Q2.5.1) but wrote it incorrectly, e.g. ethan-1-ol or 1-ethanol or ethanal. Some gave the homologous series, i.e. *alcohol* as the answer.

(j)   A common incorrect answer in Q2.5.3 was *NaOH*. Another misconception was that H_2O is needed for dehydration.

Suggestions for improvement

(a)   When writing IUPAC names, the following should be emphasised:
   - Use hyphens and commas correctly.
   - The prefixes, *di*, *tri* etc. are used to indicate more than one of the same types of substituents.
   - When a compound has only two carbon atoms, numbering must not be used to indicate the position of the functional group, e.g. it should be ethanol and not ethan-1-ol.
   - The position of functional group in the IUPAC name of haloalkanes must always be indicated for compounds containing two or more C atoms.
   - Substituents must be written in alphabetical order in IUPAC names regardless of their position in the longest chain. Numbers of substituents cater for the position of substituents in the longest chain.

(b)   When drawing structural formulae, learners should be encouraged to count the number of bonds drawn around atoms to eliminate unnecessary errors. They need to be reminded that a carbon atom cannot have less than or more than 4 bonds around it.

(c)   Teachers must ensure that learners know that ketones and aldehydes are functional isomers, and that carboxylic acid and esters are functional isomers. Such questions occur in papers every year and should be easy for learners to answer.

(d) Frequent informal tests should be used to ensure that learners write definitions correctly. Often, learners write different interpretations of a definition, and they usually end up with incorrect or partially correct statements.

(e) Emphasise the difference between molecular formulae, structural formulae and condensed structural formulae. Use condensed structural formulae more often in exercises to assist learners to interpret such formulae.

(f) Practical work will assist learners to understand and remember certain chemical reactions. For example, the reaction of concentrated H_2SO_4 with sugar can be demonstrated to learners to explain to them that H_2SO_4 is a dehydrating agent.

QUESTION 3: PHYSICAL PROPERTIES OF ORGANIC COMPOUNDS

Common errors and misconceptions

(a) Omission of keywords in the definition of melting point (Q3.1) cost many candidates one or two marks. Some omitted the word *temperature* and others the word *equilibrium*. Some candidates wrote the definition of boiling point or vapour pressure.

(b) In Q3.2 some candidates forfeited two marks because they failed to identify the independent variable, i.e. the chain length. Some of those who identified the independent variable correctly, failed to state the correct relationship between the independent variable (chain length) and the dependent variable (melting point), i.e. the higher the melting point, the longer the chain length.

A common incorrect answer was that *an increase in chain length leads to a decrease in melting point*. Such candidates interpreted the values in the table as decreasing from pentane to octane.

Some candidates wrote conclusions irrelevant for the given situation, e.g. *as the number of carbons increases, the boiling point increases,* or *as the number of carbons increases, the melting point decreases,* or *the melting point is directly proportional to the number of carbon atoms*.

(c) Q3.3 was well answered. Some candidates wrote *Van der Waals forces* which is given in the question. Others incorrectly gave *dipole-dipole forces* instead of *induced dipole forces* as the answer.

(d) Lack of skills to interpret negative values for melting points (Q3.4) cost many candidates marks in this question. They did not know that -100 °C is between -130 °C and 36,1 °C and therefore pentane will be liquid at -100 °C. A similar error also caused them to answer Q3.4.1 incorrectly.

(e) In Q3.5.1 a few candidates failed to identify that hexane and 2,2-dimethylbutane are chain isomers and were only guessing the answer. This also affected their answers in the other two subquestions.

(f) In the explanation in Q3.5.3, a few candidates mentioned that the intermolecular forces in 2,2-dimethylbutane is hydrogen bonding and forfeited the second mark. Many candidates wrote *less energy is needed to overcome the bonds* and forfeited the third mark. Some referred to b*onds between atoms* instead of *intermolecular forces* or just stated that *hexane needs more energy* without stating what the energy is needed for.

Suggestions for improvement

(a)   Most definitions are stated in the *Examination Guidelines* and teachers must ensure that learners study the definitions through regular informal tests.

(b)   Practical skills need to be taught from Grade 10 to Grade 12. Learners lack skills such as identification of variables and writing of conclusions. The difference between an investigative question, a hypothesis and a conclusion should be thoroughly explained.

(c)   Teachers must expose learners to tables with negative values for melting points and temperatures and explain to them that a greater negative value implies a smaller melting point or temperature.

