

Exemplar Book on Effective Questioning

Physical Sciences

Compiled by the Statistical Information and Research (SIR) Unit

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PREFACE

The National Senior Certificate (NSC) examinations are set and moderated in part using tools that specify the types of cognitive demand and the content deemed appropriate for Physical Sciences at Grade 12 level. Until recently, the level of cognitive demand made by a question was considered to be the main determinant of the overall level of cognitive challenge of an examination question.

However, during various examination evaluation projects conducted by Umalusi from 2008-2012, evaluators found the need to develop more complex tools to distinguish between questions which were categorised at the same cognitive demand level, but which were not of comparable degrees of difficulty. For many subjects, for each type of cognitive demand a three-level degree of difficulty designation, *easy, moderate and difficult* was developed. Evaluators first decided on the type of cognitive process required to answer a particular examination question, and then decided on the degree of difficulty, *as an attribute of the type of cognitive demand*, of that examination question.

Whilst this practice offered wider options in terms of *easy, moderate and difficult* levels of difficulty for each type of cognitive demand overcame some limitations of a one-dimensional cognitive demand taxonomy, other constraints emerged. Bloom's Taxonomy of Educational Objectives (BTEO) (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956) and the Revised Bloom's Taxonomy are based on the assumption that a cumulative hierarchy exists between the different categories of cognitive demand (Bloom *et al.*, 1956; Bloom, Hastings & Madaus, 1971). The practice of 'levels of difficulty' did not necessarily correspond to a hierarchical model of increasing complexity of cognitive demand. A key problem with using the level of difficulty as an attribute of the type of cognitive demand of examination questions is that, questions recognised at a higher level of cognitive demand are not necessarily categorised as more difficult than other questions categorised at lower levels of cognitive demand. For example, during analyses a basic recognition or

recall question could be considered more difficult than an easy evaluation question.

Research further revealed that evaluators often struggled to agree on the classification of questions at so many different levels. The finer categorization for each level of cognitive demand and the process of trying to match questions to pre-set definitions of levels of difficulty made the process of making judgments about cognitive challenge overly procedural. The complex two-dimensional multi-level model also made findings about the cognitive challenge of an examination very difficult for Umalusi's Assessment Standards Committee (ASC) to interpret.

In an Umalusi Report, *Developing a Framework for Assessing and Comparing the Cognitive Challenge of Home Language Examinations* (Umalusi, 2012), it was recommended that the type and level of cognitive demand of a question and the level of a question's difficulty should be analysed separately. Further, it was argued that the ability to assess cognitive challenge lay in experts' abilities to recognise subtle interactions and make complicated connections that involved the use of multiple criteria simultaneously. However, the tacit nature of such judgments can make it difficult to generate a common understanding of what constitutes criteria for evaluating the cognitive challenge of examination questions, despite descriptions given in the policy documents of each subject.

The report also suggested that the Umalusi external moderators and evaluators be provided with a framework for thinking about question difficulty, which would help them identify where the main sources of difficulty or ease in questions might reside. Such a framework should provide a common language for evaluators and moderators to discuss and justify decisions about question difficulty. It should also be used for building the capacity of novice or less experienced moderators and evaluators to exercise the necessary expert judgments by making them more aware of key aspects to consider in making such judgments.

The revised Umalusi examination moderation and evaluation instruments for each subject draw on research and literature reviews, together with the knowledge gained through the subject workshops. At these workshops, the proposed revisions were discussed with different subject specialists to attain a common understanding of the concepts, tools and framework used; and to test whether the framework developed for thinking about question difficulty 'works' for different content subjects. Using the same framework to think about question difficulty across subjects will allow for greater comparability of standards across subjects and projects.

An important change that has been made to the revised examination evaluation instrument is that the analysis of *the type of cognitive demand* of a question and analysis of *the level of difficulty* of each question are now treated as two separate judgments involving two different processes. Accordingly, the revised examination evaluation instrument now includes assessment of difficulty as well as cognitive demand.

LIST OF ABBREVIATIONS

Abbreviation	Full name
ASC	Assessment Standards Committee
BTEO	Bloom's Taxonomy of Educational Objectives
CAPS	Curriculum Assessment Policy Statement
DBE	Department of Basic Education
FET	Further Education and Training
IEB	Independent Examinations Board
NSC	National Senior Certificate
NQF	National Qualifications Framework
QAA	Quality Assurance of Assessment
QCC	Qualifications, Curriculum and Certification
SIR	Statistical Information and Research

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This Physical Sciences exemplar book is informed by Umalusi Research Reports of previous years, especially the report by Reeves (Umalusi, 2012) titled '*Developing a framework for assessing and comparing the cognitive challenge of Home Language examinations*'.

In addition, Physical Sciences subject experts and practitioners are acknowledged for their contribution to the content of this exemplar book. Included in this group are: Umalusi External Moderators and Maintaining Standards Subject Teams and Team Leaders; together with the South African Comprehensive Assessment Institute and the Independent Examinations Board (IEB) Examiners and Internal Moderators.

We also acknowledge the contributions of the members of the Umalusi Quality Assurance of Assessment (QAA); Qualifications, Curriculum and Certification (QCC) and Statistical Information and Research (SIR) Units. We specifically acknowledge the contribution made by the individuals listed below:

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1. INTRODUCTION

The rules of assessment are essentially the same for all types of learning because, to learn is to acquire knowledge or skills, while to assess is to identify the level of knowledge or skill that has been acquired (Fiddler, Marienau & Whitaker, 2006). Nevertheless, the field of assessment in South Africa and elsewhere in the world is fraught with contestation. A review of the research literature on assessment indicates difficulties, misunderstanding and confusion in how terms describing educational measurement concepts, and the relationships between them, are used (Frisbie, 2005).

Umalusi believes that if all role players involved in examination processes can achieve a common understanding of key terms, concepts and processes involved in setting, moderating and evaluating examination papers, much unhappiness can be avoided. This exemplar book presents a particular set of guidelines for both novice and experienced Physical Sciences national examiners, internal and external moderators, and evaluators to use in the setting, moderation and evaluation of examinations at the National Senior Certificate (NSC) level.

The remainder of the exemplar book is organised as follows. First, the context in which the exemplar book was developed is described (Part 2), followed by a statement of its purpose (Part 3). Brief summaries of the roles of moderation and evaluation (Part 4) and cognitive demand (Part 5) in assessment follow. Examination questions selected from the NSC Physical Sciences examinations of assessment bodies, the Department of Basic Education (DBE), and/or the Independent Examinations Board (IEB) are used to illustrate how to identify different levels of cognitive demand as required by the Curriculum and Assessment Policy Statement (CAPS) Physical Sciences document (Part 6). Part 7 explains the protocols for identifying different levels of difficulty within a question paper. Application of the Umalusi framework for determining difficulty

described in Part 7 is illustrated, with reasons, by another set of questions from a range of Physical Sciences examinations (Part 8). Concluding remarks complete the exemplar book (Part 9).

2. CONTEXT

Umalusi has the responsibility to quality assure qualifications, curricula and assessments of National Qualification Framework (NQF) levels 1 – 5. This is a legal mandate assigned by the *General and Further Education and Training Act (58 of 2001)* and the *National Qualification Framework Act (67 of 2008)*. To operationalize its mandate, Umalusi, amongst other things, conducts research and uses the findings of this research to enhance the quality and standards of curricula and assessments.

Since 2003, Umalusi has conducted several research studies that have investigated examination standards. For example, Umalusi conducted research on the NSC examinations, commonly known as 'Matriculation' or Grade 12, in order to gain an understanding of the standards of the new examinations (first introduced in 2008) relative to those of the previous NATED 550 Senior Certificate examinations (Umalusi, 2009a, 2009b). Research undertaken by Umalusi has assisted the organisation to arrive at a more informed understanding of what is meant by assessing the cognitive challenge of the examinations and of the processes necessary for determining whether the degree of cognitive challenge of examinations is comparable within a subject, across subjects and between years.

Research undertaken by Umalusi has revealed that different groups of examiners, moderators and evaluators do not always interpret cognitive demand in the same way, posing difficulties when comparisons of cognitive challenge were required. The research across all subjects also showed that

using the type and level of cognitive demand of a question *only* as measure for judging the cognitive challenge of a question is problematic because cognitive demand levels on their own do not necessarily distinguish between degrees of difficulty of questions.

The new Umalusi framework for thinking about question difficulty described in this exemplar book is intended to support all key role players in making complex decisions about what makes a particular question challenging for Grade 12 examination candidates.

3. THE PURPOSE OF THE EXEMPLAR BOOK

The overall goal of this exemplar book is to ensure consistency of standards of examinations across the years in the Further Education and Training (FET) sub-sector and Grade 12 in particular. The specific purpose is to build a shared understanding among teachers, examiners, moderators, evaluators, and other stakeholders, of methods used for determining the type and level of cognitive demand as well as the level of difficulty of examination questions.

Ultimately, the common understanding that this exemplar book seeks to foster is based on the premise that the process of determining the type and level of cognitive demand of questions and that of determining the level of difficulty of examination questions, are two separate judgments involving two different processes, both necessary for evaluating the cognitive challenge of examinations. This distinction between cognitive demand and difficulty posed by questions needs to be made in the setting, moderation, evaluation and comparison of Physical Sciences examination papers.

The exemplar book includes an explanation of the new Umalusi framework which is intended to provide all role-players in the setting of Physical Sciences examinations with a common language for thinking and talking about

question difficulty. The reader of the exemplar book is taken through the process of evaluating examination questions, first in relation to determining the type and level of cognitive demand made by a question; and then in terms of assessing the level of difficulty of a question. This is done by providing examples of a range of questions, which make different types of cognitive demands on candidates, and examples of questions at different levels of difficulty.

Each question is accompanied by an explanation of the reasoning behind why it was judged as being of a particular level of cognitive demand or difficulty, and the reasoning behind the judgements made is explained. These examples of examination questions provided were sourced by Physical Sciences evaluators from previous DBE and the IEB Physical sciences question papers, pre- and post- the implementation of CAPS during various Umalusi workshops.

This exemplar book is an official document. The process of revising the Umalusi examination evaluation instrument and of developing a framework for thinking about question difficulty for both moderation and evaluation purposes has been a consultative one, with the DBE and the IEB assessment bodies. The new framework for thinking about question difficulty is to be used by Umalusi in the moderation and evaluation of Grade 12 Physical Sciences examinations, and by all the assessment bodies in the setting of the question papers, in conjunction with the CAPS documents.

4. MODERATION AND EVALUATION OF ASSESSMENT

A fundamental requirement, ethically and legally, is that assessments are fair, reliable and valid (American Educational Research Association [AERA], American Psychological Association [APA] and National Council on Measurement in Education [NCME], 1999). Moderation is one of several quality

assurance assessment processes aimed at ensuring that an assessment is fair, reliable and valid (Downing & Haladyna, 2006). Ideally, moderation should be done at all levels of an education system, including the school, district, provincial and national level in all subjects.

The task of Umalusi examination **moderators** is to ensure that the quality and standards of a particular examination are maintained each year. Part of this task is for moderators to alert examiners to details of questions, material and/or any technical aspects in examination question papers that are deemed to be inadequate or problematic and that therefore, challenge the validity of that examination. In order to do this, moderators need to pay attention to a number of issues as they moderate a question paper – these are briefly described below.

Moderation of the technical aspects of examination papers includes checking correct question and/or section numbering, and ensuring that visual texts and/or resource material included in the papers are clear and legible. The clarity of instructions given to candidates, the wording of questions, the appropriateness of the level of language used, and the correct use of terminology need to be interrogated. Moderators are also expected to detect question predictability, for example, when the same questions regularly appear in different examinations, and bias in examination papers. The adequacy and accuracy of the marking memorandum (marking guidelines) needs to be checked to ensure that it reflects and corresponds with the requirements of each question asked in the examination paper being moderated.

