Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION 2015

PHYSICS AND CHEMISTRY

CHIEF EXAMINER'S REPORT

Contents

1. Introduction

1.1 Syllabus Structure

The Leaving Certificate *Physics and Chemistry* syllabus consists of approximately 50% physics and 50% chemistry. Students presenting for examination in this subject may not present for either of the individual subjects, Leaving Certificate *Physics* or Leaving Certificate *Chemistry*. *Physics and Chemistry* is an experimental and practical subject, and practical work by students is regarded as an integral part of the course. The syllabus dates from before 1970 and is therefore not presented in the same way as more modern ones. It consists simply of a list of topics. Depth of treatment at each level has been established through custom and practice over many years by means of past examination papers and marking schemes. In the *Physics and Chemistry* syllabus, objectives are not specified. For the purposes of the design of the examination paper, the evaluation of candidate work, and the commentary in this report, the objectives have been inferred from past papers and past marking schemes and are characterised in terms of knowledge, understanding, skills, competence and attitudes. These assumed syllabus objectives are used as the headings for the commentary in Section 3.2 (Key Syllabus Objectives, Engagement and Performance) below.

Note: This report should be read in conjunction with the examination papers, the published marking schemes and the syllabus for this subject. The examination papers and marking schemes are available on the State Examination Commission's website www.examinations.ie and the syllabuses are available at www.curriculumonline.ie.

1.2 Assessment Specification

At each level, the syllabus is assessed through a terminal written examination of three hours' duration.

At each level, the examination is marked out of 400 marks and is divided into two sections: Section I – Physics (200 marks) and Section II – Chemistry (200 marks). Each section has six questions of which three are to be answered (66 marks each[1]). The first question in each section (Question 1 and Question 7) consists of fifteen short items, of which eleven items are

[1] In each section, one additional mark is given to each of the first two questions for which the highest marks are obtained, so as to bring the available total to 200 for the section.

to be answered. The last question in each section has some internal choice. There is no compulsory question at either level.

The close correspondence between the structures of the papers at the two levels facilitates mixed-level teaching. It also facilitates candidates unsure of which level they might take in remaining at Higher level for as long as possible.

1.3 Participation Trends

Table 1 gives the overall participation rates of candidates in Leaving Certificate *Physics and Chemistry* for the last five years. There has been a small but steady increase in the number of Leaving Certificate students taking *Physics and Chemistry* in the last four years.

Given the small candidature and small number of schools offering this subject, fluctuations in cohort size at both levels and in the gender composition of the cohort occur from year to year without statistical significance.

Year	*Physics and Chemistry* candidature	Total Leaving Certificate candidature*	*Physics and Chemistry* as % of total
2011	472	54341	0.9
2012	405	52589	0.8
2013	423	52767	0.8
2014	466	54025	0.9
2015	552	55045	1.0

*Total Leaving Certificate candidature excludes Leaving Certificate Applied candidates.

Table 1: participation in Leaving Certificate *Physics and Chemistry*, 2011 to 2015

The breakdown in terms of participation at Higher and Ordinary levels over the last five years is given in **Table 2**. The breakdown in terms of gender at Higher level and at Ordinary level over the last five years is given in **Table 3** and **Table 4** respectively.

Year	Total *Physics and Chemistry* candidature	Number at Ordinary level	Number at Higher level	% Ordinary level	% Higher level
2011	472	93	379	19.7	80.3
2012	405	96	309	23.7	76.3
2013	423	93	330	22.0	78.0
2014	466	105	361	22.5	77.5
2015	552	115	437	20.8	79.2

Table 2: number and percentage of candidates at each level, 2011 to 2015

Year	Total Higher level	Female Candidates	Male Candidates	Female as % of total	Male as % of total
2011	379	168	211	44.3	55.7
2012	309	132	177	42.7	57.3
2013	330	131	199	39.7	60.3
2014	361	167	194	46.3	53.7
2015	437	171	266	39.1	60.9

