

CHAPTER 11

PHYSICAL SCIENCES

The following report should be read in conjunction with the Physical Sciences question papers of the November 2022 examinations.

11.1 PERFORMANCE TRENDS (2018–2022)

The number of candidates who sat for the Physical Sciences examination in 2022 increased substantially by 12 036 compared to that of 2021.

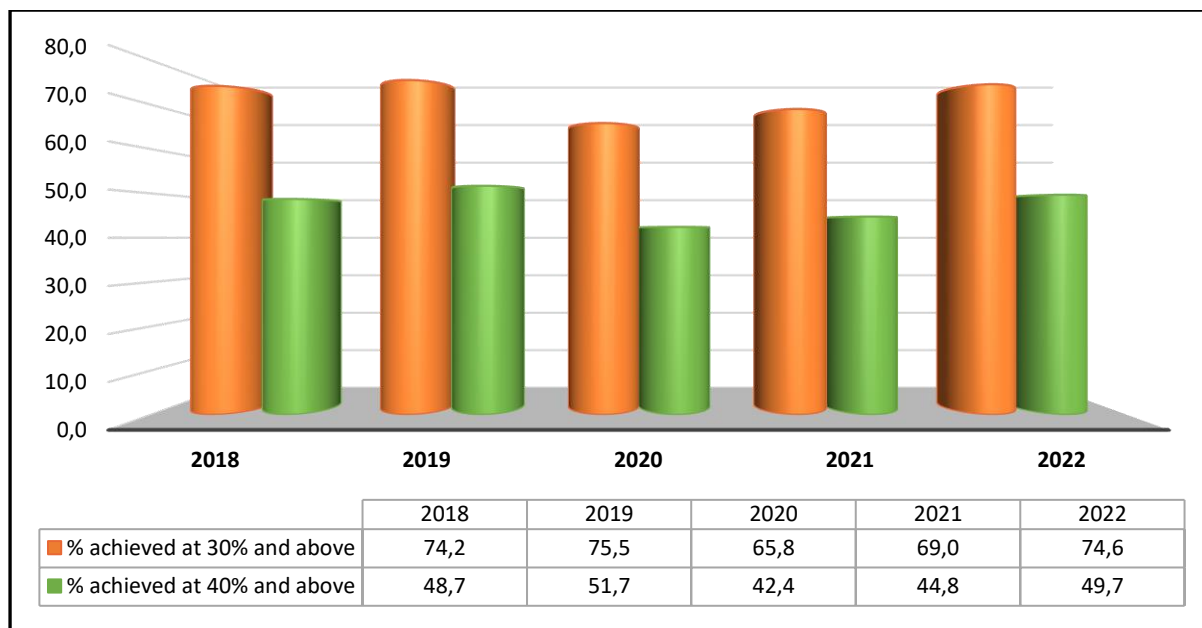
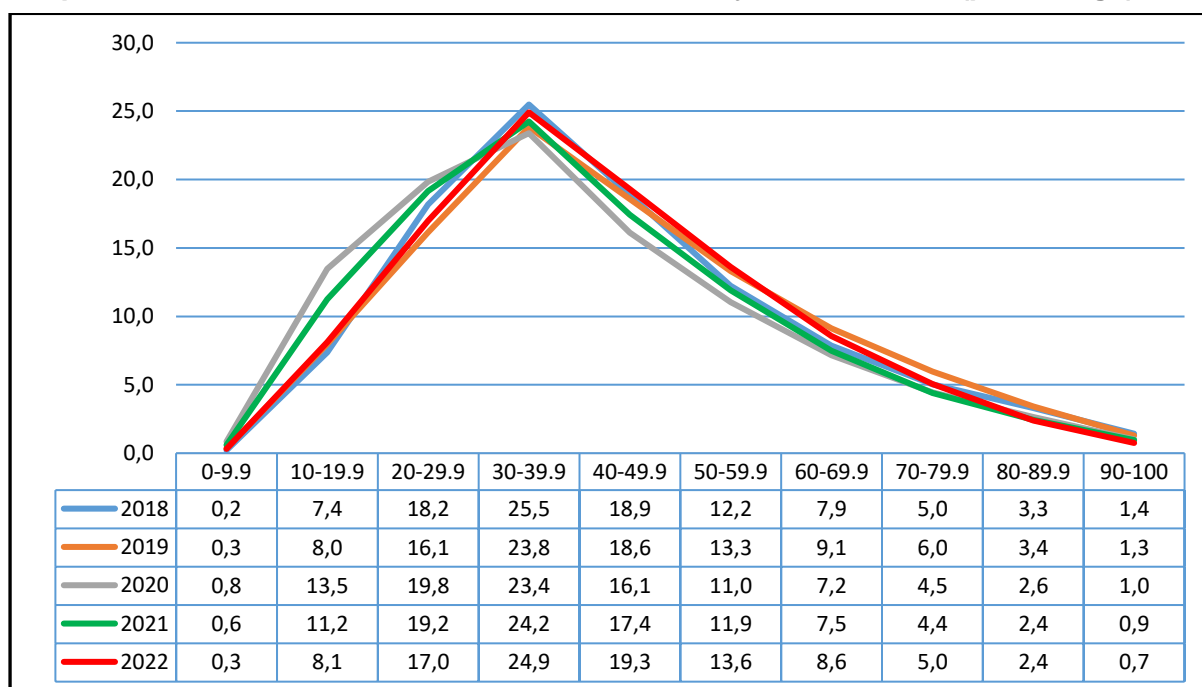
Although the table below indicates variable trends over the years 2018-2022, a significant improvement in results was evident this year. Candidates who passed at 30% (Level 2) improved from 69,0% in 2021 to 74,6% in 2022. There was also a corresponding improvement in the pass rate at 40% (Level 3) over the past two years from 44,8% to 49,7%.

There was a marginal decrease in the percentage of distinctions over 80% (Level 7) from 3,3% to 3,1%. This converts into a decrease of only 21 in the total number of distinctions.

In view of disruption to academic programmes in 2020 and 2021, the results achieved by this cohort are particularly commendable. Strategic intervention programmes at all levels (National, Provincial, Districts and Schools) ensured that learners were adequately prepared. The diligence and perseverance of the above-average candidates also contributed to the favourable overall performance.

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
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
2022	209 004	155 877	74,6	103 811	49,7

Graph 11.1.1 Overall achievement rates in Physical Sciences (percentage)**Graph 11.1.2 Performance distribution curves in Physical Sciences (percentage)****General comments on Paper 1 and Paper 2**

The questions in Paper 1 on Newton's Laws and Projectile Motion were generally well answered. The multiple-choice questions, as well as the questions on the Photo-electric Effect and Static and Current Electricity were poorly answered. Performance pertaining to physical properties of organic compounds and galvanic cells in Paper 2 was good. The question on chemical equilibrium in Paper 2 was 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

Questions 1 and 10 were the worst answered questions. The poor performance in Question 1 may be one of the reasons for the contributing factors to the increase in the percentage of candidates achieving below 30% and the decrease in candidates achieving level 7.

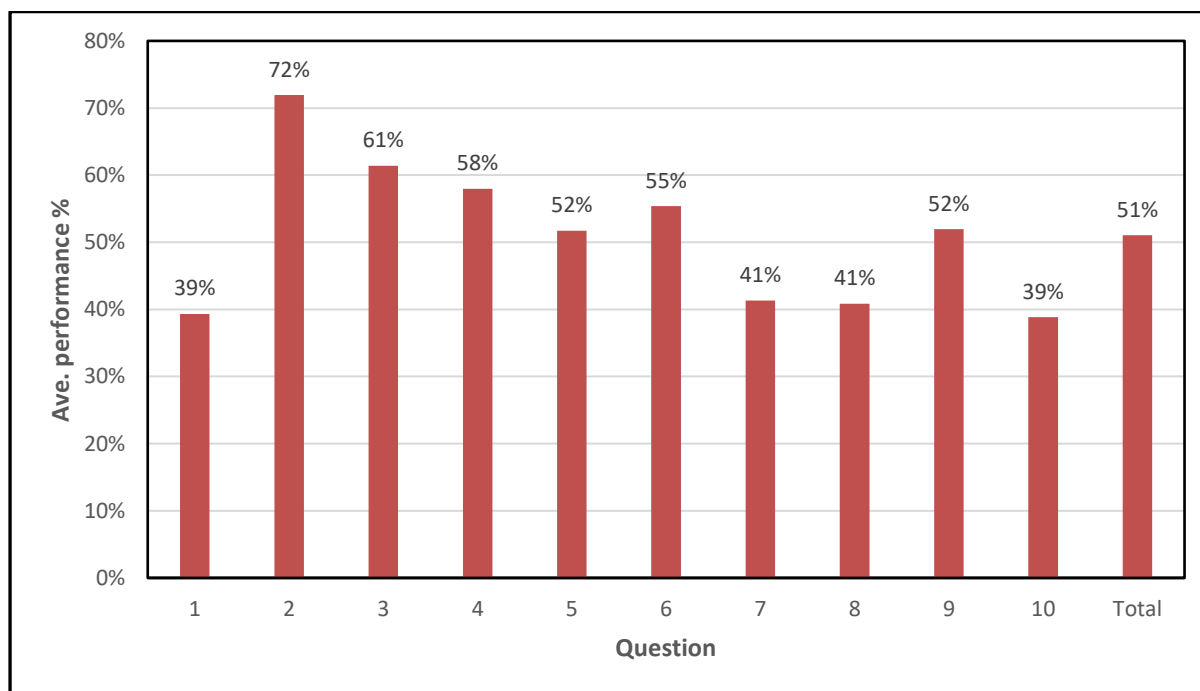
- (a) In 2021, Question 1 (Multiple-choice Questions – All topics) was one of the best answered questions, while in 2022, this was one of the questions answered very poorly. Many candidates were unable to use basic content knowledge of physics to answer these questions. Physical Science is a learning area which promotes critical thinking and higher-level reasoning. Some of the multiple-choice questions tested these two skills. The poor performance cannot be contributed entirely to the fact that there were some level 3 questions. One reason for this may be that many learners are only exposed to the answering of multiple-choice questions in the control tests and the preliminary examinations before they write their final examinations.
- (b) Teachers must differentiate between *vectors* and *scalars* in all topics. Learners must continually be reminded to use the formulae on the data sheet. They must be taught to read the questions slowly and with attention.
- (c) Interpretation and drawing of sketch 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.
- (d) 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.
- (e) The lack of knowledge of topics taught in Grades 10 and 11 can be seen in the poor performance of the candidates in Questions 7 and 8. Electrostatics and electric circuits must be completed in Grades 10 and 11 with only the internal resistance to be done in Grade 12. These two questions had the second lowest averages.
- (f) Many candidates lost marks unnecessarily: for not writing formulae; not showing their substitutions and for not writing the exact formula as given on the data sheet, e.g. leaving out subscripts such as F_{net} , $E_{k(\text{max})}$, W_{nc} . Some candidates did not give the correct units for the answers or they did not convert their numerical answers to a minimum of two decimal places and therefore lost the mark for the answer.