In addition, the task of moderators is to check that papers adhere to the overall examination requirements as set out by the relevant assessment body with regard to the format and structure (including the length, type of texts or reading selections prescribed) of the examination. This includes assessing compliance with assessment requirements with regard to ensuring that the

content is examined at an appropriate level and in the relative proportions (weightings) of content and/or skills areas required by the assessment body.

The role of Umalusi examination **evaluators** is to perform analysis of examination papers after they have been set and moderated and approved by the Umalusi moderators. This type of analysis entails applying additional expert judgments to evaluate the quality and standard of finalised examination papers before they are written by candidates in a specific year. However, the overall aim of this evaluation is to judge the comparability of an examination against the previous years' examination papers to ensure that consistent standards are being maintained over the years.

The results of the evaluators' analyses, and moderators' experiences provide the Umalusi's Assessment Standards Committee (ASC) with valuable information, which is used in the process of statistical moderation of each year's examination results. Therefore, this information forms an important component of essential qualitative data informing the ASC's final decisions in the standardisation of the examinations.

In order for the standardisation process to work effectively, efficiently and fairly, it is important that examiners, moderators and evaluators have a shared understanding of how the standard of an examination paper is assessed, and of the frameworks and main instruments that are used in this process.

5. COGNITIVE DEMANDS IN ASSESSMENT

The *Standards for educational and psychological testing* (AERA, APA, & NCME, 1999) require evidence to support interpretations of test scores with respect to cognitive processes. Therefore, valid, fair and reliable examinations require that the levels of cognitive demand required by examination questions are appropriate and varied (Downing & Haladyna, 2006). Examination papers

should not be dominated by questions that require reproduction of basic information, or replication of basic procedures, and under-represent questions invoking higher level cognitive demands.

Accordingly, the Grade 12 CAPS NSC subject examination specifications state that examination papers should be set in such a way that they reflect proportions of marks for questions at various level of cognitive demand. NSC examination papers are expected to comply with the specified cognitive demand levels and weightings. NSC examiners have to set and NSC internal moderators have to moderate examination papers as reflecting the proportions of marks for questions at different levels of cognitive demand as specified in the documents. Umalusi's external moderators and evaluators are similarly tasked with confirming compliance of the examinations with the CAPS cognitive demand levels and weightings, and Umalusi's revised examination evaluation instruments continue to reflect this requirement.

Despite subject experts, examiners, moderators and evaluators being familiar with the levels and explanations of the types of cognitive demand shown in the CAPS documents, Umalusi researchers have noted that individuals do not always interpret and classify the categories of cognitive demand provided in the CAPS the same way. In order to facilitate a common interpretation and classification of the cognitive demands made by questions, the next section of this exemplar book provides a clarification of each cognitive demand level for Physical Sciences followed by illustrative examples of examination questions that have been classified at that level of cognitive demand.

6. EXPLANATIONS AND EXAMPLES OF QUESTIONS ASSESSED AT THE DIFFERENT COGNITIVE DEMAND LEVELS IN THE PHYSICAL SCIENCES TAXONOMY ACCORDING TO CAPS

The taxonomies of cognitive demand for each school subject in the CAPS documents are mostly based on the Revised Bloom's Taxonomy (Anderson and Krathwohl, 2001) but resemble the original Bloom's taxonomy in that categories of cognitive demand are arranged along a single continuum. Bloom's Taxonomy of Educational Objectives (BTEO) (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956) and the Revised Bloom's Taxonomy imply that each more advanced or successive category of cognitive demand subsumes all categories below it. The CAPS Taxonomies of Cognitive Demand make a similar assumption (Crowe, 2012).

Note:

In classifying the type and level of cognitive demand, each question is classified at the highest level of cognitive process involved. Thus, although a particular question involves recall of knowledge, as well as comprehension and application, the question is classified as an 'analysis' question if that is the highest level of cognitive process involved. If 'evaluating' is the highest level of cognitive process involved, the question as a whole should be classified as an 'evaluation' question. On the other hand, if one of more sub-sections of the question and the marks allocated for each sub-section can stand independently, then the level of cognitive demand for each sub-section of the question should be analysed separately.

The CAPS documents for many subjects also give examples of descriptive verbs that can be associated with each of the four levels of cognitive demand. However, it is important to note that such 'action verbs' can be associated with more than one cognitive level depending on the context of a question.

The Physical Sciences CAPS document states that Grade 12 NSC Physical Sciences examination papers should examine four levels of cognitive demand (Table 1).

TABLE 1: THE TAXONOMY OF COGNITIVE DEMAND LEVELS FOR THE PHYSICAL SCIENCES NSC EXAMINATIONS

Levels of Cognitive Demand for Physical Sciences Taxonomy
1. Recall
2. Comprehension
3. Analysis and Application
4. Evaluation and Synthesis

Source: CAPS (DBE, 2011 p.144)

To facilitate reading of this section, each of the above cognitive demand levels in the Physical Sciences Taxonomy are explained, and the explanation is followed by at least **three** examples of questions from previous Physical Sciences NSC examinations classified at each of the levels of cognitive demand shown in Table 1 above. These examples were selected to represent the **best and clearest** examples of each level of cognitive demand that the Physical Sciences experts could find. The discussion below each example question explains the reasoning processes behind the classification of the question at that particular type of cognitive demand (Table 2 to Table 5).

Note:

Be mindful that analyses of *the level of cognitive process* of a question and *the level of difficulty* of each question are to be treated as two separate judgments involving two different processes. Therefore, whether the question is easy or difficult should not influence the categorisation of the question in terms of the type and level of cognitive demand. Questions should NOT be categorised as higher order evaluation/synthesis questions because they are difficult questions. Some questions involving the cognitive process of recall or recognition may be more difficult than other recall or recognition questions. Not all comprehension questions are easier than questions involving analysis or synthesis. Some comprehension questions may be very difficult, for example explanation of complex scientific processes. For these reasons, you need to categorise the level of difficulty of questions separately from identifying the type of cognitive process involved.

TABLE 2: EXAMPLES OF QUESTIONS AT LEVEL 1: RECALL

Example 1:
Question 1.1, November 2013 Paper 1, DBE:
Give one word/term for the rate of change of velocity. (1)
Discussion:
<ul style="list-style-type: none"> This is categorised as a Recall question because it is a straight-forward memorisation and recall question, requiring learners to identify a scientific concept and to recall the word or term associated with this concept. This question requires learners to provide a word or phrase, a definition, or a learned description of a scientific phenomenon, would be a recall question.
Memorandum/Marking guidelines
1.1 Acceleration. ✓
Example 2:
Question 5.1.1, November 2009 Paper 2, DBE:
Name the homologous series to which the following pair of compounds belongs: CH ₃ COOH and CH ₃ (CH ₂)COOH (1)
Discussion:
<ul style="list-style-type: none"> This is categorised as a Recall question because it involves recognition and recall, requiring learners to identify the category to which organic compounds belong given the molecular formula, and to recall the name of this category. This question involves identification of chemical species; categorisation and naming would be a recall question. <p>NB: Although this question is likely to be experienced as more challenging than the one in the previous example, it still involves the cognitive processes of memorisation and recall. The level of difficulty of the questions is considered separately, as the type of cognitive process does not give an indication of how difficult the question would be to the envisaged candidate.</p>
Memorandum/Marking guidelines
i. Carboxylic acids ✓
Example 3:
Question 4.2, November 2012 Paper 1, DBE:
State the principle of conservation of linear momentum in words. (2)
Discussion:
<ul style="list-style-type: none"> This is categorised as a Recall question because it involves memorisation and recall, requiring learners to recall from memory and correctly state a scientific principle.

- This question requires learners to state a law, principle or theory, or to describe a scientific model, would be a recall question.

Memorandum/Marking guidelines

4.2 The total (linear) momentum remains constant/is conserved[√] in an isolated/a closed system/the absence of external forces/if the impulse of the external force is zero. [√]

Table 3: Examples of questions at level 2: COMPREHENSION

Example 1:

Question 11.4, November 2008 Paper 2, DBE:

Explain why carbon dioxide is formed at one of the electrodes in an electrolytic cell used for the extraction of aluminium. (2)

Discussion:

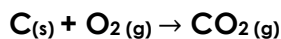
- This question is categorised as a **Comprehension** question because it requires learners to explain the reason behind a scientific phenomenon.
- This requires that the learner understand/comprehend the scientific process that is taking place.
- Although the question involves some level of recall, the cognitive process involved in providing the explanation is a higher-order skill, and thus the question would be categorised as a comprehension question.
- This question requires a learner to explain the reason behind some observation or phenomenon would be classified as a comprehension question.

NB: It should be noted that not all comprehension questions are simpler than questions involving high-order thinking skills such as analysis or synthesis. Some comprehension questions may be very difficult, for example explanation of complex scientific processes. This is why it is important to categorise level of difficulty separately from type of cognitive skill involved.

Memorandum/Marking guidelines

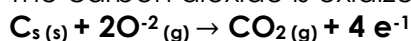
11.4 Carbon will burn in/react with O₂ because of the high temperature to form CO₂ ^{√√}

OR



OR

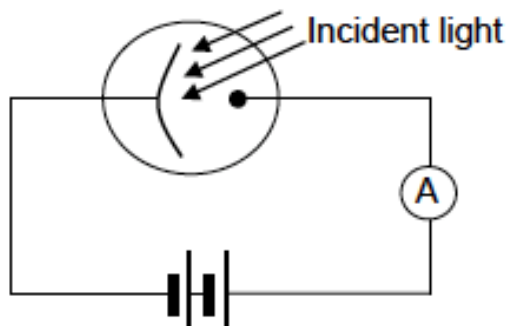
The carbon dioxide is oxidized according to the following half-reaction:



Example 2:

Question 2.10, November 2012 Paper 1, DBE:

The diagram below shows light incident on the cathode of a photocell. The ammeter registers a reading.



Which ONE of the following correctly describes the relationship between the intensity of the incident light and the ammeter reading? (2)

- A. Intensity increases, Ammeter reading increases.
- B. Intensity increases, Ammeter reading remains the same.
- C. Intensity increases, Ammeter reading decreases.
- D. Intensity decreases, Ammeter reading increases.

Discussion:

- This question is categorised as a **Comprehension** question because it requires learners to understand/comprehend the concepts of intensity and current in a photocell, and how these are related to one another. It also requires learners to understand the processes involved in a photocell.
- Although the question involves some level of recall, the cognitive process involved in understanding the relationships between the concepts is a higher-order skill, and thus the question would be categorised as a comprehension question.
- This question requires a learner to demonstrate their understanding of scientific concepts and the relationship between them is a comprehension question.

Memorandum/Marking guidelines

2.10 A ✓✓

Example 3:

Question 4.2, November 2012 Paper 2, DBE:

During a practical investigation, the boiling points of the first six straight-chain ALKANES were determined and the results were recorded in the table below.

ALKANE	MOLECULAR FORMULA	BOILING POINT (°C)
Methane	CH ₄	-164
Ethane	C ₂ H ₆	-89
Propane	C ₃ H ₈	-42
Butane	C ₄ H ₁₀	-0,5
Pentane	C ₅ H ₁₂	36
Hexane	C ₆ H ₁₄	69

For this investigation, write down the following:

1. Dependent variable
2. Independent variable
3. Conclusion that can be drawn from the above results

Discussion:

- This question is categorised as a **Comprehension** question because it requires learners to understand/comprehend the scientific method, and to identify variables, trends and relationships. It also requires learners to comprehend a set of results in order to identify relationships and draw conclusions.
- This question requires a learner to demonstrate their understanding of the scientific method is a comprehension question.