Table 3: gender composition of Higher level cohort, 2011 to 2015

Year	Total Ordinary level	Female Candidates	Male Candidates	Female as % of total	Male as % of total
2011	93	32	61	34.4	65.6
2012	96	29	67	30.2	69.8
2013	93	24	69	25.8	74.2
2014	105	18	87	17.1	82.9
2015	115	37	78	32.2	67.8

Table 4: gender composition of Ordinary level cohort, 2011 to 2015

2. Performance of candidates

2.1 Higher Level Statistics

The distribution of grades awarded over the last five years is given in **Table 5** (lettered grades) and **Table 6** (sub-grades).

Year	A	B	C	A, B, C	D	E	F	NG	E, F, NG
2011	22.4	27.1	22.2	71.7	17.4	8.2	2.4	0.3	10.9
2012	19.1	31.1	24.2	74.4	14.6	7.4	2.3	1.3	11.0
2013	18.2	26.7	26.4	71.3	17.6	9.4	1.2	0.6	11.2
2014	20.8	26.5	23.6	70.9	18	7.2	3.6	0.3	11.1
2015	14.4	27.0	26.6	68.0	19.7	6.4	4.3	1.6	12.3

Table 5 Percentage of candidates awarded each lettered grade in Higher Level *Physics and Chemistry*, 2011 – 2015

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2011	12.9	9.5	7.9	9.2	10.0	6.9	6.9	8.4	5.5	6.1	5.8	8.2	2.4	0.3
2012	8.7	10.4	10.0	10.7	10.4	5.8	8.4	10.0	3.9	4.2	6.5	7.4	2.3	1.3
2013	10.3	7.9	7.3	11.5	7.9	7.6	10.3	8.5	5.8	7.0	4.8	9.4	1.2	0.6
2014	9.4	11.4	8.3	9.1	9.1	7.5	7.2	8.9	5.8	5.8	6.4	7.2	3.6	0.3
2015	4.6	9.8	7.1	8.5	11.4	6.4	9.2	11.0	5.3	7.8	6.6	6.4	4.3	1.6

Table 6 Percentage of candidates awarded each sub-grade in Higher Level *Physics and Chemistry*, 2011 – 2015

The increase in candidature in 2015 was accompanied by a decrease in the percentage of candidates achieving an A grade and in the percentage achieving A, B and C grades. The shift in candidature from Ordinary to Higher level in an otherwise stable candidature could fully account for the latter of these changes if not the former. However, it is noted that this is still a relatively small cohort, so that what appear to be large percentage changes can arise from comparatively modest changes in absolute numbers. For example, the fall in the actual number of A grades awarded between 2014 and 2015 is only 12, (being 63 in 2015 as opposed to 75 in 2014). Furthermore, it may be noted that the cohort in 2015 included candidates from schools that had not previously entered candidates in this subject, which complicates year-on-year comparisons.

The distribution of sub-grades by gender over the last five years is given in **Table 7** (female candidates) and **Table 8** (male candidates).

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2011	15.5	11.3	7.7	8.3	5.4	8.9	8.3	10.7	6.0	4.8	1.8	8.9	2.4	0.0
2012	8.3	12.9	15.2	12.9	9.1	6.8	4.5	8.3	1.5	3.0	6.1	10.6	0.8	0.0
2013	14.5	9.2	13.0	12.2	6.9	8.4	7.6	4.6	6.1	4.6	4.6	6.9	0.8	0.8
2014	11.4	12.0	8.4	12.0	12.0	6.0	7.2	9.0	7.2	3.0	4.2	4.8	3.0	0.0
2015	6.4	11.1	8.8	8.2	12.9	4.1	7.0	11.1	4.7	8.8	6.4	6.4	2.9	1.2

Table 7: Percentage of female candidates awarded each sub-grade in Higher Level *Physics and Chemistry*, 2011 – 2015