11.3 DIAGNOSTIC QUESTION ANALYSIS OF PAPER 1

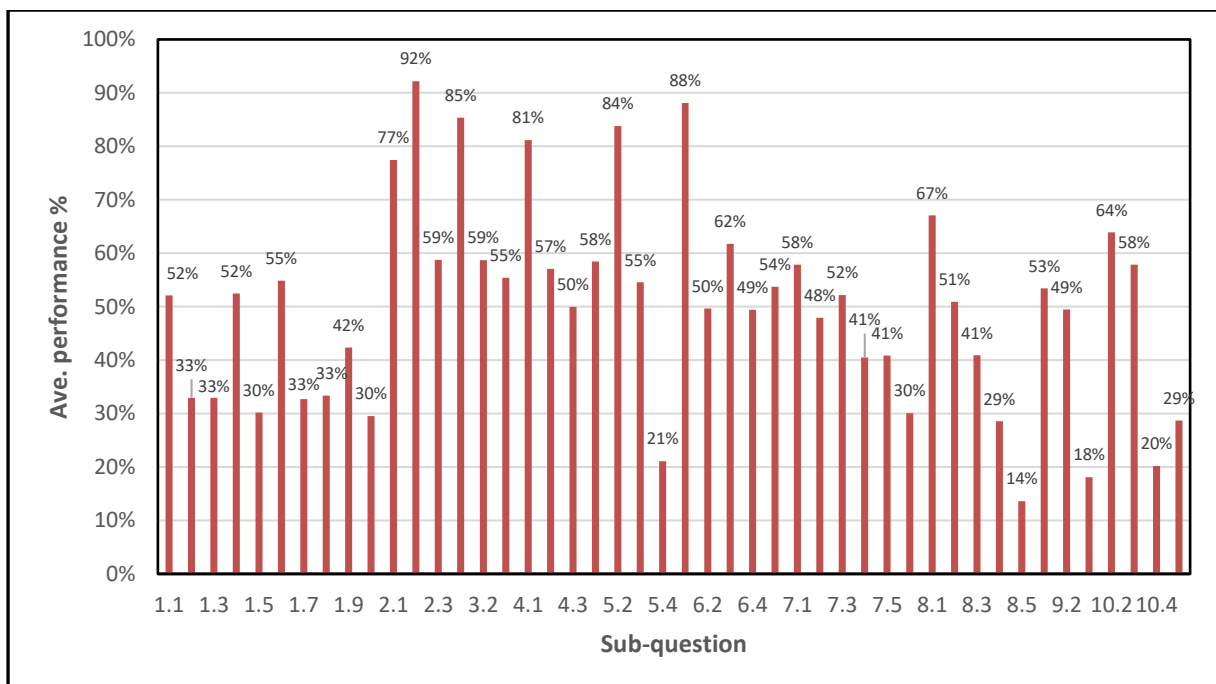
The following graph is based on data from a random sample of candidates. While this graph might not accurately reflect national averages, it is useful in assessing the relative degrees of challenge of each question as experienced by candidates.

There was poor performance in Question 1 (Multiple-choice questions). It must be noted that the *Examination Guidelines* do not restrict multiple-choice questions to level 1 and 2 questions. The averages also reflect the poor performance in Question 10 and Questions 7 and 8.

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, AC and DC
5	Work, energy and power	10	Photoelectric effect

Graph 11.3.2 Average performance per subquestion in Paper 1

Sub-Q	Topic	Sub-Q	Topic
1.1	Vectors and Scalars	6.3	Graph: proportionality
1.2	Newton's Gravitational Law	6.4	Calculating v_L using gradient
1.3	Vertical Projectile Motion	6.5	Graph with increased v_L
1.4	Work and Energy	7.1	Statement Coulomb's Law
1.5	Work and Energy	7.2	Polarity of charge M
1.6	Doppler Effect	7.3	Free-body diagram
1.7	Electrostatics	7.4	Calculating Q_M
1.8	Circuit Electricity	7.5.1	Magnitude F_{MN}
1.9	Electrodynamics	7.5.2	Direction F_{MN}
1.10	Optical Phenomenon	7.6	Calculating E_{net}
2.1	Statement Newton's 2nd Law	8.1	Statement Ohm's Law
2.2	Free-body diagram	8.2.1	Calculating R_{ext}
2.3.1	Application Newton 2	8.2.2	Calculating V_{ext}
2.3.2	Application Newton 2	8.2.3	Comparison voltmeter readings
3.1	Defining free fall	8.3.1	Defining emf
3.2.1	Calculating time for maximum height	8.3.2	Comparison emf and voltmeter reading
3.2.3	Calculating final velocity	8.3.3	Explanation emf and voltmeter reading
3.2.3	Calculating time to pass door	8.4.1.	Addition of voltmeter effect on power
3.3	Velocity-times ketch graph	8.4.2	Addition of voltmeter effect on V_1
4.1	Statement Conservation of p	8.3	Explanation reading on V_1
4.2.1	Calculation conservation of p	9.1.1	Component DC generator
4.2.2	Calculation impulse	9.1.2	Direction of current in coil
4.3	Elastic/Inelastic collisions	9.1.3	Determining period
4.1	Conservation of p	9.1.4	Sketching V vs Δt graph
5.1	Defining non- conservative force	9.2	Calculating average power dissipated
5.2	Free-body diagram	10.1	Evidence particle nature of light
5.3	Calculate W_{nc}	10.2	Defining work function
5.4	Calculate Δx	10.3	Calculation max E_K
6.1	Naming phenomenon illustrated	10.4	Calculation number of photons
6.2	Application Doppler	10.5	Influence of light intensity

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

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Common errors and misconceptions

- (a) In Q1.2 many candidates struggled with the application of *ratio* and *proportion*.
- (b) Two principles – conservation of mechanical energy and the fact that g stays constant irrespective of the velocity – had to be identified in Q1.3. Candidates could not identify the principles at stake.
- (c) For Q1.4 candidates had to realise that the engine must exert a constant force to overcome the frictional force to stay at constant velocity: The formula $P = Fv$ is not used often. However, candidates could also have derived the correct answer by using the formula $\frac{F_{\text{net}}\Delta x \cos\theta}{\Delta t}$ and realising that $\frac{\Delta x}{\Delta t} = v$. Both F_{net} and v are constant.
- (d) A few concepts were involved in Q1.5, namely negative acceleration, work done by frictional force and mechanical energy, making this a challenging question.
- (e) In Q1.7 candidates either failed to realise that the electrostatic force (F) that one charge exerts on the other is inversely proportional to the square of the distance between them (r^2) or that a hyperbola represents an inverse proportionality.
- (f) Candidates generally seem to have a problem with the interpretation of circuit diagrams and the relationship between the voltmeter readings across the series and parallel connections as well as the V_{ext} . The poor performance in Q1.8 was repeated in Q8.
- (g) Candidates should have known that the induced emf in a generator is dependent on the speed of rotation of the coil, the number of loops and the strength of the magnet. Although this has been tested repeatedly in past papers, candidates failed to realise in Q1.9 that doubling the speed of the coil will double the induced emf and halve the period.
- (h) The poor performance in Q1.10, a level-2 question, suggests that the teaching of the *photoelectric effect* and the *types of line spectra and their formation* is neglected in many schools as this is the last section to be taught. The poor performance in this question was repeated in Q10, which supports this assumption.