Memorandum/Marking guidelines

4.2.1 Boiling point ✓

4.2.2 Chain length/ Molecular size/Molecular mass ✓

4.2.3

Criteria for conclusion	Marks
Dependent and independent variable correctly identified.	✓
Relationship between the independent and dependent variables correctly stated.	✓

Examples:

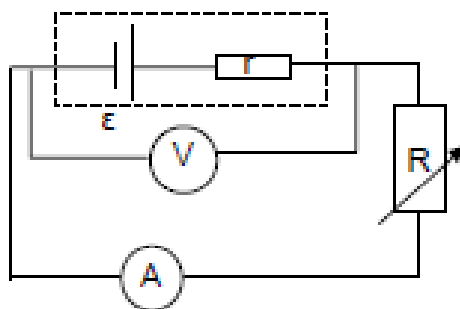
- Boiling point increases with increase in chain length/molecular size/molecular mass.
- Boiling point decreases with decrease in chain length/molecular size/molecular mass.
- Boiling point is proportional to chain length/molecular size/molecular mass.

TABLE 4: EXAMPLES OF QUESTIONS AT LEVEL 3: ANALYSIS AND APPLICATION

Example 1:

Question 4.5, November 2008 Paper 1, DBE:

In the circuit represented below, the resistance of the variable resistor is decreased. How would this decrease affect the readings on the voltmeter and ammeter? (3)



Discussion:

- This question would be categorised as an **Analysis** question because it requires learners to analyse and interpret a circuit diagram, and to determine the effects of some change to the circuit.
- Although this question involves some level of recall, and also some comprehension of the concepts involved, the cognitive process involved in analysing the situation is a higher-order skill.
- This question requires a learner to analyse and interpret a given situation, in the form of a description or a diagram, would be classified as an analysis question.

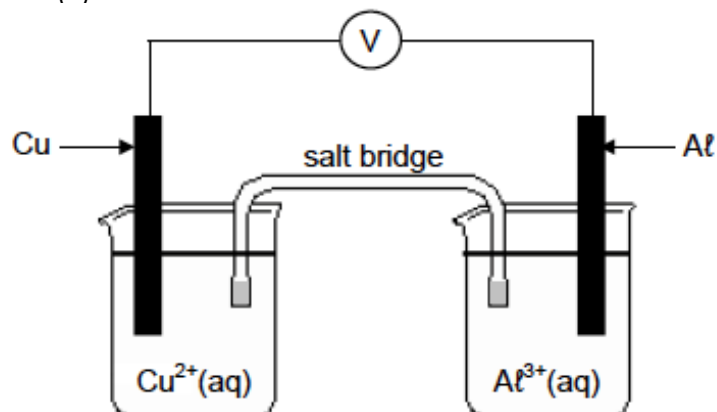
Memorandum/Marking guidelines

4.5 B ✓✓✓

Example 2:

Question 8.2.3, November 2012 Paper 2, DBE:

The electrochemical cell shown below functions at standard conditions. Calculate the emf of this cell. (4)



Discussion:

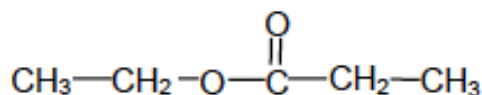
- This question would be categorised as an **Application** question because it requires learners to apply their knowledge of galvanic cells to the given scenario, and to perform a calculation.
- Although this question involves some level of recall, and also some comprehension of the concepts involved, the cognitive process involved in application of their knowledge to the scenario is a higher-order skill.
- This question requires a learner to apply their knowledge in a given scenario would be classified as an application question.

Memorandum/Marking guidelines

$$\begin{aligned} 8.2.3 \quad E^{\circ}_{\text{cell}} &= E^{\circ}_{\text{cathode}} - E^{\circ}_{\text{anode}} \checkmark \\ &= 0,34 - (-1,66) \checkmark \\ E^{\circ}_{\text{cell}} &= 2, (00) \text{ V } \checkmark \end{aligned}$$

Example 3:**Question 3.3.3, November 2012 Paper 2, DBE:**

Write down the IUPAC name of the following compound (2)

**Discussion:**

- This question would be categorised as an **Analysis/Application** question because it requires learners to analyse a given structural formula, and to apply their knowledge of IUPAC naming.
- Although this question involves some level of recall, the cognitive process involved in analysis and in application of their knowledge to the given scenario is a higher-order skill.
- This question requires a learner to analyse a given scenario, diagram or structure, and to apply their knowledge would be classified as an analysis/application question.

Memorandum/Marking guidelines

3.3.3 Ethyl propanoate $\checkmark\checkmark$

TABLE 5: EXAMPLES OF QUESTIONS AT LEVEL 4 – EVALUATION AND SYNTHESIS**Example 1:****Question 10.5, November 2011 Paper 2, DBE:**

The chlor-alkali industry is sometimes blamed for contributing to the greenhouse effect. Briefly explain how the membrane cell contributes to the greenhouse effect.

Discussion:

- This question would be categorised as an **Evaluation/Synthesis** question because it requires learners to evaluate the impact of the membrane cell on the greenhouse effect, which is a serious real-life issue.
- Although the question involves some level of recall and comprehension, the cognitive process involved in evaluation is a higher-order skill.
- This question requires a learner to evaluate the impact of some scientific or technological phenomenon on society or the environment would be classified as an evaluation/synthesis question.

NB: It should be noted that not all evaluation/synthesis questions are more difficult than questions involving lower-order thinking skills such as comprehension or application. In fact, in a subject such as Physical Sciences it is not always possible to set meaningful, challenging questions in this cognitive category. Questions should NOT be categorised as evaluation/synthesis questions simply because they are difficult questions. This is why it is important to categorise level of difficulty separately from type of cognitive skill involved.

Memorandum/Marking guidelines

10.5 Uses huge amount of electricity/energy. ✓ Combustion of coal during generation of electricity releases huge amount of carbon dioxide into atmosphere. ✓

Example 2:

Question 4.4.3, November 2012 Paper 1, DBE:

The diagram below shows a car of mass m travelling at a velocity of 20ms^{-1} east on a straight level road and a truck of mass $2m$ travelling at 20ms^{-1} west on the same road.



On impact, the car exerts a force of magnitude F on the truck and experiences an acceleration of magnitude a . Both drivers are wearing identical seat belts. Which driver is likely to be more severely injured on impact? Explain the answer by referring to acceleration and velocity.

Discussion:

- This question would be categorised as an **Evaluation/Synthesis** question because it requires learners to synthesise their knowledge of force, momentum, acceleration and velocity, and to use this to evaluate the effect of seatbelts in a collision.
- This question requires a learner to synthesise their knowledge of a range of concepts, and to use this to evaluate some scenario would be classified as an evaluation/synthesis question.

Memorandum/Marking guidelines

- 4.4.3** Car driver. ✓
(Car – driver system) have greater acceleration. ✓
(Car – driver system) have greater change in velocity/greater Δv . ✓

Example 3:

Question 10.5, November 2010 Paper 2, DBE:

One of the safety concerns related to the lead-acid battery is the danger associated with recharging (that is reversing the net reaction) of a flat battery. Water in the battery can be electrolysed to produce hydrogen and oxygen gas during recharging. Why is the recharging of flat batteries a safety concern? (1)

Discussion:

- This question would be categorised as an **Evaluation/Synthesis** question because it requires learners to synthesise their knowledge of the properties of gases (hydrogen and oxygen) with their knowledge of batteries, and to use this to evaluate the safety concerns of an everyday process.

Memorandum/Marking guidelines

- 10.5** The gases produced during recharging (hydrogen and oxygen) may explode if sparked. ✓

To accomplish the goal of discriminating between high achievers, those performing very poorly, and all candidates in between, examiners need to vary the challenge of examination questions. Until recently, the assumption has been that 'alignment' with the allocated percentage of marks for questions at the required cognitive demand levels meant that sufficient examination questions were relatively easy; moderately challenging; and difficult for candidates to answer.

However, research and candidate performance both indicate that a range of factors other than type of cognitive demand contribute to the cognitive challenge of a question. Such factors include the level of content knowledge required, the language used in the question, and the complexity or number of concepts tested. In other words, cognitive demand levels on their own do not necessarily distinguish between degrees of difficulty of questions.

This research helps, to some extent, explain why, despite that some NSC examination papers have complied with the specified cognitive demand weightings stipulated in the policy, they have not adequately distinguished between candidates with a range of academic abilities in particular between higher ability candidates. As a result, examiners, moderators and evaluators are now required to assess the difficulty level of each examination question in addition to judging its cognitive demand.

Section 7 below explains the new protocol introduced by Umalusi for analysing examination question difficulty.

7 ANALYSING THE LEVEL OF DIFFICULTY OF EXAMINATION QUESTIONS

When analysing the level of difficulty of each examination question, there are six important protocols to note. These are:

1. Question difficulty is **assessed independently** of the type and level **of cognitive demand**.
2. Question difficulty is assessed against **four levels of difficulty**.
3. Question difficulty is determined against the assumed capabilities of the **ideal 'envisaged'** Grade 12 Physical Sciences NSC examination **candidate**.
4. Question difficulty is determined using **a common framework** for thinking about question difficulty.
5. Question difficulty entails **distinguishing unintended sources of difficulty** or ease **from intended sources of difficulty** or ease.
6. Question difficulty entails identifying **differences** in levels of difficulty **within a single question**.

Each of the above protocols is individually explained and discussed below.

7.1 Question difficulty is assessed independently of the type and level of cognitive demand

As emphasised earlier in this exemplar book, the revised Umalusi NSC examination evaluation instruments separate the analysis of the type of cognitive demand of a question from the analysis of the level of difficulty of each examination question. Cognitive demand describes the *type of cognitive process* that is required to answer a question, and this does not necessarily equate or align with the *level of difficulty* of other aspects of a question, such as the difficulty of the content knowledge that is being assessed. For example, a recall question can ask a candidate to recall very complex and abstract scientific content. The question would be categorised as Level 1 in terms of the cognitive demand taxonomy but may be rated as 'difficult' (Level 3 Table 6 below).

Note:

Cognitive demand is just one of the features of a question that can influence your comparative judgments of question difficulty. The type and level of cognitive process involved in answering a question does not necessarily determine how difficult the question would be for candidates. Not all evaluation/synthesis/analysis questions are more difficult than questions involving lower-order processes such as comprehension or application.

7.2 Question difficulty is assessed at four levels of difficulty

The revised Umalusi NSC examination evaluation instruments require evaluators to exercise expert judgments about whether each examination question is 'Easy', 'Moderately challenging', 'Difficult' or 'Very difficult' for the envisaged Grade 12 candidate to answer. Descriptions of these categories of difficulty are shown in Table 6.

TABLE 6: LEVELS OF DIFFICULTY OF EXAMINATION QUESTIONS

1	2	3	4
Easy for the envisaged Grade 12 student to answer.	Moderately challenging for the envisaged Grade 12 student to answer.	Difficult for the envisaged Grade 12 student to answer.	Very difficult for the envisaged Grade 12 student to answer. The skills and knowledge required to answer the question allow for the top students (<i>extremely</i> high-achieving/ability students) to be discriminated from other high achieving/ability students).

Note:

The fourth level, 'very difficult' has been included in the levels of difficulty of examination questions to ensure that there are sufficient questions that discriminate well amongst higher ability candidates.

7.3 Question difficulty is determined against the assumed capabilities of the ideal 'envisaged' Grade 12 Physical Sciences NSC examination candidate

The revised Umalusi NSC examination evaluation instruments require evaluators to exercise expert judgments about whether each examination question is 'Easy', 'Moderately challenging', 'Difficult' or 'Very difficult' for the '**envisaged**' Grade 12 learner to answer (Table 6). In other words, assessment of question difficulty is linked to a particular target student within the population of NSC candidates, that is, the Grade 12 candidate of average intelligence or ability.