(d)   When discussing intermolecular forces, the concepts *atoms*, *molecules* and *ions* should be revised. Emphasise the difference between bonds between atoms in molecules (intramolecular) and forces between molecules (intermolecular) and that the strength of intermolecular forces are responsible for the different phases. Interatomic or intramolecular forces, which are much stronger than intermolecular forces, are formed or broken during chemical reactions when new compounds are formed. Intermolecular forces are overcome (not broken) during phase changes.

(e)   When writing explanations related to physical properties of compound, learners should be taught to follow the following steps:
  - Comparing two compounds from the same homologous series:
    - Compare the surface areas of the molecules.
    - Compare the strength of intermolecular forces.
    - Compare the energy needed to overcome intermolecular forces.
  - Comparing two compounds from different homologous series:
    - State the type of intermolecular force in each compound.
    - Compare the strength of these intermolecular forces.
    - Compare the energy needed to overcome intermolecular forces.

QUESTION 4: REACTIONS OF ORGANIC COMPOUNDS

Common errors and misconceptions

(a)   Although well answered, the difference between the reaction of a haloalkane with dilute NaOH (Q4.1.1) and the reaction with concentrated NaOH (Q4.1.4) was a challenge to some candidates and reaction II was identified as a substitution.

(b)   Q4.1.2 was well answered. Common errors when giving a reason why the compound is a primary alcohol were:
  - Referring to the - OH group as a hydroxide ion
  - Using OH^- instead of - OH in explanations
  - Stating that *oxygen is connected to the terminal carbon*
  - Stating that an alcohol is bonded to the first carbon
  - Not mentioning the functional group and just stating that the molecule has one carbon bonded to another carbon

(c)   A common incorrect structural formula in Q4.1.3 was that of 1-bromopentane instead of 1-bromo-2-methylbutane. Such candidates ignored the product formed in reaction I before deciding on the structural formula compound P. The product of reaction I provided the key to identification of the structural formula.

Other common errors were:
- Placing the Br atom on C2 instead of C1 of the chain
- Using BR or br instead of Br as the symbol for bromine
- Drawing the structural formula for 2-bromopentane

(d)   The most common incorrect answer to Q4.1.5 was *alcohol*. Candidates did not know that the reaction of a haloalkane with a concentrated strong base gives an alkene as product. The lack of this basic knowledge affected answers in Q4.1.4, Q4.1.5 and Q4.1.7.

(e)   In Q4.1.6 candidates had to choose between the three types of reactions given in the question paper. Some deduced from the HBr given as reactant that the reaction should be a *hydrohalogenation* but did not link it to an addition reaction. Others incorrectly thought it is a *dehydrohalogenation*.

(f)   Q4.1.7 was poorly answered and many candidates left it unanswered. The most common incorrect answers were *1-bromopentane* or *2-bromopentane*.

(g)   In Q4.2 most candidates lacked the necessary skills to analyse the question and come up with a complete solution. Subquestions could not be answered in isolation without analysing the data given in the question.

Q4.2.2 (identification of the cracking reaction) was the best answered subquestion, followed by Q4.2.1 (hydrogenation of but-2-ene). Very few candidates obtained marks for Q4.2.3 and Q4.2.4, possibly because they did not see the link between the 4-carbon starting reactant and the final product containing only 3 C atoms.

Some candidates wrote only the condensed structural formula of either the reactant or product instead of a full equation in Q4.2.1 and Q4.2.4.

Other common errors were:
- Using molecular or structural formulae instead of condensed structural formulae when writing equations (Q4.2.1, Q4.2.4)
- Using incorrect condensed structural formulae for the compounds given in the question (Q4.2.1, Q4.2.4)
- Omitting the arrow when writing a chemical equation (Q4.2.1, Q4.2.4)
- Writing the IUPAC name of propene as propan-1-ene (Q4.2.3)
- Using HBr instead of Br_2 as reactant in step 3 to obtain 1,2, dibromopropane (Q4.2.4)

Suggestions for improvement

(a)   Emphasise the difference between structural, condensed structural, molecular, general and empirical formulae.

(b)   Ensure that learners know that the rules applicable to the writing of balanced equations are also valid when writing balanced equations using structural or condensed structural formulae. An equation must have a reactant or reactants followed by an arrow and then the product(s).

(c)   Learners must be given more opportunities to solve flow diagrams related to organic reactions to improve analysing skills. Sometimes, working backwards from the final answer is needed to determine compounds/reactions in the first steps. The full diagram should be analysed before answering subquestions as all the questions are linked.