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2011	10.9	8.1	8.1	10.0	13.7	5.2	5.7	6.6	5.2	7.1	9.0	7.6	2.4	0.5
2012	9.0	8.5	6.2	9.0	11.3	5.1	11.3	11.3	5.6	5.1	6.8	5.1	3.4	2.3
2013	7.5	7.0	3.5	11.1	8.5	7.0	12.1	11.1	5.5	8.5	5.0	11.1	1.5	0.5
2014	7.7	10.8	8.2	6.7	6.7	8.8	7.2	8.8	4.6	8.2	8.2	9.3	4.1	0.5
2015	3.4	9.0	6.0	8.6	10.5	7.9	10.5	10.9	5.6	7.1	6.8	6.4	5.3	1.9

Table 8: Percentage of male candidates awarded each sub-grade in Higher Level *Physics and Chemistry*, 2011 – 2015

In terms of the percentage of candidates scoring at or above any given grade, these results show that female candidates consistently outperformed male candidates at all points in the grade distribution for each of the last three years.

2.2 Ordinary Level Statistics

The distribution of grades awarded over the last five years is given in **Table 9** (lettered grades) and **Table 10** (sub-grades).

Year	A	B	C	A, B, C	D	E	F	NG	E, F, NG
2011	4.4	23.7	22.6	50.7	23.7	10.8	11.8	3.2	25.8
2012	6.2	20.9	15.7	42.8	29.1	8.3	10.4	9.4	28.1
2013	4.4	14.1	30.1	48.6	25.8	11.8	8.6	5.4	25.8
2014	1.9	12.4	26.7	41.0	25.7	10.5	15.2	7.6	33.3
2015	1.7	13.1	23.5	38.3	25.2	13.0	14.8	8.7	36.5

Table 9: Percentage of candidates awarded each lettered grade in Ordinary Level *Physics and Chemistry*, 2011 – 2015

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2011	2.2	2.2	2.2	4.3	17.2	7.5	4.3	10.8	6.5	4.3	12.9	10.8	11.8	3.2
2012	1.0	5.2	4.2	7.3	9.4	2.1	6.3	7.3	13.5	5.2	10.4	8.3	10.4	9.4
2013	2.2	2.2	2.2	2.2	9.7	7.5	8.6	14.0	5.4	3.2	17.2	11.8	8.6	5.4
2014	0.0	1.9	0.0	5.7	6.7	6.7	9.5	10.5	7.6	8.6	9.5	10.5	15.2	7.6
2015	0.0	1.7	0.9	2.6	9.6	7.0	6.1	10.4	7.0	5.2	13.0	13.0	14.8	8.7

Table 10 Percentage of candidates awarded each sub-grade in Ordinary Level *Physics and Chemistry*, 2011 – 2015

The distribution of sub-grades by gender over the last five years is given in **Table 11** (female candidates) and **Table 12** (male candidates).

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2011	0.0	0.0	6.3	0.0	18.8	9.4	3.1	12.5	3.1	3.1	18.8	12.5	6.3	6.3
2012	3.4	0.0	0.0	10.3	6.9	0.0	13.8	3.4	13.8	3.4	17.2	10.3	3.4	13.8
2013	8.3	0.0	4.2	0.0	8.3	12.5	12.5	0.0	4.2	0.0	20.8	20.8	4.2	4.2
2014	0.0	0.0	0.0	5.6	11.1	5.6	0.0	16.7	11.1	16.7	5.6	11.1	16.7	0.0
2015	0.0	0.0	2.7	5.4	13.5	8.1	10.8	10.8	2.7	2.7	5.4	18.9	13.5	5.4

Table 11 Percentage of female candidates awarded each sub-grade in Ordinary Level *Physics and Chemistry*, 2011 – 2015