The Grade 12 learners that you may have taught over the course of your career cannot be used as a benchmark of the 'envisaged' candidate as we cannot know whether their abilities fall too high, or too low on the entire spectrum of all Grade 12 Physical Sciences candidates in South Africa. The revised Umalusi NSC examination evaluation instruments thus emphasise that, when rating the level of difficulty of a particular question, your conception of the 'envisaged'

candidate needs to be representative of the entire population of candidates for all schools in the country, in other words, of the overall Grade 12 population.

Most importantly, the conception of this 'envisaged' candidate is a learner who has been taught the whole curriculum adequately by a teacher who is qualified to teach the subject, in a functioning school. There are many disparities in the South African education system that can lead to very large differences in the implementation of the curriculum. Thus this 'envisaged' learner is not a typical South African Grade 12 learner – it is an intellectual construct (an imagined person) whom you need to imagine when judging the level of difficulty of a question. This ideal 'envisaged' Grade 12 learner is an aspirational ideal of where we would like all Physical Sciences learners in South Africa to be.

Note:

The concept of the **ideal envisaged Grade 12 candidate** is that of an imaginary learner who has the following features:

- a. Is of average intelligence or ability
- b. Has been taught by a competent teacher
- c. Has been exposed to the entire examinable curriculum

This ideal learner represents an imaginary person who occupies the middle ground of ability and approaches questions *having had all the necessary schooling*.

7.4 Question difficulty is determined using a common framework for thinking about question difficulty

Examiners, moderators and evaluators **in all subjects** are now provided with a common framework for thinking about question difficulty to use when identifying sources of difficulty or ease in each question, and to provide their reasons for the level of difficulty they select for each examination question.

The framework described in detail below provides the main sources of difficulty or 'ease' inherent in questions. The four sources of difficulty which must be considered when thinking about the level of difficulty of examination questions in this framework are as follows.

1. **'Content difficulty'** refers to the difficulty inherent in the subject matter and/or concept/s assessed.
2. **'Stimulus difficulty'** refers to the difficulty that candidates confront when they attempt to read and understand the question and its source material. The demands of the reading required to answer a question thus form an important element of 'stimulus difficulty'.
3. **'Task difficulty'** refers to the difficulty that candidates confront when they try to formulate or produce an answer. The level of cognitive demand of a question forms an element of 'Task difficulty', as does the demand of the written text or representations that learners are required to produce for their response.
4. **'Expected response difficulty'** refers to difficulty imposed by examiners in a marking guideline, scoring rubric or memorandum. For example, mark allocations affect the amount and level of answers students are expected to write.

This framework derived from Leong (2006) was chosen because it allows the person making judgments about question difficulty to grapple with nuances and with making connections. The underlying assumption is that judgment of question difficulty is influenced by the interaction and overlap of different aspects of the four main sources of difficulty. Whilst one of the above four sources of difficulty may be more pronounced in a specific question, the other three sources may also be evident. Furthermore, not all four sources of difficulty need to be present for a question to be rated as difficult.

The four-category conceptual framework is part of the required Umalusi examination evaluation instruments. Each category or source of difficulty in this framework is described and explained in detail below (Table 7). Please read the entire table very carefully.

TABLE 7: FRAMEWORK FOR THINKING ABOUT QUESTION DIFFICULTY

CONTENT/CONCEPT DIFFICULTY
Content/concept difficulty indexes the difficulty in the subject matter, topic or conceptual knowledge assessed or required. In this judgment of the item/question, difficulty exists in the academic and conceptual demands that questions make and/or the grade level boundaries of the various 'elements' of domain/subject knowledge (topics, facts, concepts, principles and procedures associated with the subject).

For example:

Questions that assess '**advanced content**', that is, subject knowledge that is considered to be in advance of the grade level curriculum, are *likely* to be difficult or very difficult for most candidates. Questions that assess subject knowledge which forms part of the core curriculum for the grade are *likely* to be moderately difficult for most candidates. Questions that assess '**basic content**' or subject knowledge candidates would have learnt at lower grade levels, and which would be familiar to them are *unlikely* to pose too much of a challenge to most candidates.

Questions that require general everyday knowledge or knowledge of 'real life' experiences are *often* easier than those that test more **specialized school knowledge**. Questions involving only concrete objects, phenomena, or processes are *usually* easier than those that involve more **abstract constructs, ideas, processes or modes**.

Questions which test learners' understanding of theoretical or **de-contextualised issues or topics**, rather than their knowledge of specific examples or contextualised topics or issues *tend* to be more difficult. Questions involving familiar, contemporary/current contexts or events are *usually* easier than those that are more **abstract or involve 'imagined' events** (e.g. past/future events) or **contexts** that are **distant from learners' experiences**.

Content difficulty may also be varied by changing **the number of knowledge elements or operations assessed**. *Generally*, the difficulty of a question increases with the number of knowledge elements or operations assessed. Questions that assess learners on two or more knowledge elements or operations are *usually* (but not always) more difficult than those that assess a single knowledge element or operation.

Assessing learners on **a combination of knowledge elements or operations that are seldom combined** *usually* increases the level of difficulty.

EXAMPLES OF INVALID OR UNINTENDED SOURCE OF CONTENT DIFFICULTY

- Testing obscure or unimportant concepts or facts that are not mentioned in the curriculum, or which are unimportant to the curriculum learning objectives.
- Testing very advanced concepts or operations that candidates are extremely unlikely to have had opportunities to learn.

STIMULUS DIFFICULTY

Stimulus difficulty refers to the difficulty of the linguistic **features of the question** (linguistic complexity) and the challenge that candidates face when they attempt to read, interpret and understand the words and phrases in the question AND when they attempt to read and understand the **information or 'text' or source material (diagrams, tables and graphs, pictures, cartoons, passages, etc.) that accompanies the question.**

For example:

Questions that contain words and phrases that require only simple and straightforward comprehension are *usually* easier than those that require the candidate to understand **subject specific phraseology and terminology** (e.g. idiomatic or grammatical language not usually encountered in everyday language), or that require more technical comprehension and specialised command of words and language (e.g. everyday words involving different meanings within the context of the subject).

Questions that contain information that is 'tailored' to an expected response, that is, questions that contain no irrelevant or distracting information, are *generally* easier than those that require candidates to select relevant and appropriate information or **unpack a large amount of information** for their response. A question **set in a very rich context** can increase question difficulty. For example, learners *may* find it difficult to select the correct operation when, for example, a mathematics or accountancy question is set in a context-rich context.

Although the level of difficulty in examinations is *usually* revealed most clearly through the questions, text complexity or the degree of **challenge or complexity in written or graphic texts** (such as a graph, table, picture, cartoon, etc.) that learners are required to read and interpret in order to respond *can* increase the level of difficulty. Questions that depend on reading and selecting content from a text *can* be more challenging than questions that do not **depend on actually reading the accompanying text** because they test reading comprehension skills as well as subject knowledge. Questions that require candidates to **read a lot** *can* be more challenging than those that require limited reading. Questions that tell learners where in the text to look for relevant information are *usually* easier than those where **learners are not told where to look**.

The level of difficulty *may* increase if texts set, and reading passages or other **source material** used are challenging for the grade level, and make **high reading demands** on learners at the grade level. Predictors of textual difficulty include:

- **semantic content** – for example, if vocabulary and words used are typically outside the reading vocabulary of Grade 12 learners, 'texts' (passage, cartoon, diagram, table, etc.) are *usually* more difficult. 'Texts' are *generally* easier if words or images are made accessible by using semantic/context, syntactic/structural or graphophonetic/visual cues.
- **syntactic or organisational structure** – for example, sentence structure and length. For example, if learners are likely to be *familiar with the structure of*

the 'text' or resource, for example, from reading newspapers or magazines, etc. 'texts' are *usually* easier than when the structure is unfamiliar.

- **literary techniques** – for example, abstractness of ideas and imagery – and **background knowledge required**, for example, to make sense of allusions.
- if the **context** is **unfamiliar** or remote, or if candidates do not have or are **not provided with access to the context** which informs a text (source material, passage, diagram, table, etc.) they are expected to read, and which informs the question they are supposed to answer and the answer they are expected to write, then constructing a response is *likely* to be more difficult than when the context is provided or familiar.

Questions which require learners to **cross-reference different sources** are *usually* more difficult than those which deal with one source at a time.

Another factor in stimulus difficulty is presentation and visual appearance. For example, type face and size, use of headings, and other types of textual organisers etc. can aid '**readability**' and make it easier for learners to interpret the meaning of a question.

EXAMPLES OF INVALID OR UNINTENDED SOURCES OF STIMULUS DIFFICULTY

- Meaning of words unclear or unknown.
- Difficult or impossible to work out what the question is asking.
- Questions which are ambiguous.
- Grammatical errors in the question that could cause misunderstanding.
- Inaccuracy or inconsistency of information or data given.
- Insufficient information provided.
- Unclear resource (badly drawn or printed diagram, inappropriate graph, unconventional table).
- Dense presentation (too many important points packed in a certain part of the stimulus).

TASK DIFFICULTY

Task difficulty refers to the **difficulty that candidates confront when they try to formulate or produce an answer.**

For example:

In most questions, to generate a response, candidates have to work through the steps of a solution. *Generally*, questions that **require more steps in a solution** are more difficult than those that require fewer steps. Questions involving only one or two steps in the solution are *generally* easier than those where several operations required for a solution.

Task difficulty may also be mediated by the **amount of guidance present in the question.** Although question format is not necessarily a factor and difficult questions can have a short or simple format, questions that provide guided steps or cues (e.g. a clear and detailed framework for answering) are *generally* easier than those that are more open ended and require candidates to form or tailor their **own response strategy** or argument, work out the steps **and maintain the**

strategy for answering the question by themselves. A high degree of prompting (a high degree of prompted recall, for example) *tends* to reduce difficulty level.

Questions that test specific knowledge are *usually* less difficult than **multi-step, multiple-concept or operation questions**.

A question that requires the candidate to **use a high level of appropriate subject specific, scientific or specialised terminology in their response** *tends* to be more difficult than one which does not.

A question requiring candidates to **create a complex abstract (symbolic or graphic) representation** is *usually* more challenging than a question requiring candidates to create a concrete representation.

A question requiring writing a one-word answer, a phrase, or a simple sentence is *often* easier to write than **responses that require more complex sentences, a paragraph or a full essay or composition**.

Narrative or descriptive writing, for example where the focus is on recounting or ordering a sequence of events chronologically, is *usually* easier than **writing discursively (argumentatively or analytically)** where ideas need to be developed and ordered logically. Some questions reflect task difficulty simply by '**creating the space**' for **A-Grade candidates** to demonstrate genuine insight, original thought or good argumentation, and to write succinctly and coherently about their knowledge.

Another element is the **complexity in structure of the required response**. When simple connections between ideas or operations are expected in a response, the question is *generally* easier to answer than a question in which the significance of the relations between the parts and the whole is expected to be discussed in a response. In other words, a question in which an unstructured response is expected is *generally* easier than a question in which **a relational response** is required. A response which involves **combining or linking a number of complex ideas or operations** is *usually* more difficult than a response where there is no need to combine or link ideas or operations.

On the other hand, questions which require continuous prose or extended writing *may* also be easier to answer correctly or to get marks for than questions that require no writing at all or single letter answer (such as multiple choice), or a brief response of one or two words or short phrase/s because they **test very specific knowledge**.

The **cognitive demand** or **thinking processes** required form an aspect of task difficulty. Some questions test thinking ability, and learners' capacity to deal with ideas, etc. Questions that assess inferential comprehension or application of knowledge, or that require learners to take ideas from one context and use it in another, for example, *tend* to be more difficult than questions that assess recognition or retrieval of basic information. On the other hand, questions requiring recall of knowledge are *usually* more difficult than questions that require simple recognition processes.

When the **resources for answering** the question are included in the examination paper, then the task is *usually* easier than when candidates have to **use and select their own internal resources** (for example, their own knowledge of the subject) or transform information to answer the question.