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 should 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) Assessment of multiple-choice questions should be included in all class activities and not only in control tests and preliminary examinations. It is recommended that a booklet containing multiple-choice questions from different topics, from different sources, such as previous NSC and provincial papers and textbooks is prepared. The booklet should also have a step-by-step explanation on how to answer multiple-choice questions.

QUESTION 2: NEWTON'S LAWS OF MOTION

Common errors and misconceptions

- (a) Candidates omitted key words in the definitions. Some only wrote the first part of *Newton's Second Law*, which carried no marks, and failed to relate *acceleration* to the *resultant force* and *mass of an object*.
- (b) The free-body diagram was very well answered, perhaps because it was on a horizontal plane. Common errors in the free-body diagram were missing labels, missing arrows, arrows not touching the dot, additional forces, the normal force not perpendicular to the plane and the gravitational force not perpendicular to the horizontal. Some candidates drew the free-body diagram for Q instead of P.
- (c) Units were often left out of the final answer of the calculation. Some candidates still used the system approach with the two objects. In Q2.3.2 most candidates failed to calculate the angle because of the substitution of incorrect values due to their inability to resolve forces correctly.

Suggestions for improvement

- (a) Learners must be exposed to the definitions in the *Examination Guidelines* and the 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. 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 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.
- (e) Teachers should expose their learners to all scenarios for this section as described in the *Examination Guidelines*.

QUESTION 3: VERTICAL PROJECTILE MOTION

Common errors and misconceptions

- (a) Some candidates omitted the word *only* in Q3.1. Candidates must distinguish between the terms *free fall* and a *projectile*.

- (b) Not applying the correct sign convention to each vector quantity was a problem throughout Q3.2. There are many different displacements, velocity, and time values. A number of candidates failed to substitute the correct values for the different stages of the motion. In Q3.2.2 most candidates omitted the direction of the vector at the final answer.
- (c) Graphs are always a challenge. Many candidates drew a curved graph in Q3.3 instead of a straight line. Some candidates used scales to subdivide the axes and did not show the correct values of the initial velocity and time.

Suggestions for improvement

- (a) Learners must first make sure that they understand the motion of the projectile and which values are relevant at each position. A rough drawing or diagram indicating the physical motion of the projectiles together with all information given (velocities, displacements etc.) is necessary in all scenarios.
- (b) Advise learners 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. They should keep to one sign convention when solving a problem and not change their chosen sign convention within a problem as this could lead to confusion.
- (c) Time cannot be a negative. Learners simply change it to a positive without thinking about it. This creates a substitution error.
- (d) Teach learners the skills of interpreting and sketching graphs especially for projectiles, e.g. to have reference points and to collect all relevant data before calculating any quantity.
- (e) Expose learners to several questions involving different scenarios of projectile motion, including two objects.

QUESTION 4: MOMENTUM AND IMPULSE

Common errors and misconceptions

- (a) In Q4.1 candidates lost marks due to the omission of the words *total* or *isolated system*. Note that the correct term is an *isolated system* and not a *closed system*.
- (b) The safest way to start a calculation applying the conservation of total momentum is $\Sigma p_i = \Sigma p_f$ as was done by many candidates in Q4.2.1. However, some candidates wrote $E p_i = E p_f$. Others combined the masses after the collision – this may be due to incorrect reading or assumptions based on previous questions on momentum.
- (c) In applying $F_{\text{net}}\Delta t = m(v_f - v_i)$ in Q4.2.2 many candidates swapped the initial and final velocities of the trolley or used an incorrect sign convention for the velocities. Many candidates used the incorrect time value which they read off from the graph.
- (d) Several candidates used momentum in Q4.3 to determine whether the collision was elastic or inelastic and then concluded that it was elastic. Candidates who started off with $\Sigma K_i = \Sigma K_f$ lost one mark. They needed to calculate ΣK_i and ΣK_f separately and then compare the values.

Suggestions for improvement

- (a) The vector nature of momentum and impulse should be emphasised during teaching.
- (b) Expose learners to many different scenarios or problems that involve the principle of conservation of linear momentum and impulse.
- (c) Teachers should emphasise to learners not to give the conclusion before starting to calculate the proof when solving questions on elastic and inelastic collisions. Learners should calculate the total kinetic energies before and after the collision separately, compare them and then conclude whether the collision was elastic or inelastic.
- (d) Questions involving graphs should be included in assessments of all topics.

QUESTION 5: WORK, ENERGY AND POWER**Common errors and misconceptions**

- (a) The average for Q5.1 requiring the definition of a non-conservative force, was disappointingly low. Many candidates omitted key words in the definition. If they did not mention the work done, no marks were awarded. If they omitted the word *force*, only one mark was awarded. Some candidates wrote *independent* instead of *dependent*.
- (b) Candidates lost unnecessary marks in Q5.2 due to writing incorrect labels like F_{app} or F_r , showing both weight and components of weight or not drawing F_N perpendicular to the surface but vertically upwards.
- (c) Some candidates were able to define a non-conservative force in Q5.1 but failed to identify that both the frictional force and the applied force are non-conservative forces in the calculation in Q5.3. Quite a few candidates copied the formula incorrectly from the data sheet as $W_{nc} = \Delta U - \Delta K$. They also swapped the initial velocity and the final velocity around.
- (d) Q5.4 was poorly answered. It is a level-4 question and not many candidates got it correct or even attempted it. This was a very innovative question requiring thorough reading and a good understanding of the physics involved.

Suggestions for improvement

- (a) Many learners use the work-energy theorem to calculate the work done by non-conservative forces. It would appear that the equation for the work done by non-conservative forces is not taught in all schools.
- (b) 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. It must be emphasised that frictional force is not the only non-conservative force that can act on an object. An applied force is also a non-conservative force.
- (c) Work done by a force is always equal to the change in energy, e.g., $W_{net} = \Delta E_k$, $W_{nc} = \Delta E_p + \Delta E_k$, $W_w = -\Delta E_p$.
- (d) Clearly explain to learners the difference between W_{net} (total work done by all forces acting on an object, i.e. both conservative and non-conservative) and W_{nc} (total work done by only non-conservative forces acting on the object).

- (e) Use *PhET* simulations for the identification of forces acting on objects.
- (f) Create a data base for questions on work, energy and power that can be shared with the learners as homework or use during interventions.

QUESTION 6: DOPPLER EFFECT

Common errors and misconceptions

- (a) There was a disappointingly low average for Q6.2 which was a level-1 question. Too many one-word answers and some strange applications were given. Language was an issue here. There is a difference between listening to something and measuring something.
- (b) In Q6.3 many candidates erroneously thought that *directly proportional* and *x increases as y increases* had the same meaning.
- (c) Many candidates struggled with questions involving graphs. For Q6.4 they did not understand that the gradient was the ratio of f_L to f_S . Quite a few candidates started with an incorrectly manipulated Doppler formula.
- (d) In Q6.5 some candidates drew either only the graph for B or did not draw the two graphs on the same set of axes.

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) Learners must be taught to write the Doppler formula as it appears on the data sheet. They should not convert it and then start the substitutions. They must always keep the plus and minus there in the first step of writing the formula. Only once substitution starts, should they change the signs.
- (c) Problem-solving exercises that involve the interpretation and drawing of sketch graphs should be done in a variety of topics. Identification of the variables in relation to the equation describing the graph should be stressed. Teachers should note that learners can be asked to draw or interpret a graph for any of the physics topics.
- (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 struggled to understand the scenario and to answer this question according to *Coulomb's Law*. Candidates did not do well in the question, especially the calculations. The candidates did not differentiate between *electrostatic force* and *electric field* at a point and therefore the calculations in Q7.4 and Q7.6 were affected.
- (b) Q7.1, a level-1 question (stating *Coulomb's Law*), was poorly answered. Quite a few candidates lost marks due to the following mistakes:

- Stating *Newton's Law of Gravitation*
 - Writing *directly proportional to charges* instead of *directly proportional to the product of the charges*
 - Not writing *square* for the inverse proportionality
 - Using *indirectly proportional* instead of *inversely proportional*
- (c) In Q7.2 many candidates did not realise that if sphere N carries a positive charge, then sphere M must have a negative charge so that the two can attract each other.
- (d) Language was an issue in the answering of Q7.3. Many candidates thought that sphere N was hanging from a string and labelled the upward force T. Several candidates labelled the upward force as N whilst others failed to identify the electrostatic forces exerted by M and N on each other.
- (e) In Q7.4 some candidates swapped/mixed the formulae for E and F as follows: $F = k \frac{Q}{r^2}$ and $E = k \frac{Q_1 Q_2}{r^2}$. Candidates did not use the absolute value of the charges when substituting in the formula of Coulomb's Law.
- (f) Some candidates failed to identify F_{MN} and F_{NM} as action-reaction forces in Q7.5.
- (g) In Q7.6 many candidates did not understand the superposition of electrostatic forces when there is more than one charge. Candidates did not draw a vector diagram for the electric fields due to each charge and thus did not realise that the magnitudes of the electric fields must be subtracted to determine the net electric field at point X.