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2011	3.3	3.3	0.0	6.6	16.4	6.6	4.9	9.8	8.2	4.9	9.8	9.8	14.8	1.6
2012	0.0	7.5	6.0	6.0	10.4	3.0	3.0	9.0	13.4	6.0	7.5	7.5	13.4	7.5
2013	0.0	2.9	1.4	2.9	10.1	5.8	7.2	18.8	5.8	4.3	15.9	8.7	10.1	5.8
2014	0.0	2.3	0.0	5.7	5.7	6.9	11.5	9.2	6.9	6.9	10.3	10.3	14.9	9.2
2015	0.0	2.6	0.0	1.3	7.7	6.4	3.8	10.3	9.0	6.4	16.7	10.3	15.4	10.3

Table 12 Percentage of male candidates awarded each sub-grade in Ordinary Level *Physics and Chemistry*, 2011 – 2015

Given the small number of candidates involved, it would not be prudent to draw any conclusions from small differences between Table 11 and Table 12.

3. Analysis of Candidate Performance

3.1 Engagement and Performance

Higher Level

Table 13 is a summary based on an analysis of a random selection of 60 scripts (approximately 14% of all scripts).

Question	**Popularity (% attempts)**	**Rank order in popularity**	**Average mark, out of 66 (and as %)**	**Rank order in average mark**	**Topic**
1	88.3	1, 2	38.8 (58.8)	7	Miscellaneous
2	88.3	1, 2	41.6 (63.1)	3	Mechanics (momentum)
3	45.0	9	37.0 (56.0)	9	Light
4	60.0	7	37.1 (56.3)	8	Gas laws, heat, temperature
5	10.0	11	41.3 (62.6)	4	Electricity
6	53.3	8	35.9 (54.4)	10	(a) Photoelectric Effect (b) Gravitation (c) Electromagnetic Induction (d) Nuclear Physics
7	81.7	4	40.8 (61.9)	5	Miscellaneous
8	70.0	6	34.4 (52.1)	11	Atomic structure
9	75.0	5	45.5 (68.9)	2	Volumetric analysis and pH
10	25.0	10	34.1 (51.6)	12	Electrochemical series, redox chemistry, electrochemistry
11	5.0	12	45.7 (69.2)	1	Organic Chemistry
12	83.3	3	39.8 (60.2)	6	(a) Transition element chemistry (b) Bonding (c) Stoichiometry (d) Thermochemistry

Table 13: popularity of and average mark for each question, Higher Level *Physics and Chemistry*

The average mark per question was 39.3 (with a standard deviation of 3.7). The small standard deviation indicates that average scoring was consistent across the questions. There is also a good comparability across sub-disciplines physics and chemistry in terms of popularity of questions and scoring in the two sections of the paper. The average mark in the physics section was 38.6 (with standard deviation of 2.17) while the average mark in chemistry was 40.1 (with standard deviation 4.7). On average the number of surplus physics questions attempted per candidate in the sample was 0.45 and the average of the number of surplus chemistry questions attempted per candidate in the sample was 0.40.

The best answered question and also the least popular was Question 11 on organic chemistry – traditionally not a popular topic with *Physics and Chemistry* candidates and clearly attempted only by those who had prepared well.

Question 1, Question 2, Question 7 and Question 12 were all answered by more than 80% of candidates in the sample. Question 5 (electricity) and Question 11 (organic chemistry) were attempted by only 10% and 5% candidates in the sample, respectively. All the other questions were attempted by more than 25% of the candidates. Given the wide choice within the paper and the popularity of Question 1 and Question 7 which both involve a multiplicity of topics, these figures are indicative of good course coverage of both parts of the syllabus in schools.

Ordinary Level

Table 14 is a summary based on an analysis of a random selection of 20 scripts (approximately 17% of all scripts). Given the small cohort, the popularity and score rankings cannot be considered representative of all the candidates' work and should be interpreted accordingly.