Questions that require learners to take or **transfer** ideas, **skills or knowledge from one context/subject area and use them in another** *tend* to be more difficult.

EXAMPLES OF INVALID OR UNINTENDED SOURCES OF TASK DIFFICULTY

- Level of detail required in an answer is unclear.
- Context is unrelated to or uncharacteristic of the task than candidates have to do.
- Details of a context distract candidates from recalling or using the right bits of their knowledge.
- Question is unanswerable.
- Illogical order or sequence of parts of the questions.
- Interference from a previous question.
- Insufficient space (or time) allocated for responding.
- Question predictability or task familiarity. If the same question regularly appears in examination papers or has been provided to schools as exemplars, learners are likely to have had prior exposure, and practised and rehearsed answers in class (for example, when the same language set works are prescribed each year).
- Questions which involve potential follow-on errors from answers to previous questions.

EXPECTED RESPONSE DIFFICULTY

Expected response difficulty refers to difficulty imposed by examiners in a **mark scheme and memorandum**. This location of difficulty is more applicable to 'constructed' response questions, as opposed to 'selected' response questions (such as multiple choice, matching/true-false).

For example:

When examiners expect few or no details in a response, the question is *generally* easier than one where the mark scheme implies that **a lot of details are expected**.

A further aspect of expected response difficulty is the clarity of the **allocation of marks**. Questions are *generally* easier when the allocation of marks is explicit, straight-forward or logical (i.e. 3 marks for listing 3 points) than when the **mark allocation is indeterminate or implicit** (e.g. when candidates need all 3 points for one full mark or 20 marks for a discussion of a concept, without any indication of how much and what to write in a response). This aspect affects difficulty because candidates who are unclear about the mark expectations in a response may not produce sufficient amount of answers in their response that will earn the marks that befit their ability.

Some questions are more difficult/easy to mark accurately than others. Questions that are **harder to mark and score objectively** are *generally* more difficult for

candidates than questions that require simple marking or scoring strategies on the part of markers. For example, recognition and recall questions are *usually* easier to test and mark objectively because they usually require the use of matching and/or simple scanning strategies on the part of markers. More complex questions requiring analysis (breaking down a passage or material into its component parts), evaluation (making judgments, for example, about the worth of material or text, or about solutions to a problem), synthesis (bringing together parts or elements to form a whole), and creativity (presenting own ideas or original thoughts) are *generally* harder to mark/score objectively. The best way to test for analysis, evaluation, synthesis and creativity is usually through extended writing. Such extended writing *generally* requires the use of more cognitively demanding *marking* strategies such as interpreting and evaluating the logic of what the candidate has written.

Questions where **a wide range of alternative answers or response/s** is possible or where the correct answer may be arrived at through different strategies *tend* to be more difficult. On the other hand, questions may be so open-ended that learners will get marks even if they engage with the task very superficially.

EXAMPLES OF INVALID OR UNINTENDED SOURCES OF EXPECTED RESPONSE DIFFICULTY

- Mark allocation is unclear or illogical. The weighting of marks is important in questions that comprise more than one component when components vary in levels of difficulty. Learners may be able to get the same marks for answering easy component/s of the item as other learners are awarded for answering the more difficult components.
- Mark scheme and questions are incongruent. For example, there is no clear correlation between the mark indicated on the question paper and the mark allocation of the memorandum.
- Question asked is not the one that examiners want candidates to answer. Memorandum spells out expectation to a slightly different question, not the actual question.
- Impossible for candidate to work out from the question what the answer to the question is (answer is indeterminable).
- Wrong answer provided in memorandum.
- Alternative correct answers from those provided or spelt out in the memorandum are also plausible.
- The question is 'open' but the memo has a closed response. Memo allows no leeway for markers to interpret answers and give credit where due.

The framework described above does not provide you with explicit links between the different sources of difficulty, or show relationships and overlaps between the different categories and concepts in the framework. This is because it is impossible to set prescribed rules or pre-determined combinations

of categories and concepts used for making judgments about the source of difficulty in a particular examination question.

The intention behind the framework is to allow you to exercise your sense of judgment as an expert. The complexity of your judgment lies in your ability as an expert to recognise subtle interactions and identify links between different categories of a question's difficulty or ease. For example, a question that tests specific knowledge of your subject can actually be more difficult than a multi-step question because it requires candidates to explain a highly abstract concept, or very complex content. In other words, although questions that test specific knowledge are *usually* less difficult than multiple-concept or operation questions, the level of difficulty of the content knowledge required to answer a question can make the question more difficult than a multi-step or multi-operation question.

Not all one-word response questions can automatically be assumed to be easy. For example, multiple-choice questions are not automatically easy because a choice of responses is provided – some can be difficult. As an expert in your subject, you need to make these types of judgments about each question.

Note:

It is very important that you become extremely familiar with the framework explained in Table 7, and with each category or source of difficulty provided (i.e. content difficulty, task difficulty, stimulus difficulty, and expected response difficulty). You need to understand the examples of questions which illustrate each of the four levels (Table 8 to Table 11). This framework is intended to assist you in discussing and justifying your decisions regarding the difficulty level ratings of questions. You are expected to **refer to all four categories or sources of difficulty** in justifying your decisions.

When considering question difficulty ask:

- How difficult is the **knowledge** (content, concepts or procedures) that is being assessed for the envisaged Grade 12 candidate? (*Content difficulty*)
- How difficult is it for the envisaged Grade 12 candidate to formulate the answer to the question? In considering this source of difficulty, you should **take into account the type of cognitive demand** made by the task. (*Task difficulty*)
- How difficult is it for the envisaged Grade 12 candidate to **understand the question and the source material** that need to be read to answer the particular question? (*Stimulus difficulty*)
- What does the **marking memorandum and mark scheme** show about the difficulty of the question? (*Expected response difficulty*)

7.5 Question difficulty entails distinguishing unintended sources of difficulty or ease from intended sources of difficulty or ease

Close inspection of the framework for thinking about question difficulty (Section 7.4, Table 7) above, shows that, for each general category or source of difficulty, the framework makes a distinction between 'valid' or intended, and 'invalid' or unintended sources of question difficulty or ease. Therefore, defining question difficulty entails identifying whether sources of difficulty or ease in a question were intended or unintended by examiners. Included in Table 7 are examples of unintended sources of difficulty or ease for each of the four categories.

Valid difficulty or 'easiness' in a question has its source in the requirements of the question, and is **intended** by the examiner (Ahmed and Pollit, 1999). Invalid sources of difficulty or 'easiness' refer to those features of question difficulty or 'easiness' that were **not intended** by the examiner. Such unintended 'mistakes' or omissions in questions can prevent the question from assessing what the examiner intended, and are likely to prevent candidates from demonstrating their true ability or competence, and can result in a question being easier or more difficult than the examiner intended.

For example, grammatical errors in a question that could cause misunderstanding for candidates are unintended sources of question difficulty because the difficulty in answering the question could lie in the faulty formulation of the question, rather than in the intrinsic difficulty of the question itself (for example, because of stimulus difficulty). Candidates "may misunderstand the question and therefore not be able to demonstrate what they know" (Ahmed and Pollit, 1999, p.2). Another example is question predictability (when the same questions regularly appear in examination papers or textbooks) because familiarity can make a question which was intended to be difficult, less challenging for examination candidates.

Detecting unintended sources of difficulty or ease in examinations is largely the task of moderators. Nevertheless, evaluators also need to be vigilant about detecting sources which could influence or alter the intended level of question difficulty that moderators may have overlooked.

Note:

When judging question difficulty, you should distinguish **unintended sources of question difficulty or ease** from those sources that are intended, thus ensuring that examinations have a range of levels of difficulty. The framework for thinking about question difficulty allows you to systematically identify technical and other problems in each question. Examples of problems might be: unclear instructions, poor phrasing of questions, the provision of inaccurate and insufficient information, unclear or confusing visual sources or illustrations, incorrect use of terminology, inaccurate or inadequate answers in the marking memorandum, and question predictability. You should **not** rate a question as difficult/easy if the source of difficulty/ease lies in the 'faultiness' of the question or memorandum. Instead, as moderators and evaluators, you need to alert examiners to unintended sources of difficulty/ease so that they can improve questions and remedy errors or sources of confusion before candidates write the examination.

7.6 Question difficulty entails identifying differences in levels of difficulty within a single question

An examination question can incorporate more than one level of difficulty if it has subsections. It is important that the components of such questions are 'broken down' into their individual levels of difficulty.

Note:

Each subsection of a question should be analysed separately so that the percentage of marks allocated at each level of difficulty and the weighting for each level of difficulty can be ascertained as accurately as possible for that question.

8. EXAMPLES OF QUESTIONS AT DIFFERENT LEVELS OF DIFFICULTY

This section provides at least **three** examples of questions from previous Physical Sciences NSC examinations (Table 8 to Table 11) categorised at each of the four levels of difficulty described in Section 7 (Table 6) above. These examples were selected to represent the **best and clearest** examples of each level of difficulty that the Physical Sciences experts could find. The discussion below each example question tries to explain the reasoning behind the judgments made about the categorisation of the question at that particular level of difficulty.

TABLE 8: EXAMPLES OF QUESTIONS AT DIFFICULTY LEVEL 1 – EASY

Example 1:
<u>Question 10.1, November 2010 Paper 1, DBE:</u>
State Ohm's law in words. (2)
<u>Discussion:</u>
<ul style="list-style-type: none">• The wording of the question itself is simple and straightforward which makes it easy to comprehend (Stimulus).• Neither does the question require candidates to state or represent the law as an equation nor as graph. Ohm's law is part of basic content under electricity (Content/Concept).• The question does not also require candidates to generate or formulate the answer. Answering this question involves straightforward recall of a simple law (Task).• Mark allocation is clear and straight-forward. The memorandum indicates that 2 marks are allocated to the question, 1 mark for stating that current in a conductor is directly proportional to the potential difference and 1 mark for stating that temperature should remain constant. There was no difficulty imposed by the examiners in mark scheme or memorandum (Expected Response).
This question is therefore categorized as an easy question with regard to all sources of difficulty.

Memorandum/Marking guidelines

10.1 The current in a conductor is directly proportional to the potential difference across its ends at a constant temperature. ✓✓

OR

The ratio of potential difference to the current is constant at constant temperature. ✓✓

Example 2:

Question 1.1, November 2011 Paper 2, DBE:

Name the homologous series to which the compound CH_3Cl belongs. (1)

Discussion:

- The question is clearly phrased and straightforward with no hidden aspects which could confuse candidates. It does not contain superfluous or unnecessary detail which could distract candidates from understanding what is required (**Stimulus**).
- Answering this question requires basic knowledge of organic chemistry which naming of haloalkanes and the compound given is a very simple one, so it would not contribute to any difficulty (**Content/Concept**).
- The question involves a routine naming of a homologous series and they have to formulate a one-word answer (**Task**).
- Mark allocation is also clear and straightforward. The memorandum indicates that 1 mark is allocated to the question (**Expected Response**).

This question is therefore categorized as easy with regard to all sources of difficulty.