Learners need a thorough knowledge of the different prescribed organic reactions and their conditions to analyse such diagrams. They must be prepared to analyse given data and devise steps to prepare a given compound using the reactants supplied.

(d) Subject advisors should assist teachers in compiling summaries on the different types of reactions and their conditions to enable learners to memorise the required facts.

(e) Conditions under which reactions of organic compounds occur should be emphasised.

(f) Emphasise that cracking is an elimination reaction in which *LONGER hydrocarbon chains can be broken down into SHORTER MORE USEFUL molecules*. Unsaturated hydrocarbons of any length can undergo cracking to produce shorter more useful molecules such as ethene and propene which are used as starting materials in the production of different synthetic polymers. During a cracking reaction the number of C atoms per molecule can be reduced provided that the total number of C atoms before and after cracking remains equal.

QUESTION 5: REACTION RATE

Common errors and misconceptions

(a) Although well answered, some learners used both *rate* and *per unit time* in the same sentence and as a result forfeited a mark in Q5.1. Some candidates omitted key words such as *change* and forfeited one mark.

(b) The interpretation of the graph in Q5.2 was poorly answered. Many candidates confused the given reaction in the question with a reversible reaction and reasons such as *favours the forward reaction* or *favours the reverse reaction* were written.

(c) The explanation in terms of the graph (Q5.3.2) was poorly answered by most candidates. Incorrect explanations in terms of equilibrium were often used and many stated that *the reverse reaction will be favoured* and *the reaction reaches equilibrium at t_3*. Many candidates did not even refer to the graph as stated in the question. Another incorrect response was to state that *the graph increases* instead of *the gradient of the graph increases.*

It was also evident that most candidates did not understand that temperature changes within the liquid means that due to the reaction, the liquid is heating up or cooling down. They thought that an external source was changing the temperature.

(d) Most of the candidates did not fully understand Q5.4 and gave different incorrect answers. Stoichiometry was poorly understood. Some candidates did not even attempt the question.

Many candidates ignored the percentage purity of the sample and only calculated the number of moles of $CaCO_3$ followed by a calculation of the volume of CO_2 using the molar volume. Such candidates obtained only 3 of the 5 marks.

Other common errors were:
- Using incorrect formulae such as $c = \frac{n}{V}$ or even $\frac{c_aV_a}{c_bV_b} = \frac{n_a}{n_b}$
- Substituting the molar mass of CO_2 instead of that of $CaCO_3$
- Incorrect application of the molar ratio between $n(CO_2)$ and $n(CaCO_3)$
- Using the ratio between HCℓ and $CaCO_3$ instead of the ratio between HCℓ and CO_2
- Using 22,4 $dm^3 \cdot mol^{-1}$ as the molar gas volume and not the value given in the question paper.

(e)   Most candidates deduced that the pure sample would result in a faster rate and were able to choose the correct answer from the options given in Q5.5. Some incorrectly deduced that the rate would *remain constant.* Such candidates probably based their choice on the mass of the sample that remained constant.

(f)   In Q5.6 most candidates explained the answer to Q5.5 in terms of an increase in concentration of $CaCO_3$, which is a solid, instead of explaining in terms of the increased exposed surface area of $CaCO_3$.

Many candidates showed lack of understanding of the collision theory. Some used Le Chateliers' principle instead of the collision theory in their explanations thinking that it is a reversible reaction. Others omitted key words such as *effective* and/or *per unit time* and forfeited unnecessary marks.

Suggestions for improvement

(a)   Practical skills should receive more attention in schools. Learners have a poor understanding of interpretation of graphs. Learners should be exposed to more exercises involving graphs and answers should be thoroughly discussed and explained in class. They must be taught how to interpret different gradients on a graph and to discuss the reason for the change in gradient regarding the factors affecting reaction rate.

(b)   Emphasis should be placed on the difference between reversible and non-reversible reactions. Reversible reactions can reach equilibrium, whilst non-reversible reactions take place in one direction and cannot reach equilibrium. Furthermore, a reversible reaction can only reach equilibrium in a closed system. If gases are released it implies that the container should be closed to prevent the gases from escaping. When written, equilibrium reactions are indicated with double arrows. Single arrows indicate non-reversible reactions.

(c)   Ensure that learners know the different scenarios, namely change in surface area, change in temperature, change in concentration and addition of a catalyst, that should be explained in terms of the collision theory. Use previous marking guidelines to assist learners in how to explain each of these scenarios in terms of the collision theory. Use simulations, e.g. *PHET* to illustrate the collision theory in class.