Question	**Popularity (% attempts)**	**Rank order in popularity**	**Average mark, out of 66 (and as %)**	**Rank order in average mark**	**Topic**
1	95	2, 3	32.2 (48.8)	7	Miscellaneous
2	80	4	31.5 (47.7)	3	Mechanics
3	60	6, 7	25.6 (38.8)	9	Light (reflection)
4	35	10	30.9 (46.8)	8	Gas laws, heat, temperature
5	15	11, 12	25.3 (38.4)	4	Electricity (statics, capacitance)
6	60	6, 7	20.5 (31.1)	10	(a) Momentum (b) Waves (c) Electricity (current) (d) Nuclear Physics
7	95	2, 3	41.5 (62.8)	5	Miscellaneous
8	45	8	26.7 (40.4)	11	Atomic structure, bonding
9	40	9	24.8 (37.5)	2	Redox Acids, bases and pH
10	65	5	34.5 (52.3)	12	Volumetric analysis
11	15	11, 12	12.7 (19.2)	1	Organic Chemistry
12	100	1	41.0 (62.1)	6	(a) Stoichiometry (b) Sulfur dioxide (c) Atomic structure, bonding

Table 14: popularity of and average mark for each question, Ordinary Level *Physics and Chemistry*

The average mark per question was 28.9 (with a standard deviation of 7.8). The relatively small standard deviation indicates that average scoring was reasonably consistent across most of the questions. There is also a good comparability across the sub-disciplines physics and chemistry in terms of scoring and popularity of questions in the two sections of the paper. The average mark in the physics section was 27.7 (with a standard deviation of 4.22) while the average mark in chemistry was a little higher at 30.2 (but had a standard deviation of 10.1). Half the candidates in the sample attempted surplus questions and the number of surplus physics questions equalled the number of surplus chemistry questions. However, 10% of candidates in the sample did not attempt the required 3 questions from each section. Question 7 was the best answered and Question 12 was the most popular question. Question 5 (statics and capacitance) in the physics section and Question 11 (organic chemistry) in the chemistry section were the least popular questions and the latter was also the least well answered question.

Given the wide choice within the paper set against the popularity of Questions 1 and 7 and Questions 6 and 12 that all examine a multiplicity of topics, the figures in Table 14 for question popularity and scoring are indicative of good course coverage of both parts of the syllabus in schools.

3.2 Attainment of Key Syllabus Objectives

The 2015 candidates' responses to items on the Higher Level and Ordinary Level examination papers are analysed below in terms of candidate achievement in respect of *different levels in the cognitive domain*: (i) knowledge and understanding, (ii) application and analysis, and (iii) synthesis and evaluation. Candidate achievement in practical skills is also considered, but could only be indirectly assessed by questions in the written examination paper.

Higher Level

Knowledge and Understanding

The ability to display knowledge and understanding in responses to questions is fundamental to success of candidates in this examination; most candidates demonstrated good overall levels of achievement in both knowledge and in understanding with the exception of two specific syllabus topics.

Some questions required recall of facts or basic terminology in short responses, e.g. Question 1(k)(ii) (*Identify the electrical device that stores energy by means of the separation of charges.*), Question 3(e) (*Give a use for a concave mirror based on its magnifying ability.*), Question 7(k)(i) (*Name or give the formula of an oxide that is basic*.), and Question 9(e) (*Define pH*).

Other questions required the learner to demonstrate his or her broader and deeper knowledge of the principles and theories of physics and chemistry e.g. Question 4(a) (*State Charles' law*.), Question 7(d) (*Define relative atomic mass.*). In their answers, a number of candidates neglected to refer to a fixed mass of gas or the Kelvin (absolute) temperature scale when stating Charles' law and omitted the word 'average' from their definitions of relative atomic mass. In other questions, many candidates gave definitions that were lacking the accuracy and detail required for full marks.