Suggestions for improvement

- (a) Teachers need to explain to learners that calculations of net electrostatic force and electric field are similar in terms of their vector considerations.
- (b) The absolute value of the charge must be substituted in *Coulomb's Law* and the equations for calculating the electric field. (If negative charge values are substituted learners use the negative answer mistakenly as an indication of direction.)
- (c) Teachers should emphasise the difference between *electrostatic force* and *electric field* at a point as well as the equations thereof.
- (d) The application of the *principle of superposition of electric fields* and *electrostatic forces* should be revised.

QUESTION 8: ELECTRIC CIRCUITS

Common errors and misconceptions

- (a) Candidates performed very poorly in this question. Many candidates lacked understanding in this question and did not know how to express themselves. Consequently, their explanations were inadequate. The scaffolding of the question is very evident in the performance of the candidates.
- (b) The relatively poor performance of candidates in Q8.1, i.e. the statement of *Ohm's Law* which they should have been taught in Grades 10 and 11, indicates that many schools did not revise current electricity or teach internal resistance in Grade 12.

- (c) Most candidates had difficulty interpreting the circuit. Candidates could not correctly identify the resistors that are in series and those in parallel in Q8.2.1 and Q 8.2.2. Many candidates thought the $2\ \Omega$ resistor was in series in the circuit. This has been a serious misconception for many years. Candidates seemed to think that parallel resistors must be in lines that are parallel to each other. Candidates struggled to grasp the flow of current through resistors in series and parallel and were thus unable to understand that there is a potential difference across the $4\ \Omega$ resistor.
- (d) In Q8.3.1 some candidates omitted the keyword *maximum* energy and related the maximum energy to *per time* instead of per coulomb in the definition of emf. The Grade 10 explanation of emf is not the definition.
- (e) In Q8.3.2 and Q8.3.3 many candidates did not understand that V_1 measures V_{ext} and V_2 only measures V_{II} .
- (f) Q8.4 and Q8.5 both required candidates to understand what the effect is of replacing the switch in the parallel branch with a high-resistance voltmeter. The averages for these subquestions reflect the poor understanding that candidates had of this situation. Most candidates did not refer to the impact of the voltmeter in their answers. A typical incorrect or incomplete explanation given was that R_{ext} increases and therefore V_{ext} will increase because V is directly proportional to R – with no reference to total current or internal resistance and V_{LOST} not even referring to internal resistance. This is a serious misconception.

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) Learners must be exposed to the various examples of circuit diagrams where two resistors are included in a parallel branch. Use different scenarios from past question papers to expose learners to these types of questions.
- (c) Ensure learners understand that the R_1 and R_2 in the parallel resistor formula are not necessarily individual resistances but the total resistance of the branch. For example, there could be more than one resistor in a branch in a circuit but the resistance in that branch is equivalent to R_1 .
- (d) The effect on voltmeter and ammeter readings of any short circuit or bridging of resistors, opening and closing of switches, and connecting voltmeters in different positions in a circuit needs to be taught.
- (e) 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) The average for this question was relatively low considering that even the level-3 questions were easy. Q9.1.2, Q9.1.3 and Q9.2 were poorly answered. Many candidates either did not read with understanding or were not taught electrodynamics in enough detail.

- (b) In Q9.1.1 candidates had to carefully distinguish between the words *split* and *slit*. Many candidates confused the two words by answering *slipt*, *spilt*, *slipt*, *spleeted*, etc.
- (c) Q9.1.3 was not well answered. Candidates did not understand the relationship between *period* and *frequency*.
- (d) In Q9.1.4 candidates did not relate the position of the coil in the diagram to an induced starting emf of 0 V. Many did not indicate the labels for the 90 V or draw one full cycle or indicate the correct times for T or $\frac{1}{2}T$ at the correct position. Quite a few candidates drew the graph for an AC generator.
- (e) In Q9.2 candidates failed to realise that the current electricity formulae may also be used to calculate unknown quantities even though alternating current is being calculated. Conversion of time into seconds was problematic as well. Many candidates were unable to either use the W formulae directly or to first calculate P_{ave} and then W .

Suggestions for improvement

- (a) Grade 10 and 11 revision of waves needs to be done before the learners start on this chapter, especially calculations with period and frequency. Skill in graph sketching can be practised more. The Grade 11 work on electromagnetic induction must be revised in Grade 12 when motors and generators are taught.
- (b) Emphasise 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 learners must be exposed to sufficient application-type questions.
- (d) Learners must be taught to differentiate AC from DC in words, using graphs, in terms of components used, law or principle used to find the direction of motion or the induced current and the factors responsible for the difference.
- (e) *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) Theory and calculations on the photoelectric effect were attempted and done by some candidates. This question was, however, still poorly answered.
- (b) The very low averages in Q10.1, a level-1 question, and Q10.4 are proof that the photoelectric effect is not being taught in many schools. From the answers it was clear that most candidates did not understand the very crux of the photoelectric effect, i.e., that one photon with sufficient energy can only release one electron and that the photoelectric effect provides evidence that light has a particle nature.
- (c) The low average for the definition of work function (Q10.2) again supports the assumption that this last section of the syllabus is either not taught at all or taught after the trial examinations in many schools.

- (d) Many candidates omitted the subscript 'max' in the equation $E = W_0 + E_{k(\text{max})}$ in Q10.3. Some candidates confused frequency and energy.
- (e) Q10.4 was poorly answered. To relate the equation $Q = I\Delta t$, for calculating charge, to the number of photons that strikes the cathode was very difficult for the candidates. The concept that a photon is needed for each electron (causing the current to flow) was a challenge.
- (f) The lack of understanding the concept of intensity of light as the number of photons per unit time and that the increase in current implies an increase in electrons emitted per unit time was the reason for the poor performance in Q10.5, which had an average of 27%. Very few candidates used the terms *per unit time* or *per second*. Most of the candidates got 1 out of 3 marks.

Suggestions for improvement

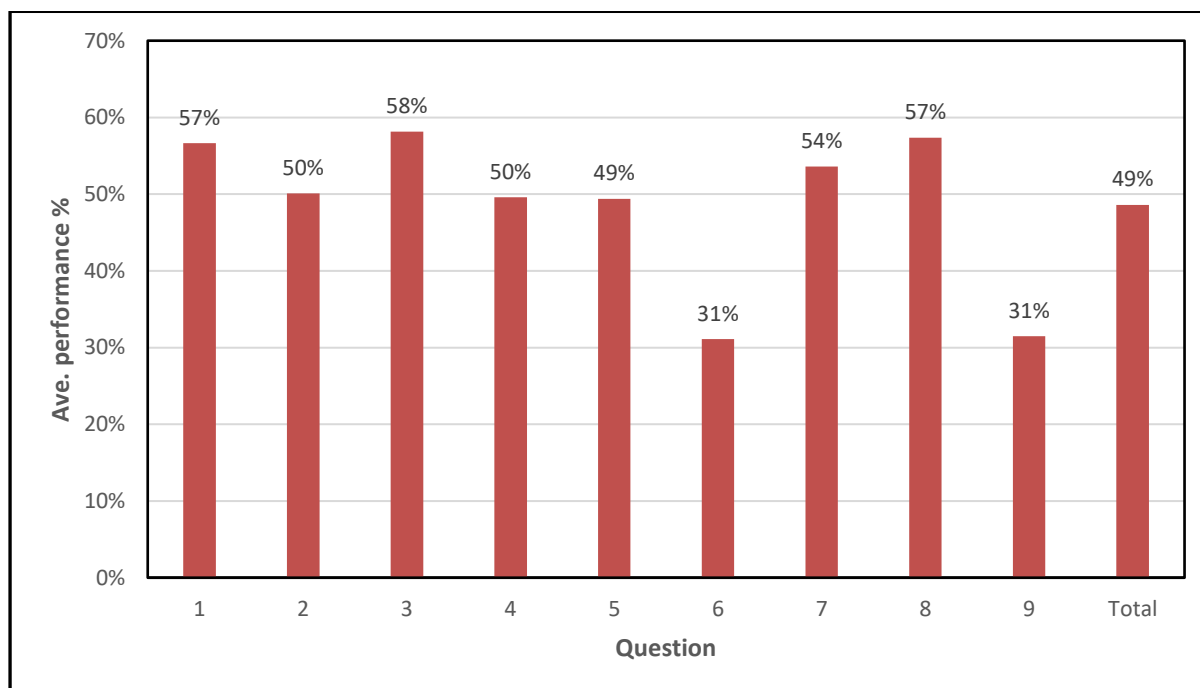
- (a) The importance of the phenomenon of the photoelectric effect in understanding the nature of light and that the particle nature of light was the only way of explaining this phenomenon must be emphasised.
- (b) Learners must understand that the formulae must be copied from data sheet as is and definitions studied from the *Examination Guidelines*.
- (c) Learners must use the formula $E = W_0 + E_{k(\text{max})}$ as per data sheet (including the subscript max). Make sure that learners understand the meaning of the different expressions in this formula and that they can relate this to a straight-line graph.
- (d) Ensure that learners can explain the influence of the changes in the light (intensity and frequency) incident on a cathode/surface.
- (e) Teachers should use computer simulations (e.g. *PhET*) when teaching the photoelectric effect. This will assist in improving learners' understanding of the concept.
- (f) Teachers should 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.