(d)   Subject advisors need to support teachers with stoichiometry and worksheets should be designed involving calculations on percentage purity, percentage yield and limiting reactants. The revision booklet designed by the DBE can be valuable in this regard. Learners have a poor understanding of stoichiometry and are very uncertain when selecting formulae for a specific calculation.

(e)   It should be emphasised that the molar gas volume of 22,4 $dm^3 \cdot mol^{-1}$ is only applicable to STP.

(f)   In their teaching of topics involving concentration of solutions, teachers should emphasise that a solid does not have a concentration. The effect of a solid on, for example, reaction rate can only be explained in terms of the exposed surface area.

QUESTION 6: CHEMICAL EQUILIBRIUM

Common errors and misconceptions

(a)   Although Q6.1 was well answered, some candidates omitted key words such as *rate* when defining chemical equilibrium. Such candidates stated that it is the *stage where the forward reaction equals the reverse reaction.*
Other incorrect answers were:
- The amount of products equals reactants
- The concentration of products equals reactants
- The stage where the reaction becomes constant

(b)   In Q6.2.1 many candidates could not deduce that the increased temperature favoured the reverse reaction, hence they had ΔH > 0 and chose *positive* as the answer.

(c)   In their explanation in Q6.2.2, many candidates stated Le Chatelier's principle instead of using it. Interpreting questions involving two different equilibria (changes made in the first equilibrium until the second equilibrium was reached) proved to be a challenge to many candidates. They contradicted themselves when answering this question and they did not know the influence of temperature on the equilibrium.

(d)   In the K_c calculation (Q6.2.3), some candidates did not use a table and forfeited marks because they did not include all steps in their calculations.

Several candidates who used *+* and *-* in the *change* column of the table did not realise that the reverse reaction took place and incorrectly placed the *-* at the reactants and *+* at the products. Such candidates then calculated values in the table incorrectly and forfeited 4 marks.

A considerable number of candidates calculated the equilibrium concentrations using the given number of moles at the 300 K and substituted in the K_c expression. Few candidates still wrote Kc.

Common errors were:
- No K_c expression (NOTE: $\frac{[products]}{[reactants]}$ is NOT a K_c expression)
- Incorrect K_c expression or omission of subscripts, e.g. $K_c = \frac{[PQ]^2}{[P]^2[Q]}$
- Using a correct K_c expression with round brackets instead of square brackets
- Using incorrect labels in the table, e.g. equilibrium concentrations are written next to the label for equilibrium number of moles

(e)   In Q6.2.4 many candidates did not state that only temperature affects the K_c value, so any other changes will have no effect on the value of K_c.

(f)   In Q6.3 most learners forfeited marks because they did not know:
- The effect of a change in amount of reactants on the yield of a reaction (Q6.3.1)
- That if one reactant is increased at equilibrium, the number of moles of the other reactant would decrease until a new equilibrium is established (Q6.3.2)

Suggestions for improvement

(a)   Instead of only teaching learners to state Le Chatelier's principle, there should be more emphasis on explanations requiring Le Chatelier's principle. Learners struggle to express themselves when explaining in terms of Le Chatelier's principle. When

explaining in terms of Le Chatelier's principle, learners should be taught to use the following steps:

- Identify the disturbance.
- State that the system will act to oppose this disturbance.
- State which reaction (forward or reverse) will be favoured when opposing the disturbance.
- State the effect on, for example, the number of moles of products.

(b) Correct scientific language should be used in class. For example, it is better to state that the *reverse reaction will be favoured* instead of the *equilibrium position shifts to the left*. Although both statements are acceptable, the use of the latter should be avoided because learners inadvertently omit the word *position* in their explanations.

(c) When answering questions that require explanations in terms of a change in temperature of an equilibrium system, the first step should be to state how the change in temperature influences either an exothermic or an endothermic reaction, i.e. *an increase in temperature favours an endothermic reaction or a decrease in temperature favours an exothermic reaction*.

(d) Teachers should avoid the use of $K_c = \frac{[products]}{[reactants]}$ in class. Instead, use chemical equations to teach the writing of K_c expressions.

(e) When using a table to solve K_c calculations, learners should be taught to use correct labels [n(initial), n(change), n(equilibrium), c(equilibrium)] in the table and write the correct values next to each label. Use previous marking guidelines to show learners the labelling in such tables.

(f) Use the revision booklet designed by the DBE to support learners.