Candidates were required to show knowledge of the basic theory and principles in addition to historical, economic, environmental and social aspects of physics and of chemistry in their answers to a number of questions: examples include Question 6(d), Question 8(a) – historical, Question 2(f), Question 10(b) – economic, Question 6(d), Question 12(d) – environmental and Question 6 (b), Question 7(f) – social. Candidate knowledge that physics and chemistry relate to everyday life and are fundamental to innovation and technology was explored throughout Question 2, Question 5 and Question 12. In general candidates responded well to both theoretical and applied aspects of topics.

Several question parts assessed the learner's understanding of syllabus material. Candidates were required to restate concepts or principles in their own words, e.g. Question 4(d)(ii) (*Why are standard thermometers necessary?*) and Question 10(b) (*Explain how zinc and tin can protect iron from corrosion*.). Understanding of the scientific method was required in Question 6(a) on the photoelectric effect and in Question 8(a) on Bohr's theory. Examiners reported that candidates' theoretical knowledge was in general only moderately good, with few candidates providing the level of detail required to show a sufficiently thorough understanding of the topic to be awarded full marks. Examiners also recorded some misinterpretation of questions. Examples of questions where candidates had difficulty with theory include Question 6(a) about the photoelectric effect and Question 10(c) where candidates were required to explain whether given chemical reactions were redox reactions or not and explain why.

A significant difference between candidates for this examination and candidates for Higher Level *Chemistry* is in their relative engagement with the topic of organic chemistry. In the *Physics and Chemistry* examination, organic chemistry is very unpopular every year, although well answered by the very few who attempt it. In contrast, at Higher Level *Chemistry*, organic chemistry is both very popular and well answered.

A similar lack of engagement by *Physics and Chemistry* candidates with the syllabus section on electricity and magnetism, which is observed annually, was also noted in the report of the Chief Examiner on the 2013 Leaving Certificate *Physics* examination.

Application and Analysis

Even among candidates who display similar levels of knowledge and understanding, some are more able than others to apply what they have learned and analyse information and scenarios. The presence on the examination of questions that tested these skills facilitated discrimination between candidates in this regard.

Candidates were required to apply laws and principles to answer Question 3(e) (*Use a ray diagram to show how a magnified erect image is produced by a concave mirror.*), Question 8(d) (*Write the electron configuration of a nitrogen atom showing the arrangement of electrons in orbitals in the ground state.*) and Question 7(j) (*Identify (i) the conjugate acid of* HS^- *(ii) the conjugate base of* $H_2NO_3^-$*.*). Some candidates failed to demonstrate a capacity to apply knowledge and understanding of the basic principles and theory to practical scenarios, an example being a failure to explain adequately how the mass of the astronaut was unrelated to the acceleration due to gravity in Question 6(b).

While many candidates showed that they were able to apply the rules for assigning electrons to subshells, some were unable to then state the number of occupied main energy levels and orbitals required in the next part of Question 8(d). Many candidates who attempted Question 7(j) added a proton when they should have removed it and vice versa. Another common error in answers to Question 7(j) was the failure to adjust the charge correctly.

Questions 2(f), 5(d), 6(a), 6(b), 6(d), 9(d), 10(e), 12(c) and 12(d), which were individually worth between 12 and 22 marks, required candidates to translate verbal information into mathematical form and vice versa. Candidates were required to recognise a problem; interpret information; apply mathematical analysis, rules or a formula; perform a sequence of calculations to arrive at a solution and manipulate units. Questions 1(c), 1(e), 1(h), 1(n), 7(f) and 7(i) were shorter mathematical analyses worth 6 marks each.