11.5 DIAGNOSTIC QUESTION ANALYSIS OF PAPER 2

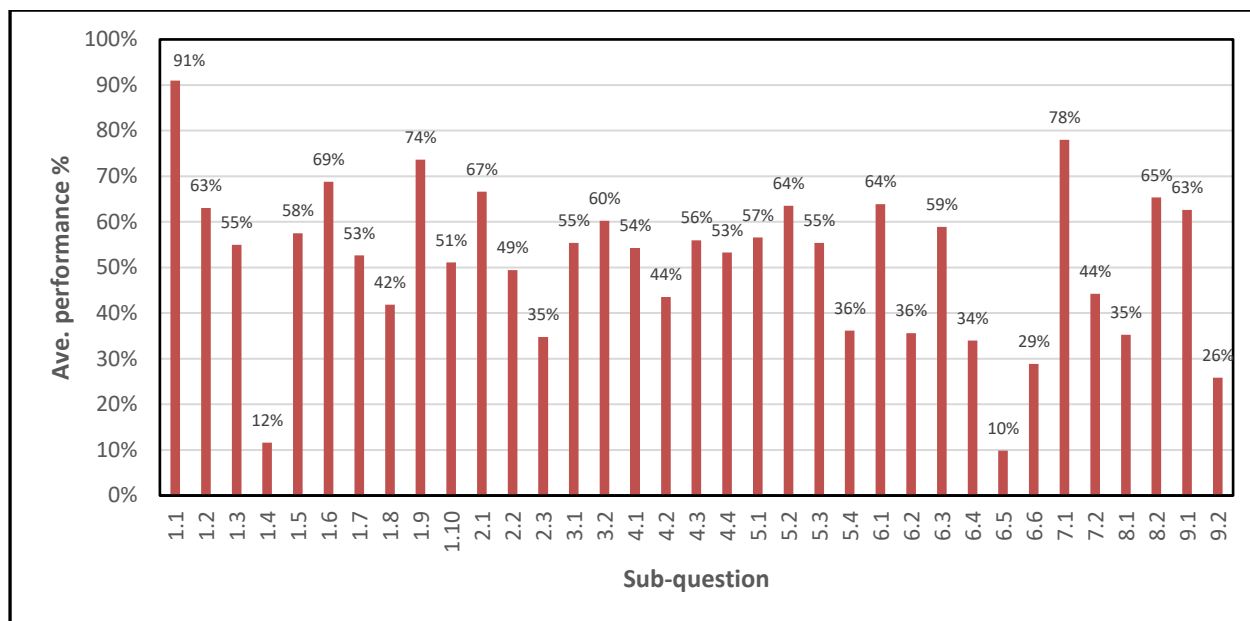
Performance improved in six questions, namely multiple-choice questions (Q1), physical properties of organic compounds (Q3), organic reactions (Q4), rate of reaction (Q5), acids and bases (Q7), galvanic cells (Q8) and electrolytic cells (Q9) as compared to 2021. While there was a significant improvement in the performance in organic reactions (Q4), rate of reaction (Q5), acids and bases (Q7) and galvanic cells (Q8), the performance in Q2 (nomenclature of organic compounds) showed a decline of more than 10%. Performance in electrolytic cells (Q9) improved by 1% from 2021.

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 11.5.1 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 11.5.2 Average performance per subquestion in Paper 2

SubQ.	Topic	SubQ	Topic
1.1	Definition of saturated hydrocarbons	5.1	Factors affecting reaction rate; Collision theory
1.2	Identify intermolecular forces in ethanoic acid and methyl propanoate	5.2	Effect of temperature on Maxwell-Boltzmann distribution curve
1.3	Reaction of bromine water with alkenes	5.3	Volume reading on syringe and stoichiometric calculation
1.4	Definition of reaction rate	5.4	Interpret mass versus time graph and calculate time using stoichiometry and reaction rate.
1.5	Factors affecting reaction rate	6.1	State Le Chatelier's principle
1.6	Chemical equilibrium	6.2	K_c calculation
1.7	Hydrolysis of salts	6.3	Apply Le Chatelier's principle
1.8	Acid-base titration and indicators	6.4	Explanation in terms of Le Chatelier's principle
1.9	Definition of an oxidising agent	6.5	K_c calculation
1.10	Spontaneous redox reaction	6.6	Interpretation of changes made to reaction rate versus time graph
2.1	Isomers, types of isomers, general formula of alkynes, functional group of alcohols	7.1	Lowry-Brønsted theory, weak acids, conjugate bases
2.2	IUPAC name of a haloalkane, alkyne and aldehyde	7.2	Calculate number of moles from concentration, concentration of base from pH; Stoichiometric calculation
2.3	Esterification, determination of molecular formula of an ester from its empirical formula.	8.1	Identify the reducing agent and explanation in terms of relative strengths of the oxidising agents
3.1	Homologous series – ketones, controlled variable, explain the difference in the melting points of two ketones	8.2	Galvanic cell: Function of salt bridge, direction of electron flow, calculation of initial emf, balanced equation for net cell reaction, effect of ion concentration on voltmeter reading
3.2	Definition of vapour pressure, conclusion from results in a table, identification of alcohol with highest boiling point from given vapour pressures and writing of its IUPAC name, change in vapour pressure as temperature increases	8.3	Definition of a reducing agent
4.1	Tertiary haloalkanes	8.4	Reducing agent and cell reaction
4.2	Elimination of a haloalkane – reaction conditions, type of reaction that takes place, writing of balanced equation using structural formulae	9.1	Definition of electrolysis
4.3	Hydration of an alkene, conditions needed and structural formula of alcohol	9.2	Interpretation of graph to identify cathode, calculation of total charge transferred, and mass of metal deposited onto cathode
4.4	Hydrolysis of a haloalkane and conditions needed		

11.6 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 the best. Most candidates were familiar with the term *saturated hydrocarbon*.
- (b) Q1.2 was well-answered. The most common incorrect answer was A, which implied that most candidates thought that the ester, methyl propanoate, also has hydrogen bonds like carboxylic acids.
- (c) Many candidates failed to select the correct answer in Q1. The saturation test to determine whether a hydrocarbon is saturated (alkane) or unsaturated (alkene), was not done in most schools.
- (d) Q1.4 was the poorest answered multiple-choice question. The most common incorrect answer was D. Candidates were tricked by the phrase *per unit time* not knowing that *rate of change* already implies *per unit time*.
- (e) Those candidates who got Q1.5 wrong mainly chose D (adding more Mg powder) as the answer. Such candidates failed to relate addition of more Mg to an increase in surface area. Many candidates did not know that volume has no effect on reaction rate and therefore did not choose A, the correct answer.
- (f) Q1.6 was well-answered. The most common incorrect answer was A. These candidates failed to recognise that at equilibrium the reaction has not stopped, but that both forward and reverse reactions proceed at the same rate. This implies that not all the 2 moles of HI (jar S) would have reacted and therefore it will not form 1 mole of I₂.
- (g) Q1.7 tested hydrolysis. The salt of a strong acid and a strong base does not hydrolyse. The resulting salt will be neutral and will not affect the pH of water. NaCl is the salt formed when hydrochloric acid reacts with sodium hydroxide.
- (h) In Q1.8 candidates did not understand the phrase *at the equivalence point the pH is 7* and did not link it to a strong acid reacting with a strong base. They were therefore not able to identify the correct acid and suitable indicator.
- (i) In Q1.10 most candidates did not know how to use the Table of Standard Reduction Potentials to determine whether a reaction is spontaneous or not.

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. Practise multiple-choice questions regularly in short tests where learners can self-assess or peer mark. Learners must be told not to leave any multiple-choice question unanswered – they should rather take a guess if they do not know the answer.
- (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) The types of intermolecular forces in all organic compounds must be thoroughly revised with learners before they are expected to explain why physical properties differ:
- London forces – (all organic compounds) – weakest
 - Dipole-dipole forces – (all polar organic compounds, i.e. haloalkanes, aldehydes, ketones, esters, alcohols, and carboxylic acids) – stronger than London forces but weaker than hydrogen bonds
 - Hydrogen bonds – (only alcohols and carboxylic acids) – strongest
- (d) When defining reaction rate, learners must be made aware that there are two ways of writing the definition, namely *change in concentration of reactants or products per unit time* or *rate of change in concentration of products or reactants*. When the second definition is used, the *rate of change* already implies *per unit time* and stating it again, will result in an incorrect definition.
- (e) When teaching reaction rate, learners should be made aware that increasing the volume of a solution does not affect the concentration and hence does not affect reaction rate.
- (f) The difference between a *reaction that reaches completion* and a *reaction that reaches equilibrium* must be well explained to learners. They must know that a reaction reaches completion because one or both reactants are used up. However, when a reversible reaction reaches equilibrium, the reaction has not stopped, but both forward and reverse reactions take place at the same rate. None of the reactants or products are used up.

In Q1.6 the equilibrium constant is the same for a specific reaction at a constant temperature. Using the process of elimination, option A can be eliminated because it is only true for a reaction reaching completion. To obtain 1 mole of I_2 , 2 moles of HI in jar S must be converted to a maximum of 1 mole of I_2 . Similarly, option B can be eliminated - if all the reactants in jar R are converted to products, then a maximum of 2 moles of HI will form which is not possible in an equilibrium reaction. For the equilibrium constant to be the same at this temperature, the ratio of the concentration of the products to concentration of reactants needs to be the same, as seen from the balanced equation given. Therefore, R and S will each contain the same concentrations of HI, I_2 and H_2 . Thus, jar R and S will contain the same amount of HI(g) at equilibrium.