QUESTION 7: ACIDS AND BASES

Common errors and misconceptions

(a) Some candidates wrote the Arrhenius theory instead of the Lowry-Bronsted theory (Q7.1.1).
Other common errors were:
- Omitting the positive sign of the hydrogen ion, i.e. H ions instead of H^+ ions
- An acid is an electron donor

(b) In Q7.1.2 many candidates incorrectly chose H_2O as the ampholyte. Although H_2O can be an ampholyte, it does not act as ampholyte in the reactions given.

(c) Q7.1.3 was poorly answered. Most candidates failed to relate the K_a values given in the question to the ionisation and conductivity of the acids. Many candidates did not compare the given K_a values and only mentioned that HSO_4^- is a weaker acid and ionises only partially.
Other common errors were:
- Stating that a diprotic acid has a higher conductivity than a monoprotic acid
- Stating that the H_2SO_4 solution has the lower conductivity because it is a stronger acid

(d) Many candidates substituted the values correctly in the correct formula in Q7.2.1 but failed to find the concentration due to lack of calculator skills. Some candidates failed to copy the pH formula correctly from the data sheet.
Other common errors were:
- Using an incorrect pH formula, e.g. pH = - log [$HC\ell$] or pH = -log[H_3O] or pH = -log(H_3O^+) or ph = -log[H_3O^+] or [$HC\ell$] = -log[H_3O]
- Incorrect substitution of the pH value, i.e. pH = -log(1,02)
- Omitting the unit of concentration at the final answer or using an incorrect unit, e.g. mol·dm^3

(e) In Q7.2.2 most candidates managed to use the titration formula correctly to calculate the concentration of the acid used and obtained 4 of the 8 marks. Some candidates forfeited marks due to incorrect usage of the mole ratio between Na_2CO_3 and $HC\ell$.
Common errors when calculating the excess acid and the final answer:
- Subtracting the number of moles of Na_2CO_3 from the number of moles of $HC\ell$ to obtain the number of moles of $HC\ell$ in excess
- Using the final volume as 50 cm^3 instead of 50 + 25 = 75 cm^3
- Incorrect conversion from cm^3 to dm^3
- Omitting the unit of concentration at the final answer or using an incorrect unit, e.g. mol·dm^3

Suggestions for improvement

(a) Learners must be taught to interpret K_a values to obtain relative strength of acids which in turn will show their conductivity. In this case, the K_a value of HSO_4^- is lower than that of H_2SO_4 indicating that HSO_4^- ionises incompletely in water to form a low concentration of H_3O^+ ions. It is thus a weaker acid than H_2SO_4.

(b) Learners should be taught to copy formulae correctly from the data sheet.

(c) Learners should be taught to label formulae when doing multistep calculations, e.g. when calculating the number of moles of NaOH, the formula should be as follows: n($HC\ell$) = cV.

(d) Ensure that stoichiometric calculations are properly taught in Grade 11. Expose learners to stoichiometric calculations involving limiting reagents from the beginning of their Grade 12 year to give them enough practice.

(e) Rounding off should only be done at the final answer of a calculation. Learners should be taught not to round off in each step as it leads to an incorrect answer.

QUESTION 8: REDOX REACTIONS AND GALVANIC CELLS

Common errors and misconceptions

(a) The common incorrect answer in Q8.1 was *electrical energy to chemical energy*. Candidates did not know the difference between a galvanic and an electrolytic cell. Another common incorrect answer was *mechanical energy to electrical energy*.

(b) In Q8.2 many candidates did not use 1 mol·dm^{-3} (standard condition for galvanic cells) as the concentration of $AgNO_3$. They used the formula n = $\frac{V}{V_m}$ (used only for gases at STP) to calculate the number of moles of $AgNO_3$.

Other common errors were:
- Incorrect or no conversion of units e.g. cm^3 to dm^3
- Substituting the molar mass of silver instead of the molar mass of silver nitrate

(c)   When stating the definition of a reducing agent (Q8.3) some candidates wrote the definition of an oxidising agent or of reduction instead. There was also a tendency to define a reducing agent as *the place where reduction takes place*.

(d)   In Q8.4.1 many candidates failed to use the Table of Standard Reduction Potentials to determine the reducing agent from the information given in the question paper. Some wrote the formula for the oxidising agent (Cu^{2+}).

There was also a tendency to write either the oxidation half-reaction or the reduction half-reaction for copper instead of the name or formula of the reducing agent.