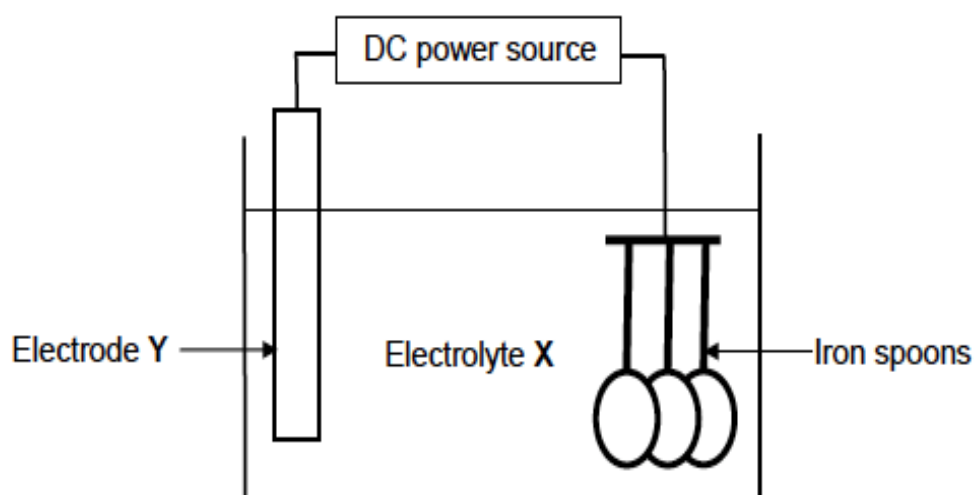
Memorandum/Marking guidelines

1.1 Haloalkane ✓

Example 3:

Question 9.1, November 2012 Paper 2, DBE:

The simplified diagram below shows an electrolytic cell used at an electroplating company to coat iron spoons with silver.



Write down the energy conversion that takes place in this cell. (1)

Discussion:

- There is no complication caused by complex wording of the question or irrelevant information. The diagram given is an illustration of a familiar application of the electrolytic cell, and would therefore require no analysis or interpretation (**Stimulus**).
- The content being assessed in the question is electrochemistry, specifically electrolytic cells taught in Grade 12 under chemical change knowledge area. Electrolysis is a known process and the envisaged candidate will have no difficulty in answering the question (**Content/Concept**).
- Mark allocation is also suitable for the question, that is, 1 mark for writing the energy conversion (**Expected Response**).
- This question is categorized as easy because it involves a routine identification of an energy conversion process. Candidates do not have to work through the steps of a solution but to generate a simple answer, that is, energy conversion taking place in the electrolytic cell (**Task**).

This question is therefore categorized as easy with regard to all sources of difficulty.

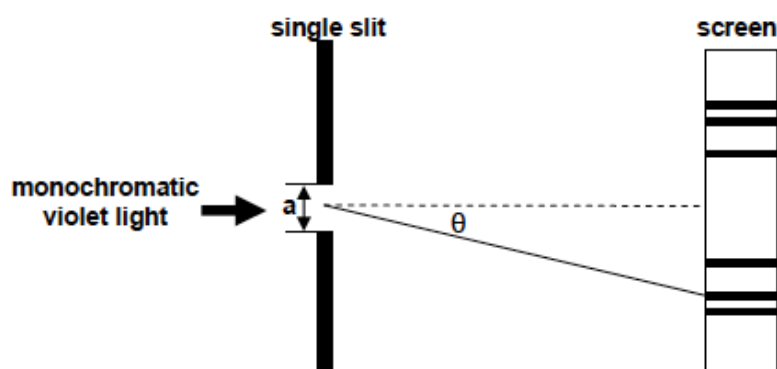
Memorandum/Marking guidelines

9.1 Electrical energy to chemical energy. ✓

Example 4:

Question 7.5, November 2011 Paper 1, DBE:

A candidate investigates the change in broadness of the central bright band in a diffraction pattern when light passes through single slits of different widths. She uses monochromatic violet light of wavelength 4×10^{-7} m. The apparatus is set up as shown in the diagram below.



Calculate the angle θ at which the second minimum is formed if a slit of width $2,2 \times 10^{-6}$ m is used. (5)

Discussion:

- The question is easy to understand and provides very clear, concise procedure for an investigation. Candidates are provided with a well labelled diagram. All the necessary information is given for the candidates to work out the solution (**Stimulus**).
- The content being assessed in this question is diffraction of light under waves, sound and light knowledge area. Diffraction is a known concept taught in Grade 11. Any learner who has been taught this section of work is able to answer the question as this question requires basic knowledge (**Content**).
- This question is categorized as easy because it involves a very straightforward calculation which is a routine procedure. There is no variation on the usual approach to this kind of problem, and learners are not required to perform any unit conversions, so it would be experienced as easy by the envisaged candidate (**Task**).
- Mark allocation is appropriate. The memorandum indicates that 5 marks are allocated to the question, 1 mark for the formula, 3 marks for correct substitution of the following: the order of the minima or maxima (m) (1 mark), wavelength (λ) (1 marks) and the width (a) of the slit (1 mark) respectively as well as 1 mark for the correct answer (**Expected Response**).

This question is therefore categorized as easy with regard to all sources of difficulty.

Memorandum/Marking guidelines

7.5 Option 1

$$\sin \theta = \frac{m\lambda}{a} \sqrt{\quad}$$

$$= \frac{(2)(4 \times 10^{-7})}{2,2 \times 10^{-6}} \sqrt{\quad}$$

$$\therefore \theta = 21,32^\circ \checkmark$$

Option 2

$$\begin{aligned} \sin \theta &= \frac{m\lambda}{a} \checkmark \\ &= \frac{(-2)(4 \times 10^{-7})}{2,2 \times 10^{-6}} \checkmark \checkmark \end{aligned}$$

$$\therefore \theta = -21,32^\circ \checkmark$$

TABLE 9: EXAMPLES OF QUESTIONS AT DIFFICULTY LEVEL 2 – MODERATE

Example 1:

Question 6.2, November 2011 Paper 1, DBE:

A train approaches a station at a constant speed of $20 \text{ m} \cdot \text{s}^{-1}$ with its whistle blowing at a frequency of 458 Hz. An observer, standing on the platform, hears a change in pitch as the train approaches him, passes him and moves away from him. Calculate the frequency of the sound that the observer hears while the train is approaching him. Use the speed of sound in air as $340 \text{ m} \cdot \text{s}^{-1}$. (4)

Discussion:

- The question itself is easy to understand. The words and phrases used are simple and straight forward. The question or the source material does not make very high reading demands (**Stimulus**).
- This question has not been categorised as easy because it involves identification of the sign of the velocity (positive or negative), and is thus more challenging than a straight-forward routine procedure where learners substitute given values into a known formula. Answering this question does not simply depend on recalling, recognizing or retrieving information but requires analytical thinking. There is no variation on the usual approach to this kind of problem, so it would not be experienced as difficult by the envisaged candidate, but would have a moderate level of challenge (**Task**).
- The question requires the knowledge of the Doppler Effect (relative motion between source of sound and observer) concept under waves, sound and light knowledge area. Answering this question therefore requires among other concepts: frequency of sound as detected by the listener and speed of the source of sound, however these concepts do not raise the level of difficulty as the candidates are provided with values that guides them in answering the question. The Doppler Effect would either involve a moving source (stationary observer) or a moving observer (stationary source) (**Content**).
- The memorandum indicates that 4 marks are allocated to the question, 1 mark for the correct formula, 2 marks for correct substitution and 1 mark for the answer. The choice of the appropriate formula and proper substitution make the question moderately difficult. Mark allocation is also clear (**Expected Response**).

This question is therefore categorized as moderate with regard to task difficulty.

Memorandum/Marking guidelines

$$6.2 \quad f_L = \frac{v \pm v_L}{v \pm v_s} f_s \quad \checkmark$$

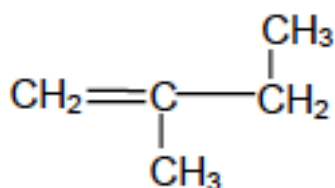
$$\therefore f_L = \frac{340 \pm 0}{340 - 20} \checkmark (458) \checkmark$$

$$\therefore f_L = 486,63 \text{ Hz} \checkmark$$

Example 2:

Question 3.2.1, November 2012 Paper 2, DBE:

Write down the IUPAC name of the following compound. (2)



Discussion:

- The question involves IUPAC naming of an organic compound that contains a functional group and a side chain and hence it is a difficult question (**Content**).
- This involves a number of steps of reasoning, and would thus be experienced as difficult by the envisaged candidate. In writing the IUPAC name, learners have to follow the IUPAC rules of naming organic compounds. The IUPAC rules include, among other things, identifying the parent or the longest chain and naming it; numbering the carbons of the parent chain so the double bond carbons have the lowest possible numbers in case of alkenes; identifying and naming the side chain; and lastly writing out the full name, numbering the substituents according to their positions in the chain (**Task**).
- The words used in this question are simple and straightforward. Candidates are familiar with the IUPAC acronym and structural formulae (**Stimulus**).
- Mark allocation is clear. The memorandum indicates that 2 marks are allocated to the question, 1 mark for naming the parent chain – alkene, and 1 mark for naming the branch or side chain – the alkyl group (**Expected Response**).

This question is therefore categorized as difficult with regard to content and task difficulties.

Memorandum/Marking guidelines

3.2.1 2-methyl ✓ but-1-ene ✓

Example 3:

Question 3.3, November 2010 Paper 2, DBE:

Write down the structural formula of Methanal. (2)

Discussion:

- The knowledge of different functional groups, homologous series and showing correct number of bonds around carbon atom makes this question moderately difficult. The question involves the writing of structural formulae of an organic compound (an aldehyde) that contains a functional group with no side chains and hence it is a moderate question (**Content**).
- The words used in this question are simple and straightforward (**Stimulus**).
- This is a fairly routine procedure, and would thus be experienced as moderate by the envisaged candidate. To generate a response, candidates do not have to work through the steps of a solution for this question. Answering this question does not also simply depend on recalling and recognizing information but requires learners to write appropriate functional groups and showing all hydrogen atoms. This makes the question moderately difficult (**Task**).
- Mark allocation is clear. The memorandum indicates that 2 marks are allocated for to the question for correct answer showing all hydrogen atoms and correct number of bonds around carbon (**Expected Response**).

This question is therefore categorized as moderate with regard to task and content difficulty.

Memorandum/Marking guidelines

3.3

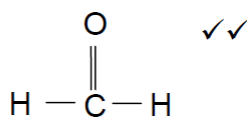


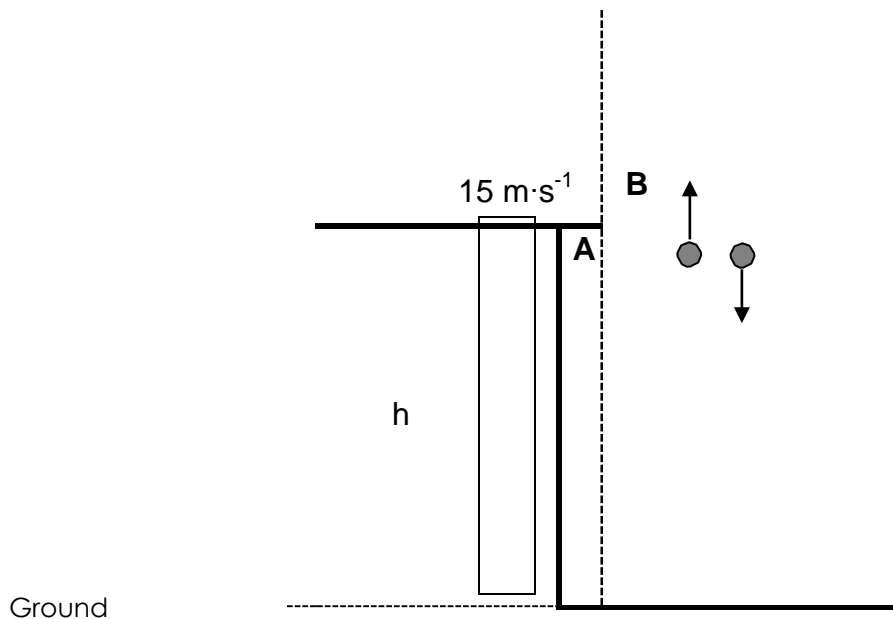
TABLE 10: EXAMPLES OF QUESTIONS AT DIFFICULTY LEVEL 3 – DIFFICULT

Example 1:

Question 3.2 and 3.3, November 2014 Paper 1, DBE:

A ball, **A**, is thrown vertically upward from a height, h , with a speed of $15 \text{ m}\cdot\text{s}^{-1}$. AT THE SAME INSTANT, a second identical ball, **B**, is dropped from the same height as ball **A** as shown in the diagram below.