- (g) When determining if a salt is acidic, basic, or neutral, learners must be taught to identify the positive and negative ion of the salt. Ions that originally come from strong acids and bases will not hydrolyse. The salt solution will be neutral and will not affect the pH of water. Ions from weak acids or bases will react with water (hydrolyse) to form OH^- (basic) or H_3O^+ (acidic) solutions.
- (h) Learners must be taught which indicator is suitable based on the strength of an acid and a base. The table below gives the pH ranges for the three most common indicators.

Indicator	Strength of acid	Strength of base	pH range
Methyl orange	Strong	Weak	3,1–4,4 (acidic)
Bromothymol blue	Strong	Strong	6,0–7,6 (neutral)
Phenolphthalein	Weak	Strong	5,3–10 (basic)

- (i) The use of Tables 4A and 4B must be explained to learners. Expose learners to enough exercises in which they can practise how to identify the strongest reducing agent and the strongest oxidising agent. Also noteworthy is that oxidising agents appear to the left of the double arrows in both tables and reducing agents to the right. The spontaneous redox reaction will always be between the strongest reducing agent and the strongest oxidising agent.

When marking the relevant half-reactions in Q1.10 on Table 4B, it is easy to see that Mg is the strongest reducing agent followed by Mn etc.

Mg (strongest reducing agent) will reduce Mn^{2+} to Mn and Mg will reduce Cd^{2+} to Cd. Zn is a weaker reducing agent than Mn and will NOT reduce Mn^{2+} to Mn, but Zn is a stronger reducing agent than Cd and will reduce Cd^{2+} to Cd. Both Ni and Ag are weaker reducing agents than Mn and Cd and will not reduce Mn^{2+} to Mn and Cd^{2+} to Cd.

$\text{Mg}^{2+} + 2\text{e}^- = \text{Mg}$	-2,36
$\text{Al}^{3+} + 3\text{e}^- = \text{Al}$	-1,66
$\text{Mn}^{2+} + 2\text{e}^- = \text{Mn}$	-1,18
$\text{Cr}^{2+} + 2\text{e}^- = \text{Cr}$	-0,91
$2\text{H}_2\text{O} + 2\text{e}^- = \text{H}_2(\text{g}) + 2\text{OH}^-$	-0,83
$\text{Zn}^{2+} + 2\text{e}^- = \text{Zn}$	-0,76
$\text{Cr}^{3+} + 3\text{e}^- = \text{Cr}$	-0,74
$\text{Fe}^{2+} + 2\text{e}^- = \text{Fe}$	-0,44
$\text{Cr}^{3+} + \text{e}^- = \text{Cr}^{2+}$	-0,41
$\text{Cd}^{2+} + 2\text{e}^- = \text{Cd}$	-0,40
$\text{Co}^{2+} + 2\text{e}^- = \text{Co}$	-0,28
$\text{Ni}^{2+} + 2\text{e}^- = \text{Ni}$	-0,27
$\text{Sn}^{2+} + 2\text{e}^- = \text{Sn}$	-0,14
$\text{Pb}^{2+} + 2\text{e}^- = \text{Pb}$	-0,13
$\text{Fe}^{3+} + 3\text{e}^- = \text{Fe}$	-0,06
$2\text{H}^+ + 2\text{e}^- = \text{H}_2(\text{g})$	0,00
$\text{S} + 2\text{H}^+ + 2\text{e}^- = \text{H}_2\text{S}(\text{g})$	+0,14
$\text{Sn}^{4+} + 2\text{e}^- = \text{Sn}^{2+}$	+0,15
$\text{Cu}^{2+} + \text{e}^- = \text{Cu}^+$	+0,16
$\text{SO}_4^{2-} + 4\text{H}^+ + 2\text{e}^- = \text{SO}_2(\text{g}) + 2\text{H}_2\text{O}$	+0,17
$\text{Cu}^{2+} + 2\text{e}^- = \text{Cu}$	+0,34
$2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^- = 4\text{OH}^-$	+0,40
$\text{SO}_2 + 4\text{H}^+ + 4\text{e}^- = \text{S} + 2\text{H}_2\text{O}$	+0,45
$\text{Cu}^+ + \text{e}^- = \text{Cu}$	+0,52
$\text{I}_2 + 2\text{e}^- = 2\text{I}^-$	+0,54
$\text{O}_2(\text{g}) + 2\text{H}^+ + 2\text{e}^- = \text{H}_2\text{O}_2$	+0,68
$\text{Fe}^{3+} + \text{e}^- = \text{Fe}^{2+}$	+0,77
$\text{NO}_3^- + 2\text{H}^+ + \text{e}^- = \text{NO}_2(\text{g}) + \text{H}_2\text{O}$	+0,80
$\text{Ag}^+ + \text{e}^- = \text{Ag}$	+0,80

QUESTION 2: ORGANIC NOMENCLATURE

Common errors and misconceptions

- (a) In Q2.1.4 many candidates wrote the name of the homologous series instead of the name of the functional group. It was also evident that many candidates did not know the difference between a *hydroxyl group* ($-\text{OH}$) and the *hydroxide ion* (OH^-).
- (b) When writing IUPAC names in Q2.2, many candidates failed to apply the rules correctly. Hyphens, commas, and alphabetical order were not adhered to, and marks were forfeited. Some candidates forgot to put a hyphen between a number and a letter or a comma between two numbers.

Most learners used incorrect numbering in Q2.2.1. The halogen was incorrectly given preference over the alkyl groups. When determining the parent chain, many candidates did not consider the longest chain and named the compound 3-bromo-2-ethyl-2-methylpentane. These candidates forfeited 3 marks.

In Q2.2.2 many candidates forfeited a mark because they did not give preference to the functional group resulting in incorrect numbering. Some used *pentyl* instead of *pentyne*.

Some candidates numbered the functional group of the aldehyde in Q2.2.3 and forfeited a mark.

- (c) Although most candidates identified the reaction in Q2.3.1 correctly as an *esterification*, many did not even attempt Q2.3.2. Candidates seemed to be unfamiliar with the concept *empirical formula*. Many of those who attempted the question, obtained the molecular formula of compound S, the ester, and stopped there. They did not read/understand the entire question correctly because they had to use the molecular formula of compound S (the ester) to determine the molecular formula of the carboxylic acid. Such candidates forfeited two marks.

Suggestions for improvement

- (a) When writing general formulae of the different homologous series, learners must be made aware that the correct subscripts are crucial. Instead of writing C_nH_{2n-2} , many candidates wrote one of the following incorrect answers:
 C_nC2N-2 , $CnC2N-2$, $CxH2x - 2$, $Cn + H2n+2$, $Cn 2n-2$, $Cn H2-2$, $CHn-2$, $CNH2N-2$
- (b) When writing IUPAC names, the following should be emphasised:
- Correct use of hyphens (between a number and a letter) and commas (between two numbers).
 - The prefixes, *di*, *tri*, etc. are used to indicate more than one of the same type of substituents.
 - In aldehydes and carboxylic acids, the functional group is always on C-1 and numbering must not be used to indicate the position of the functional group, e.g. it should be *butanal* and not *butan-1-al*.
 - The functional group of haloalkanes do not get preference over the alkyl groups. Therefore, numbering should not necessarily start from the side closest to the halogen. Instead, numbering should start from the side giving substituents, halogen and alkyl, the lowest total number.
 - Numbering should always be from the side giving substituents the lowest number, for example when deciding between 4-bromo-3,3-dimethyl or 3-bromo-4,4-dimethyl, the numbers of each should be added to determine the lowest total. 4-bromo-3,3-dimethyl: $4 + 3 + 3 = 10$; bromo-4,4-dimethyl: $3 + 4 + 4 = 11$. Therefore, the lowest total is 10 and numbering should be such that the name is 4-bromo-3,3-dimethyl.
 - 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.
- (c) 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.

- (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 empirical formulae and molecular formulae.

QUESTION 3: PHYSICAL PROPERTIES OF ORGANIC COMPOUNDS

Common errors and misconceptions

- (a) Q3.1.2 involved identification of variables and was not well answered. *Temperature* was the most common incorrect controlled variable selected. Other incorrect responses were *molecular weight* or *chain length* or *type of compound*.
- (b) Lack of skills to interpret negative values for melting points (Q3.1.3) cost many candidates marks. They did not know that $-92\text{ }^{\circ}\text{C}$ is lower than $-72\text{ }^{\circ}\text{C}$. Many stated general facts instead of explaining the answer by comparing compounds C and D. In most instances they contradicted themselves and forfeited marks.
Other common errors were:
 - Referring to *boiling point* instead of *melting point*;
 - Stating the correct intermolecular forces without comparing their strengths;
 - Referring to *breaking of bonds* instead of *overcoming of intermolecular forces*;
 - Omitting the last step that refers to the energy needed.
- (c) Some candidates wrote the definition of *boiling point* instead of *vapour pressure* in Q3.2.1. Those who wrote the definition for *vapour pressure*, omitted key words such as *equilibrium* or *closed system*.
- (d) The term *conclusion* (Q3.2.2) seemed to be unfamiliar to many candidates. Some wrote an aim or a hypothesis or even an investigative question. Some of those who wrote a conclusion, stated an inverse proportionality between chain length and vapour pressure. Others identified the dependent and independent variables incorrectly, e.g. giving *molecular mass* as the independent variable instead of *chain length*.
- (e) Common errors when writing the IUPAC name of the alcohol in Q3.2.3 were: hexan-1-ol, hex-1-ol, hexane-1-ol, hexanol.