(e)   When writing the balanced equation for the reaction in Q8.4.2, many candidates failed to correctly identify the reducing and oxidising agents and hence a common incorrect answer was $Cu^{2+} + 2Ag \rightarrow Cu + 2Ag^+$.
Other common errors were:
- Not cancelling electrons when balancing the equation
- Using an incorrect copper half-reaction ($Cu^{2+} + e^- \rightarrow Cu^+$)
- Omitting charges of ions in the equation
- Leaving the equation as unbalanced

(f)   When calculating cell potential (Q8.5) common errors were:
- Using abbreviations in the formula, e.g. $E_{cell} = E_{red} - E_{ox}$ or $E_{cell} = E_{oxidising} - E_{reducing}$
- Swapping the reduction potential of the anode with that of the cathode when substituting
- Substituting the reduction potential of $Cu^+|Cu^{2+}$ instead of $Cu|Cu^{2+}$
- No unit at the final answer

(g)   Q8.6 was poorly answered. Those candidates, who provided either no cell reaction or an incorrect cell reaction as a response to Q8.4.2, failed to give a correct response to this question.

Suggestions for improvement

(a)   Concepts such as reducing agent, oxidation, oxidising agent and reduction should be taught with understanding. Learners must be able to identify, for example, the reducing agent in a reaction. Regular assessment on this identification is needed to ensure that learners fully understand these concepts and how to identify them on the Table of Standard Reduction Potentials.

(b)   Learners should be taught how to use the Table of Standard Reduction Potentials to identify the anode, cathode, reducing agent, oxidising agent, reduction half-reaction and oxidation half-reaction in a galvanic cell. Regular assessment on this identification is needed to ensure that learners understand the use of the Table of Standard Reduction Potentials.

(c)   Teachers should ensure that learners study and understand the section on the effect of a change in concentration on the cell potential in the *Examination Guidelines*. The answer to a question like Q8.6 is provided in the phrase *V_{cell} decreases as the concentration of product ions increases and the concentration of reactant ions decreases until equilibrium is reached at which the $V_{cell} = 0$.*

QUESTION 9: ELECTROLYTIC CELLS

Common errors and misconceptions

(a)   The definition of an electrolyte was poorly answered in Q9.1. Some candidates wrote the definition of electrolyses instead. Another common incorrect answer was *a substance that conducts electricity* instead of *a solution that conducts electricity* or *a substance that conducts electricity through the movement of ions*.

(b)   Although many candidates correctly chose *anode* as the answer in Q9.2, most failed to give a correct reason for their choice. Some candidates chose *cathode* as the answer and gave the reason that *it was connected to the positive terminal of the cell* as is the case in a galvanic cell.

(c)   In Q9.3 many candidates wrote the incorrect half-reaction ($Cr^{3+} + e^- \rightarrow Cr^{2+}$) or the oxidation half-reaction for chromium ($Cr \rightarrow Cr^{3+} + 3e^-$) instead of the reduction half-reaction ($Cr^{3+} + 3e^- \rightarrow Cr$). Other common errors were:
   * Using terms such as *left-hand side and right-hand side* to refer to the anode and cathode implying that the anode should always be drawn on the left side
   * Using a *double arrow* in the correct reduction half-reaction
   * Using an *equal sign* instead of an arrow in the correct reduction half-reaction

(d)   Q9.4 was the poorest answered question in the paper. Many candidates left the question unanswered without even converting mass of chromium to number of moles. Candidates showed poor understanding of stoichiometry. Common errors were:
   * Using an incorrect or no mole ratio when calculating the number of electrons transferred
   * Multiplying the number of moles of chromium with the charge on one electron instead of first using the ratio to calculate the number of moles of electrons followed by calculating the number of electrons using Avogadro's number
   * Substituting number of moles of electrons as *n* in $n = \dfrac{Q}{q}$ (In this formula, only supplied in paper 1, *n* is the number of electrons.)

Suggestions for improvement

(a)   The difference between the definitions of *electrolysis*, an *electrolytic cell* and an *electrolyte* should be emphasised. An electrolyte is a solution that conducts electricity through the movement of ions.

(b)   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.

(c)   Teachers should provide learners with a summary of the four types of prescribed electrolytic cells and thoroughly explain the functioning of each. This will enable learners to answer different questions on electrolytic cells with understanding rather than guessing.

(d)   Teachers should prepare Grade 12 learners on how to answer questions that involve stoichiometry and should not assume that these calculations were taught in Grades 10 and 11. Learners should be made aware that stoichiometry is an integral part of Chemistry and could be assessed in any topic in the curriculum.

(e)   Videos downloaded from different websites e.g. Khan Academy, should be used in class to ensure that learners understand how different electrolytic cells function.