Both balls undergo free fall and eventually hit the ground.



3.2 Calculate the time it takes for ball **A** to return to its starting point. (4)

3.3 Calculate the distance between ball **A** and ball **B** when ball **A** is at its maximum height. (7)

Discussion:

- In Question 3.2 learners were required to calculate the time it takes for Ball A to return to its starting point. The time was calculated as 3.06 s. This was a straightforward calculation. The question involves possible follow-on errors because of reliance on previous answers is likely to be made more difficult than a stand-alone question (**Task**).
- The words used in this question are simple and straightforward (**Stimulus**).
- Mark allocation is also clear and straightforward. The memorandum indicates that four (4) marks are allocated to Question 3.2 and seven (7) marks are allocated to Question 3.3 (**Expected Response**).
- However, in Question 3.3 they had to make use of $\frac{1}{2}$ of the time calculated in 3.2 as the question only asked for time to the maximum height. In order to calculate the distance between ball A and B when A was at its maximum height meant that the problem dealt with a second object (Object B) which had to travel for the same time as Object A (which was half of the answer of 3.2 namely 1.53 seconds.). The fact that learners had to use the same time factor to determine the distances travelled by the two objects and then add the calculated two distances i.e. from maximum height of A to its starting

point and the distance of Object B from the same starting point as A to 1.53 seconds in its fall, make this a difficult problem (**content**).

This question is therefore categorized as difficult with regard to content and task difficulties.

Memorandum/Marking guidelines

$$3.2 \Delta y = v_i \Delta t + \frac{1}{2} a \Delta t^2 \checkmark \checkmark$$

$$0 \checkmark = \underline{15 \Delta t + \frac{1}{2} (-9,8) \Delta t^2} \checkmark \checkmark$$

$$\Delta t = 3,06 \text{ s}$$

It takes 3,06 s $\checkmark \checkmark \checkmark$

3.3 Upwards positive:

For ball A

$$V_f^2 = V_i^2 + 2a\Delta y \checkmark$$

$$0 = (15)^2 \checkmark \checkmark + 2 (-9,8) \Delta y \checkmark \checkmark$$

$$\checkmark y_A = 11,48 \text{ m}$$

When A is at highest point

$$\Delta y_B = v_i \Delta t + \frac{1}{2} a \Delta t^2$$

$$= 0 + \frac{1}{2} (-9,8) (1,53)^2 \checkmark \checkmark \checkmark$$

$$\Delta y_B = -11,47 \text{ m}$$

$\Delta y_B = 11,47 \text{ m}$ downward

Distance = $y_A + y_B$

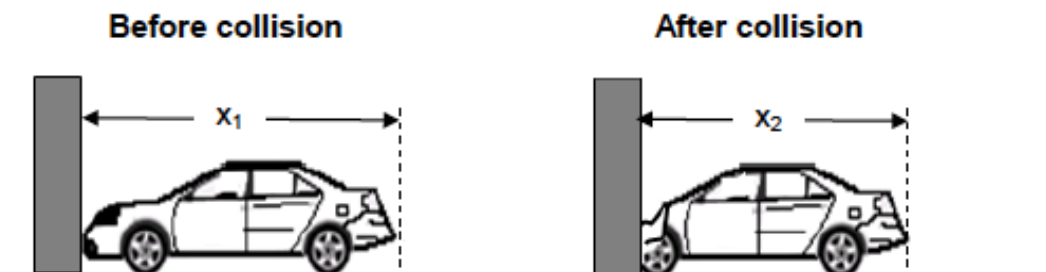
$$= 11,47 + 11,48 \checkmark \checkmark$$

$$= 22,95 \text{ m} \checkmark$$

Example 2:

Question 5.3.1, November 2012 Paper 1, DBE:

In order to measure the net force involved during a collision, a car is allowed to collide head-on with a flat, rigid barrier. The resulting crumple distance is measured. The crumple distance is the length by which the car becomes shorter in coming to rest.



In one of the tests, a car of mass 1 200 kg strikes the barrier at a speed of 20ms⁻¹. The crumple distance, (x₁ - x₂), is measured as 1,02 m. (Ignore the effects of frictional forces during crumpling.) Assume that the net force is constant during crumpling. USE THE WORK-ENERGY THEOREM to calculate the magnitude of the net force exerted on the car as it is brought to rest during crumpling. (4)

Discussion:

- This question is categorized as difficult since it involves the interpretation of a diagram as well as extraction of information from a piece of text. This question also requires more steps of reasoning in a solution. The steps reasoning and calculation include among other things, analysis of the data given from the diagram and in the text, selection of the appropriate formula (work-energy theorem as an equation) from the list of formulae given, correct substitution into the formula including correct angles for directions and finally calculate the answer (**Task**).
- The question is set in a non-routine kind of way, where information is presented in a different way to what learners are familiar with, or where learners have to use a different approach to the familiar practiced approach, is likely to be experienced as difficult. The stimulus material makes high reading demands on the envisaged Grade 12 candidate (**Stimulus**).
- To answer this question, candidates need to have a clear understanding of the work-energy theorem. The topic (work-energy theorem) itself is a challenging one to learners. This question would thus be experienced as difficult by the envisaged candidate (**Content**).
- The question and mark allocation guide learners as to how much they should write to obtain the maximum marks. The marking memorandum indicated that 4 marks are allocated to the question, 1 mark for appropriate formula, 2 marks for correct substitution and 1 mark for the answer. The memorandum also provided an alternative formula which led to the same answer. The alternative formula is scientifically accepted. Markers had to carefully take note of the alternative formula (**Expected Response**).

This question is therefore categorized as difficult with regard to content, stimulus and task difficulties.

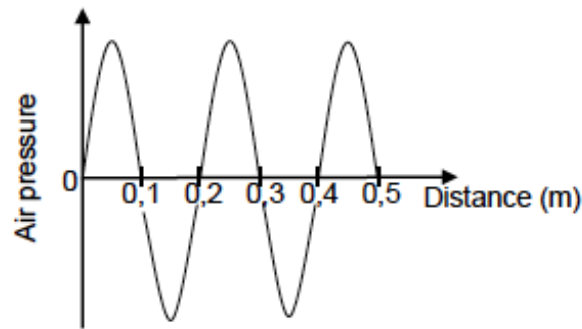
Memorandum/Marking guidelines

$$5.3.1 \quad W_{\text{net}} = \Delta E_k / \Delta K \quad \checkmark \quad \text{OR/OF} \quad F_{\text{net}} \Delta x \cos \theta = \frac{1}{2} m (v_f^2 - v_i^2)$$
$$\underline{F_{\text{net}}(1,02)\cos 180^\circ} \quad \checkmark = \underline{\frac{1}{2} (1\,200)(0 - 20^2)} \quad \checkmark$$
$$F_{\text{net}} = 235\,294,12 \text{ N} \quad \checkmark \quad (2,35 \times 10^5 \text{ N})$$

Example 3:

Question 6.4, November 2012 Paper 1, DBE:

A bird flies directly towards a stationary birdwatcher at constant velocity. The bird constantly emits sound waves at a frequency of 1 650 Hz. The birdwatcher hears a change in pitch as the bird comes closer to him. The air pressure versus distance graph below represents the waves detected by the birdwatcher as the bird comes closer to him. The speed of sound in air is 340ms^{-1} .



Calculate the:

1. Frequency of the waves detected by the birdwatcher. (3)
2. Magnitude of the velocity at which the bird flies. (5)

Discussion:

- The question or problem is formulated in an unfamiliar, non-routine way. Hence this question would be experienced as difficult by the envisaged candidate. Any question which involves an unexpected stimulus (such as a graph or diagram that appears to relate to some other topic) is likely to be experienced as more difficult than a straight-forward question on the topic (**Stimulus**).
- The question involves possible follow-on errors because of reliance on previous answers is likely to be made more difficult than a stand-alone question. Question 2, from the above, is categorised as difficult because it relies on the correct answer from Question 1, and this involves analysis of information from a diagram and from the text. Learners have to select the appropriate formulae to firstly calculate frequency in Question 1 and also appropriate use of signs (positive and negative) in the Doppler Effect formula for calculation in Question 2. Velocity is a vector quantity, that is, it includes both magnitude and direction. However, Question 2 is specific and requires only the magnitude. Learners have to recognize that the answer for Question 2 does not include a direction according to the question (**Task**).
- To answer this question, candidates need to have a clear understanding of the Doppler Effect as a concept. To calculate frequency in Question 1, candidates need to know how to read the graph in order to determine the magnitude of the wavelength as presented or shown in the graph. This is however not difficult for an envisaged Grade 12 candidate (**Content**).
- Mark allocation is clear. The memorandum indicates that 3 marks are allocated to Question 1, 1 mark for the choosing the correct formula, 1 mark for proper substitution and 1 mark for the answer. The memorandum also indicates that 5 marks are allocated to Question 2, 1 mark for the formula, 1 mark for frequency of the listener (the answer carried over from the Question 1), 2 marks for correct substitution of the speed of sound and the frequency of the source (1 mark each) and 1 mark for the answer including unit. In addition, candidates also get credits for carry-over (wrong answer carried over from Question 1 and substituted correctly in Question 2) (**Expected Response**).

This question is therefore categorized as difficult with regard to stimulus and task difficulties.

Memorandum/Marking guidelines

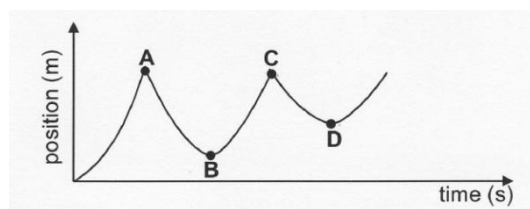
$$\begin{aligned} 6.4.1 \quad v &= f\lambda \quad \checkmark \\ 340 &= f(0,2) \quad \checkmark \\ \therefore f &= 1\,700 \text{ Hz} \quad \checkmark \end{aligned}$$

$$\begin{aligned} 6.4.2 \quad f_L &= \frac{v \pm v_L}{v \pm v_s} f_s \quad \text{OR/OF} \quad f_L = \frac{v}{v - v_s} f_s \quad \checkmark \\ \therefore 1\,700 \quad \checkmark &= \frac{340}{340 - v_s} \quad \checkmark (1\,650) \quad \checkmark \\ \therefore v_s &= 10 \text{ m}\cdot\text{s}^{-1} \quad \checkmark \end{aligned}$$

Example 4:

Question 2.3, November 2011 Paper 1, DBE:

A ball is released from rest from a certain height above the floor and bounces off the floor a number of times. The position-time graph represents the motion of the bouncing ball from the instant it is released from rest.



Which point, A, B, C or D on the graph represents the position-time coordinates of the maximum height reached by the ball after the SECOND bounce? (2)

Discussion:

- This is a multiple-choice question, but illustrates the fact that it is possible to get extremely challenging multiple-choice questions. This question is categorised as very difficult because it involves interpretation of information from a complex, unfamiliar graph where the frame of reference is opposite to what learners would expect. Candidates do not simply choose an answer because they need to have a deep understanding of graphs of motion and of the analysis of the motion of a bouncing ball to be able to answer this question correctly. Learners have to analyse the graph in terms of number of bounces, shape of the graph as related to speed or velocity (increase or decrease) as soon the ball is released from rest from a certain height above the floor and bounces off the floor. This is a very difficult question which only A-type candidates are likely to be able to answer correctly (**Task**).
- The question assesses content based on vertical projectile motion in one dimension (1D) represented in graph under mechanics knowledge area. Vertical projectile motion in one dimension (1D) is not a difficult concept (**Content**).
- Words and phrases used in this test item are easy to understand, however, the question involves an unexpected stimulus, that is, a complex and unfamiliar graph where the frame of reference is opposite to what learners would expect and hence the question is very difficult (**Stimulus**).