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.

Advise learners to explain the relationship between variables, such as *boiling point* and *vapour pressure*, in terms of *increase or decrease* and not in terms of *proportionality*. When mentioning a direct proportionality, it means if values are plotted, a straight line passing through the origin must be obtained which is not the case in these relationships.

- (c) Teachers must expose learners to tables with negative values for temperatures and explain to them that a greater negative value implies a lower temperature.
- (d) When discussing intermolecular forces, the concepts *atoms*, *molecules*, and *ions* should be revised. Emphasise the differences between: bonds between atoms in molecules (intramolecular) and forces between molecules (intermolecular) and that the strength of intermolecular forces is 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 compounds, learners should be taught to follow the following steps:
 - Comparing two compounds from the same homologous series:
 - Compare the surface areas/chain length 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) In Q4.1 candidates referred to the compound as a *tertiary alcohol* instead of a *tertiary haloalkane*. Instead of stating that a tertiary haloalkane is where the halogen/bromine/functional group is bonded to a C atom that is bonded to three other C atoms, some candidates stated that the halogen is bonded to three C atoms. Many referred to *halide* instead of *halogen* or *bromide* instead of *bromine*.
- (b) Reaction conditions of organic reactions (Q4.2.1, Q4.2.3 and Q4.4.2) were a challenge to most candidates. Those who knew that the inorganic reactant in Q4.2.1 and Q4.4.2 is NaOH, omitted the words *concentrated* and *dilute* respectively and forfeited the two marks.
- (c) Apart from choosing the incorrect inorganic reactant in Q4.2.3, other common errors when writing the balanced equation were:
 - Drawing the structural formula of a product with 5 C atoms in the chain (with no substituent) whereas the reactant had 4 C with an alkyl substituent;
 - Omission of the arrow;
 - Writing structural formulae for only reactants or only products;
 - Writing the structural formula of the minor product;
 - Using molecular or condensed structural formulae instead of structural formulae in the equation;
 - Omitting the inorganic reactant in the equation and thus writing the reaction as haloalkane \rightarrow alkene + HBr;
 - Placing the double bond in the product after C-1 instead of after C-2.

Suggestions for improvement

- (a) Explain to learners that (-Br) is not a haloalkane, but a halogen. The halogen together with the C it is bonded to (with correct number of bonds), form the functional group. The presence of a halogen makes the whole molecule a haloalkane. This must also be explained for tertiary alcohols. The terms *primary*, *secondary* and *tertiary* refer to the number of C atoms (one, two and three respectively) bonded to the C atom of the functional group.
- (b) Reaction conditions needed for organic reactions to take place need more attention. The following table summarises reaction conditions for some organic reactions.

Type of organic reaction	Name of reaction	Reactants	Reaction conditions	Products
Substitution	Halogenation	alkane + halogen	hf/ Δ	haloalkane + hydrogen halide
	Hydrolysis	haloalkane + base (NaOH/KOH/LiOH)	<ul style="list-style-type: none"> dilute strong base mild heat 	alcohol + halide salt
		haloalkane + water	<ul style="list-style-type: none"> add water mild heat 	alcohol + hydrogen halide
	Substitution	alcohol + hydrogen halide	no water	haloalkane + water
Addition	Hydration	alkene + water	concentrated H_2SO_4	alcohol
	Hydrogenation	alkene + hydrogen	Pt, Pd, Ni; dissolved in non-polar solvent	alkane
	Halogenation	alkene + halogen		haloalkane
	Hydrohalogenation	alkene + hydrogen halide	no water	haloalkane
Elimination	Cracking	alkanes	high temperature and high pressure OR catalyst	alkene + hydrogen OR alkane + alkene(s)
	Dehydrohalogenation	haloalkane + base (NaOH/KOH)	<ul style="list-style-type: none"> concentrated strong base heat 	alkene + salt + water
	Dehydration	alcohol	<ul style="list-style-type: none"> concentrated H_2SO_4 heat 	alkene + water

- (c) It is important to explain the difference between a *formula* and an *equation*. Learners sometimes write structural formulae of reactants or products when they are supposed to give the entire equation (using structural formulae). An equation must also have an arrow between reactants and products.
- (d) Difference between *minor* and *major* products must be explained clearly and structural and condensed formulae drawn clearly for learners to see the difference and how they are drawn.

QUESTION 5: REACTION RATE**Common errors and misconceptions**

- (a) In Q5.1 most candidates correctly identified *B* as the reaction at the higher rate due to the presence of the catalyst but failed to state the function of the catalyst and give a correct explanation in terms of the collision theory. Many candidates omitted key words in the explanation, e.g. instead of *more effective collisions per unit time* candidates wrote the following partially correct phrases:
- 'Effective collisions per unit time';
 - 'More collisions per unit time';
 - 'More effective collisions'.
- (b) Most candidates failed to interpret that when no more oxygen is produced (Q5.4.1), the rate will be $0 \text{ g}\cdot\text{s}^{-1}$. Common errors were:
- Using the mass of 0,9 g given on the graph as the rate;
 - Stating that the reaction reached equilibrium (These candidates did not know that only a reversible reaction can reach equilibrium.);
 - The reaction stopped or was completed without stating what happened to the rate of the reaction.
- (c) In Q 5.3.2 many candidates used an incorrect formula to calculate the number of moles. Other common errors were:
- Substituting the volume of H_2O , a liquid, in $n = \frac{V}{V_M}$ which is only for gases;
 - Using $V_M = 22,4 \text{ dm}^3\cdot\text{mol}^{-1}$ instead of the given $24\,000 \text{ cm}^3\cdot\text{mol}^{-1}$;
 - Omitting the mole ratio step;
 - Using the volume ratio of water (a liquid) and the O_2 .
- (d) The calculation in Q5.4.3 was poorly answered. Common errors were:
- Substituting the $M(\text{O}_2)$ as $16 \text{ g}\cdot\text{mol}^{-1}$;
 - Omission of mole ratio step;
 - Using $22,4 \text{ dm}^3\cdot\text{mol}^{-1}$ as the molar gas volume and not the value given in the question paper.

Suggestions for improvement

- (a) Explanations in terms of the *collision theory* need improvement. Learners must be taught to write a full explanation including the necessary key words.

When a catalyst is added:

- The activation energy is lowered.
- More particles have kinetic energy equal to or higher than the activation energy/More particles have sufficient kinetic energy.
- More effective collisions per unit time.

It is important to note that the catalyst does not increase the kinetic energy of the molecules. The catalyst lowers the energy needed (activation energy) and therefore, more particles have sufficient kinetic energy.

- (b) Emphasis should be placed on the difference between *reversible* and *non-reversible* reactions. Reversible reactions can reach equilibrium, while 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) *Stoichiometry* will always be an important part of a Chemistry paper. The understanding of *stoichiometry* should be a continuous theme in the teaching of Chemistry. The more thoroughly it is done in Grades 10 and 11, the more successful candidates will be in Grade 12.

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.

- (d) It should be emphasised that the molar gas volume of $22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$ is only applicable for gases to STP.
- (e) Remind learners of how to calculate diatomic substances' molar mass, e.g. oxygen's molar mass is $32 \text{ g} \cdot \text{mol}^{-1}$ and not $16 \text{ g} \cdot \text{mol}^{-1}$.

QUESTION 6: CHEMICAL EQUILIBRIUM

Common errors and misconceptions

- (a) When stating *Le Chatelier's principle* (Q6.1) some candidates omitted the phrase *closed system*. Others common errors were:
- The *reaction is disturbed* instead of *equilibrium is disturbed*;
 - Favouring the reaction that will *cancel the motion* instead of *cancelling the disturbance*;
 - Stating that the reverse reaction will be favoured.
- (b) Q6.2 was poorly answered. Common errors were:
- Substituting number of moles of CS_2 in the K_c expression;
 - Rounding off the final answer to one decimal place (0,2 instead of 0,23 $\text{mol} \cdot \text{dm}^{-3}$);
 - No K_c expression e.g., $K_c = \frac{[\text{products}]}{[\text{reactants}]}$;
 - K_c expressions containing writing errors, such as $K_c = \frac{(\text{CS}_2)}{(\text{S})^2}$, $K_c = \frac{[\text{CS}]}{[\text{S}]^2}$ or $K_c = \frac{[\text{CS}_2]}{[\text{S}]}$;
 - Using incorrect K_c expressions, i.e. $K_c = \frac{[\text{CS}_2]}{[\text{C}][\text{S}]^2}$ (solid included) or $K_c = \frac{[\text{S}]^2}{[\text{CS}_2]}$ (swapping reactant and product)
- (c) Most candidates got the answer correct in Q6.3 but could not explain this answer in Q6.4. Candidates failed to link the increase in volume to a decrease in pressure. Therefore, some candidates explained the answer in terms of a change in temperature or a change in concentration. Other common errors were:
- Using the *collision theory* instead of *Le Chatelier's principle* in the explanation.
 - Stating *Le Chatelier's principle* instead of applying it when explaining.
- (d) Q6.5 was the poorest answered subquestion in the paper. Many of those candidates who attempted the question, did not realise that the volume decreased by half and thus the initial concentrations for the new situation must be divided by two. Others did not realise that there were reagents initially present in the container.