The quality of answering varied from calculation to calculation. Some candidates failed to use the *Formulae and Tables* booklet to furnish the constants required for some of the calculations or in other ways that could have helped them, such as to look up units for their answers. Candidates misinterpreted Question 1(e), giving definitions of amplitude and wavelength instead of values from the graph, and most struggled with the molar ratios in Question 1(h). Very few candidates were able to do parts (ii) and (iii) of Question 2(f) on momentum correctly but most did part (i) very well. Question 5 on electricity was unpopular. Nonetheless, almost all those who attempted it managed to complete the calculation in part (d) correctly. The calculation part of Question 6(a) on photons was well answered and the calculation in Question 6(b) on gravitational force was popular but not well done. The mass energy conversion in Question 6(d) was reasonably well attempted but many candidates omitted to convert to kilograms. The volumetric analysis in Question 9(d) was competently performed by many candidates. Although parts of Question 10 were poorly answered, the calculation was one of the parts that those who attempted it answered well. Question 12(c) on stoichiometry was not very popular but was well answered by those who attempted it, with parts (iii) and (iv) presenting problems for some. Many who attempted Question 12(d) were awarded full marks, thereby demonstrating competence in solving a Hess's Law problem. Examiners reported that the general standard of achievement of application in calculations was higher than in theory questions.

Candidates analytical competencies were tested by the requirement to interpret, examine evidence and make arguments in Question 4(c) (*Explain how your graph verifies Charles' law.*), and in Question 6 (a) (*Describe and explain what you would expect to observe if the zinc plate were illuminated with* …..).

Question 8(c) and (d) required the ability to analyse critically the complex relationships of atomic architecture. Questions on this topic are traditionally not well answered. As in other years, many candidates used the terms shell, sub-level and orbital incorrectly. Nonetheless, in 2015 parts (c) and (d) of Question 8 were both reasonably well answered. Question 7(b), requiring candidates to understand patterns in trends in the periodic table, was, as in other years, poorly answered.

To answer questions 12(a) and 12(b) correctly, candidates needed to organise their ideas and to link and analyse different components of their knowledge, including knowledge of chemical properties and how these relate to the layout of the periodic table. Although both parts of Question 12 were popular, the average quality of the work presented was not good: some candidates wrote a lot but their responses were vague or confused, showing familiarity with crystalline structure, trends in the periodic table, intramolecular bonding and intermolecular forces but lacking thorough differentiation of ideas. Such candidates did not then draw the correct conclusions. For example, many answers to the question requiring an explanation as to which of HCl or HBr would be expected to have the stronger bond did refer to electronegativity but did not develop the argument and also omitted mention of the relative sizes of chlorine and bromine.

Synthesis and Evaluation

Questions that served as discriminators of achievement in the higher order cognitive skills were included in both sections of the paper.

The construction of the ray diagram in Question 3(e) presented a challenge for many candidates. This is a higher order skill as candidates are required to use individual rules of reflection at curved surfaces. While a certain level of understanding of the concepts involved can be gained from considering these diagrams in textbooks or when drawn by the teacher, deficiencies in understanding are more readily exposed and addressed when students attempt to draw such diagrams for themselves.

Question 2(f)(iv) required critical assessment based on prior knowledge. (*Modern cars have 'crumple zones' built in to reduce injury to the occupants in the event of a collision. The crumple zones are designed to fold up like an accordion, as shown in Figure 4, leaving the cabin relatively intact. Explain in terms of force how crumple zones can help reduce injuries in a collision.*). This question, based on a scenario candidates were unlikely to have previously considered, tested candidates' ability to analyse and explain an unfamiliar situation, to understand how physics is used to solve problems in society and to suggest scientific explanations for experiences in everyday life. Good answering required generalisation to a context new to the candidates and the construction of an argument. These skills are challenging to develop and demonstrate: however many answers were quite satisfactory.

In Question 9(e) the abilities of the candidates to evaluate and synthesise were again tested. Candidates were required to identify, in their diagram, the pH at neutralisation. Many failed to evaluate the neutralisation volume from the information in their graph or their earlier calculations and thus came to the incorrect conclusion about pH, indicating that they had not developed these skills to the requisite level.

Questions 7(e) and 10(d) provided opportunities for candidates to display their levels of engagement and attainment in the key synthetic skill of construction of balanced chemical equations. Only those candidates who had demonstrated very high overall attainment in the examination were able to construct the equations required. Many candidates even struggled with the first stage of writing correct formulae.