- Mark allocation is clear. The memorandum indicates that 2 marks are allocated for choosing the correct answer (Multiple Choice Questions) **(Expected Response)**.

This question is therefore categorized as very difficult with regard to stimulus and task.

Memorandum/Marking guidelines

2.3 D ✓✓

TABLE 11: EXAMPLES OF QUESTIONS AT DIFFICULTY LEVEL 4 – VERY DIFFICULT

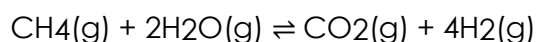
Note:

During the development of the exemplar book some subject specialists argued that there is a faint line between a difficult and a very difficult question. It was also evident that in some subjects, question papers did not have questions that could be categorised as very difficult. In order to cater for this category, subject specialists were requested to adapt existing questions and make them very difficult or create their own examples of very difficult question. However, it was noted that in some instances attempts to create very difficult questions introduced invalid sources of difficulty which in turn rendered the questions invalid. Hence Umalusi acknowledges that the very difficult category may be problematic and therefore requires especially careful scrutiny.

Example 1:

Question 7.3, Feb/March 2014 Paper 2, DBE:

The reaction of methane gas (CH₄) with steam (H₂O) produces hydrogen gas. The equation for the reaction is shown below.



Initially, 1 mol of methane and 2 mol of steam are sealed in a 5,0 dm³ container. When equilibrium is established at temperature T₁, the mixture contains 0,3 mol of CO₂(g).

7.3 Calculate the equilibrium constant (K_c) at T₁. (7)

Discussion:

- Learners are expected to apply the information provided to determine Equilibrium Concentrations of the compounds when the reaction is at equilibrium. In order to do this, they have to understand the ratio in which these compounds react in order to determine the concentrations at equilibrium. These equilibrium concentrations are then applied to the Kc formula - which learners have to produce from the balanced equation. There are two options of working out the concentrations at equilibrium (**Content**).
- The words used in this question are simple and straightforward (**Stimulus**).
- Mark allocation is also clear and straightforward. The memorandum indicates that seven (7) marks are allocated to Question 7.3 (**Expected Response**).
- There are three important steps that learners have to understand: (1) working from the data provided towards the equilibrium concentrations; (2) developing the Kc concentration from the balanced equation; and (3) then finally the equilibrium concentrations are substituted into the Kc equation. The combined effect of these three steps make this a very difficult problem (**Task**).

This question is therefore categorized as very difficult with regard to content and task difficulties.

Memorandum/Marking guidelines

	CH ₄	H ₂ O	CO ₂	H ₂
Initial Quantity (mol)	1	2	0	0
Change (mol)	0,3	0,6	0,3	1,2 √
Quantity at equilibrium (mol)	0,7	1,4√	0,3	1,2 √
Equilibrium concentration (mol.dm ⁻³)	0,14	0,28	0,06√	0,24

$$K_c = \frac{[CO_2][H_2]^4}{[CH_4][H_2O]^2} \sqrt{}$$

$$= \frac{(0,06)(0,24)^4}{(0,14)(0,28)^2} \sqrt{}$$

$$= 0,02 (0,18) \sqrt{ (7)}$$

OR

	CH ₄	H ₂ O	CO ₂	H ₂
Initial Concentration (mol.dm ⁻³)	0,2	0,4	0	0
Change (mol.dm ⁻³)	0,06	0,12	0,06	0,24√
Equilibrium concentration (mol.dm ⁻³)	0,14	0,28√	0,06√	0,24√

$$K_c = \frac{[CO_2][H_2]^4}{[CH_4][H_2O]^2} \sqrt{}$$

$$= \frac{(0,06)(0,24)^4}{(0,14)(0,28)^2} \sqrt{}$$

$$= 0,02 (0,18) \sqrt{} \quad (7)$$

Example 2:

Question 4.2, November 2011 Paper 1, DBE:

A patrol car is moving on a straight horizontal road at a velocity of $10 \text{ m} \cdot \text{s}^{-1}$ east. At the same time, a thief in a car ahead of him is driving at a velocity of $40 \text{ m} \cdot \text{s}^{-1}$ in the same direction.



A person in the patrol car fires a bullet at the thief's car. The bullet leaves the gun with an initial horizontal velocity of $100 \text{ m} \cdot \text{s}^{-1}$ relative to the patrol car. Ignore the effects of friction.

Write down the initial velocity of the **bullet** relative to the **thief's** car. (2)

Discussion:

- This question is categorised as very difficult because the concept of relative velocity is already experienced as difficult by the envisaged candidate, since the approach that is required is counter-intuitive. The required answer is a vector quantity and therefore candidates are also required to indicate both magnitude and direction. The answer has multiple elements **(Concept/Content)**.
- This question involves the interpretation of a diagram as well as interpretation of information from a piece of text. The memorandum indicates that candidates do not have to show steps of the solution but the question requires deep reasoning and to roughly work out the answer separately. The added steps involved in solving this problem, together with the unfamiliar nature of the problem, would mean that it would be experienced as very difficult by the envisaged candidate. Answering this question also requires the use of signs (positive and negative) to represent directions in calculations. Only A-type candidates are likely to be able to answer this question correctly. (Task).
- The marking memorandum indicated that 2 marks are allocated to the question, 1 mark for appropriate the magnitude and 1 mark for the direction. There is no difficulty imposed by the examiners in mark scheme or memorandum **(Expected Response)**.
- The words used in this question are simple and straightforward and candidates will be able to work out what the question requires. Although candidates have to interpret information from the statement and the diagram, this does not make the question very difficult for an envisaged learner. **(Stimulus)**.

This question is therefore categorized as very difficult with regard to task and content difficulties.

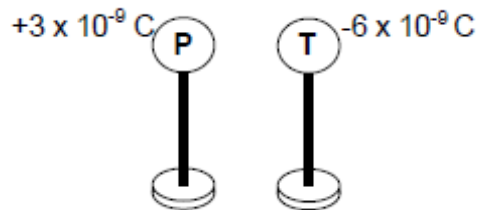
Memorandum/Marking guidelines

a. $70 \text{ m}\cdot\text{s}^{-1} \sqrt{\text{East}}$

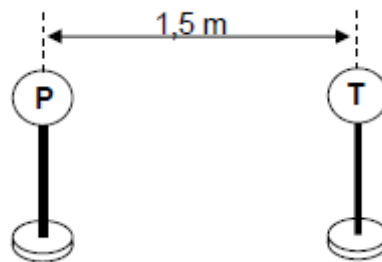
Example 3:

Question 8, November 2011 Paper 1, DBE:

Two metal spheres, **P** and **T**, on insulated stands, carry charges of $+3 \times 10^{-9} \text{ C}$ and $-6 \times 10^{-9} \text{ C}$ respectively.



The spheres are allowed to touch each other and are then placed 1,5 m apart as shown below.



Question 8.2: Calculate the net charge gained or lost by sphere P after the spheres have been in contact. (3)

Question 8.4: A third sphere **R**, carrying a charge of $-3 \times 10^{-9} \text{ C}$, is NOW placed between **P** and **T** at a distance of 1 m from **T**. Calculate the net force experienced by sphere **R** as a result of its interaction with **P** and **T**. (6)

Discussion:

- The question involves possible follow-on errors because of reliance on previous answers is likely to be made more difficult than a stand-alone question. Question 8.4 is categorised as very difficult because the information required to answer this question relies on learners having been able to respond correctly to Question 8.2. In addition, the solution to this problem involves a number of complex steps. Any learners who struggle with the previous question would have their confidence shaken, and would thus be unlikely to be able to answer the subsequent question. Answering Questions 8.2 and 8.4 requires good understanding of the application of the 'Principle of conservation of Charge' and Coulomb's Law respectively as well as knowing that force is a vector quantity meaning both magnitude and direction are essential in the final step (the answer). Learners also have to calculate the distance between charge **P** and charge **R** and the distance

between charge **T** and charge **R**. For final answer (net force), candidates have to choose signs (positive or negative) to represent directions. The net force is therefore given by the vector sum of the two forces since they are linear (**Task**).

- The question is easy to understand and provides very clear, concise procedure for an investigation. Candidates are provided with well labelled diagrams. All the necessary information is given for the candidates to work out the solution (**Stimulus**).
- The content being assessed in this question is electrostatics under electricity and magnetism knowledge area. Responding to Question 8.2 requires a sound knowledge and understanding of content covered in the prescribed curriculum. In the question, the following three knowledge elements are assessed in the context of 'Electrostatics': Principle of Conservation of Charge, Coulomb's Law and force as a vector quantity (**Content**). These concepts are not difficult when assessed individually, and also bringing them together does not make the content very difficult.
- Mark allocation is clear. The memorandum indicates that three (3) marks are allocated to Question 8.2, 1 mark for the application of the 'Principle of Conservation of Charge, 2 marks for steps in calculating the net charge gained or lost by sphere P. The memorandum indicates that six (6) marks are allocated to Question 8.4 and 1 mark for writing Coulomb's law as an equation. For correct substitution, one (1) mark is allocated, two (2) marks for working out the distance of sphere P from sphere R and the distance of sphere T from sphere R and 2 marks for the final answer (1 mark for magnitude and 1 mark for direction). In marking Question 8.4, markers have to aware of the possible follow-on errors because of reliance on previous answers (Question 8.2) (**Expected Response**).

This question is therefore categorized as very difficult with regard to task difficulty.

Memorandum/Marking guidelines

$$8.2 \quad Q = \frac{3 \times 10^{-9} + (-6 \times 10^{-9})}{2} \checkmark = -1,5 \times 10^{-9}$$
$$\Delta Q_P = Q_P(\text{final}) - Q_P(\text{initial})$$
$$= -1,5 \times 10^{-9} - 3 \times 10^{-9} \checkmark$$
$$= -4,5 \times 10^{-9} \text{ C } \checkmark$$

OR / OF

$$\Delta Q_T = Q_T(\text{final}) - Q_T(\text{initial})$$
$$= -1,5 \times 10^{-9} - (-6 \times 10^{-9}) \checkmark$$
$$= 4,5 \times 10^{-9} \text{ C } \checkmark$$

8.4

Option 1 / Opsie 1

$$F_{TR} = \frac{kQ_1Q_2}{r^2} \checkmark$$

$$= \frac{(9 \times 10^9)(1,5 \times 10^{-9})(3 \times 10^{-9})}{1^2} \checkmark$$

$$= 4,05 \times 10^{-8} \text{ N to the left/towards P}$$

na links/na P toe

$$F_{PR} = \frac{kQ_1Q_2}{r^2}$$

$$= \frac{(9 \times 10^9)(1,5 \times 10^{-9})(3 \times 10^{-9})}{0,5^2} \checkmark$$

$$= 1,62 \times 10^{-7} \text{ N to the right/towards T}$$

na regs/na T toe

To the right / towards T as positive: / Na regs / na T toe as positief

$$F_{\text{net}} = 1,62 \times 10^{-7} - 4,05 \times 10^{-8}$$

$$= 1,22 \times 10^{-7} \text{ N } (1,215 \times 10^{-7} \text{ N})$$

$$= 1,22 \times 10^{-7} \text{ N } \checkmark \text{ to the right / towards T / na regs / na T toe } \checkmark$$

✓ Any one
Enige een

9. Concluding remarks

This exemplar book is intended to be used as a training tool to ensure that all role players in the Physical Sciences Examination are working from a common set of principles, concepts, tools and frameworks for assessing cognitive challenge when examinations are set, moderated and evaluated. We hope that the discussion provided and the examples of questions shown by level and type of cognitive demand and later by level of difficulty assist users of the exemplar book to achieve this goal.

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