- (e) Most candidates failed to interpret the graph in Q6.6. They confused the rate versus time graph with a concentration versus time graph.

A common error when answering Q6.6.2 was not mentioning *increase in concentration or amount of S*. Most only stated *increase in concentration* and forfeited the mark.

In Q6.6.3 many candidates could not link the change at t_c to a drop in temperature and hence the explanation in Q6.6.4 was also poor.

Suggestions for improvement

- (a) Explain to learners why solids and pure liquids should not be included in K_c expressions and expose them to enough exercises to practise writing of K_c expressions for reactions where reactants and products are in different phases. Avoid using $K_c = \frac{[\text{products}]}{[\text{reactants}]}$ in class creating the impression that it is a correct K_c expression.
- (b) Learners should be taught to label formulae when doing multistep calculations, e.g. when calculating the concentration of CS_2 , it should be indicated as $c(\text{CS}_2)$.
- (c) When using a table to solve K_c calculations, learners should be taught to use correct labels in the first column, i.e. $n(\text{initial})$, $n(\text{change})$, $n(\text{equilibrium})$, $c(\text{equilibrium})$ and to write the correct values of these for each reactant or product in the correct cell. Use previous marking guidelines to show learners the labelling in such tables.
- (d) Learners should be exposed to many exercises requiring explanations in terms of *Le Chatelier's principle*. This will assist them in expressing themselves in such explanations. 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.
- (e) Ensure learners understand and can interpret the various graphs (rate vs time and concentration vs time) that relate to changes in equilibrium conditions.
- (f) Use the revision booklet designed by the DBE to support learners.

QUESTION 7: ACIDS AND BASES

Common errors and misconceptions

- (a) Although the definition of an acid in Q7.1.1 was well answered, some candidates referred to *photons* instead of *protons* or to *hydrogen* instead of *hydrogen ions* or *hydronium ions*. Others wrote the definition for the Arrhenius theory.
- (b) A common error in Q7.1.2 was the use of the phrase *acids that dissolve completely* instead of *acids that ionise or dissociate completely*. Many candidates used one of the following incorrect reasons for ethanoic acid being a weak acid:
- It has a low hydronium ion concentration.
 - It is used in the house or in food.
 - It can be swallowed.

- (c) Instead of writing the formulae of the two bases (Q7.1.3), some candidates wrote the formulae of one of the conjugate acid-base pairs or copied the whole equation without indicating the two bases.
- (d) In Q7.2.1 some candidates calculated *mass* instead of *number of moles*. The unit of the amount of substance, namely *moles*, also seemed to be unfamiliar to some. Many candidates substituted the values correctly in the correct formula, but failed to find the concentration due to lack of calculator skills.
- (e) Some candidates failed to copy the pH formula correctly from the data sheet in Q7.2.2. Other common errors were:
- Using an incorrect pH formula, e.g. $\text{pH} = -\log[\text{H}_3\text{O}]$ or $\text{pH} = -\log(\text{H}_3\text{O}^+)$ or $\text{ph} = -\log[\text{H}_3\text{O}^+]$ or $\text{pH} = -\log[\text{OH}^-]$;
 - Giving the concentration of H_3O^+ as the final answer without calculating $[\text{OH}^-]$;
 - Omitting the unit of concentration at the final answer or using an incorrect unit, e.g. $\text{mol}\cdot\text{dm}^3$
- (f) In Q7.2.3 most candidates did not calculate the $n(\text{NaOH})_{\text{reacted}}$. They could not identify the NaOH as being in excess and assumed all the NaOH present initially reacted and used the mole ratio to obtain $n(\text{CH}_3\text{COOH})$ from $n(\text{NaOH})_{\text{initial}}$. These candidates forfeited five of the six marks. Some tried to use the equilibrium table. Most learners could not calculate the change in number of moles of CH_3COOH .

Suggestions for improvement

- (a) Learners must be taught to convert units correctly, e.g. from cm^3 to dm^3 . Two marks are forfeited in a 3-mark question due to incorrect conversions.
- (b) Learners should be taught to copy formulae correctly from the data sheet. Manipulation of formulae can be done in a second step. Starting with an incorrect formula can result in no marks being awarded.
- (c) Ensure that learners copy the pH as it is from the data sheet and teach the calculator manipulation skills to obtain the correct concentration of hydronium or hydroxide ions when a pH is given. Include exercises involving the use of the K_{W} formula in daily assessments.
- (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) 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: $n(\text{NaOH}) = cV$
- (f) The formula $\frac{c_a V_a}{c_b V_b} = \frac{n_a}{n_b}$ must only be used when the question refers to an equivalent point/end point/neutralisation or to a colour change. This equation is usually used during an acid-base titration and not when an acid and a base are just added together and one of them is in excess. Rather use mole ratios and calculations involving $n = cV$ instead of the titration formula.
- (g) 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) In Q8.1.1 many candidates wrote the formula of an oxidising agent Zn^{2+} instead of the reducing agent Zn. Some wrote the oxidation or reduction half-reaction.
- (b) Many candidates failed to use the *Table of Standard Reduction Potentials* to explain why a redox reaction took place in Q8.1.2. The relative positions of oxidising agents and reducing agents on the table was not well understood and Zn was used as oxidising agent in the explanation. Instead of stating, e.g. that MnO_4^- is a stronger oxidising agent than Zn^{2+} , some candidates were penalised for using words such as *MnO₄⁻ is lower than/bigger than ...* Some candidates did not limit their explanation to relative strengths of oxidising agents as required.
- (c) The function of the salt bridge in Q8.2.1 was misunderstood by some. Common incorrect answers were:
- A pathway for movements of electrons to ensure electrical neutrality;
 - Neutralises the cell/electrons/reaction;
 - Connects the two half-cells;
 - Completes the cell.
- (d) When calculating cell potential (Q8.2.3) common errors were:
- Using abbreviations in the formula, e.g. $E_{\text{cell}} = E_{\text{red}} - E_{\text{ox}}$ or $E_{\text{cell}} = E_{\text{oxidising}} - E_{\text{reducing}}$
 - Swapping the reduction potential of the anode with that of the cathode when substituting
 - No unit at the final answer
- (e) In Q8.2.4 some candidates wrote the *cell notation* instead of the *cell reaction*. Some candidates wrote oxidising agents on one side of the arrow and reducing agents on the other side. A few candidates used incorrect symbols for the elements, i.e. $\text{MN} + \text{NI}^{2+} \rightarrow \text{MN}^{2+} + \text{NI}$ or omitted the charges on the ions in an otherwise correct equation. Some of those who wrote the correct equation, left it unbalanced.

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, e.g. 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*.
- Learners should also be taught how to use the *Table of Standard Reduction Potentials* in explanations in terms of the relative strength of oxidising or reducing agents.
- (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 Q8.2.5 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 $V_{\text{cell}} = 0$.

QUESTION 9: ELECTROLYTIC CELLS

Common errors and misconceptions

- Although the definition of *electrolyses* was well answered in Q9.1, some candidates wrote the definition of an *electrolyte* instead.
- In Q9.2.1 some candidates wrote the word *reduction* instead of the reduction half-reaction that took place at the electrode T. Many candidates wrote the half-reaction for Cr^{2+} instead of the half-reaction for Cr^{3+} . A double arrow was also used by some of those who wrote an otherwise correct half-reaction.
- Candidates made two vital errors when answering Q9.2.2. Many did not convert the 10 hours to seconds by multiplying it by 3 600 and some omitted the unit of charge in the final answer.
- Q9.2.3 was very similar to the last question in the 2021 paper and those who worked through that paper answered this question well. Common errors were:
 - Using an incorrect or no mole ratio when calculating the number of electrons transferred.
 - Multiplying the number of moles of chromium by 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 $n = \frac{Q}{q}$ (In this formula, n is the number of electrons.).

Suggestions for improvement

- 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 whilst *electrolysis* is a process during which electrical energy is converted to chemical energy.
- 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.
- Learners must be taught how to select half-reactions, especially for those substances with more than one half-reaction, e.g. $\text{Cr}^{3+}|\text{Cr}$, $\text{Cr}^{2+}|\text{Cr}$ and $\text{Cr}^{3+}|\text{Cr}^{2+}$. Ionisation of ionic compounds must be revised. If a learner knows that ionisation of CrCl_3 forms Cr^{3+} and 3Cl^- then it will be easier to choose the correct half reaction. More assessment must be given using the substances that appear more than once in the *Table of Standard Reduction Potentials*.
- Grade 10 and 11 *stoichiometry* must be revised in Grade 12 as *stoichiometry* is still a huge challenge.
- Use of the formulae $n = \frac{Q}{q_e}$ (n = number of electrons), $n = \frac{N}{N_A}$ (n = number of moles) must also be revised thoroughly.