In Question 8(a) (iv), (*Why is there no yellow line in the hydrogen emission spectrum?*) candidates were required to appraise information given in a diagram – or their prior knowledge – and use this to explain an observed phenomenon. Some were able to do this, hence giving a correct explanation for the non-existence of the yellow line. Candidates found that this was the most challenging part of Question 8(a).

Indirect Assessment of Practical Skills

A written paper cannot directly determine the ability of candidates to perform experiments safely and co-operatively, to select and manipulate suitable apparatus, and to make accurate observations and measurements. However, several questions on the examination paper provided candidates with an opportunity to demonstrate their familiarity with planning and design of experiments, handling laboratory apparatus, and using chemicals. Nonetheless, this is an indirect form of assessment, and the examination cannot distinguish knowledge and understanding of practical work that has been gained through laboratory experience from that acquired from textbooks, videos, or by other passive means.

Candidates were required to report experimental procedures and observations in a concise, accurate and comprehensible way, for example in Question 6(c) (*Describe an experiment to demonstrate electromagnetic induction*.) and Question 8(b) (*Describe how you would confirm the presence of lithium in a salt sample using a flame test.*). Candidates were questioned about their knowledge and their understanding of the reasons for selection of apparatus and procedures associated with conducting an experiment, for example in Question 2(e) (*Draw a labelled diagram of an arrangement of apparatus used to verify the law of conservation of momentum*), Question 9(b) (*Why is a conical flask usually preferable to a beaker as the* *container for a titration reaction?*) and Question 3(c) (*Describe with the aid of a labelled diagram how you would use a prism and lenses to project a spectrum of white light onto a screen*). Candidates were also required to explain precautions taken to reduce errors, as, for example, in Question 9(c) (*Why should only one or two drops of indicator be used?*).

While such questions cannot guarantee the completion of experimental work in class, they clearly reward candidates who have carried out such work and engaged with experimental physics and experimental chemistry. The questions referred to were all well answered, with the exception of Question 3(c), where the majority of the candidates appeared to be unfamiliar with the role of the lenses in producing a pure spectrum.

Several questions also assessed engagement with and attainment of skills in interpretation of experimental data and appropriate use of experimental data. In Questions 1(e) and 3(d), readings from graphs were required, while candidates were required to draw graphs in Question 4(c) and in Question 9(e).

In Questions 3(d), 4(c), 9(d) and 9(e), candidates were required to interpret experimental results in numerical and graphical form, apply rules or formulae that had not been provided to the data supplied, perform calculations or draw graphs of required relationships, manipulate units, and so on. As described earlier, the volumetric analysis in Question 9(d) was competently performed by many candidates, but drawing the graph of volume and temperature proved challenging for many candidates – especially those who did not convert temperatures from Celsius to the Kelvin scale first. In Question 3(d), candidates were required to interpret a graph of variables that they were not likely to have seen related graphically in their studies. In most cases, they responded well to the unfamiliar. In Question 9(e), candidates made good attempts at graphing the relationship between pH and volume, but very few read the graph correctly to give the pH at neutralisation or noticed the link to the earlier part of the question.

Ordinary Level

Knowledge and Understanding

A number of questions in the 2015 Ordinary level paper required simple recall of previously learned facts and physics and chemistry terminology, given in the form of short answers, (‘what term’, ‘name’, etc). Examples include Question 1(e) (*What term is used to describe* *what happens when white light is split into its component colours?*) and Question 7(m) (*Name the carboxylic acid found in vinegar*.) These included questions that nearly all Ordinary level candidates could reasonably be expected to answer well, along with some more discriminating questions on less well known facts. To encourage engagement and to access candidate knowledge, questions on the Ordinary Level paper included a small number of completion-type questions, such as Question 2 (*Copy and complete the following statement of Newton's first law of motion*) and Question 7(f) (*Copy and complete the following statement about Bohr's atomic theory.*). One part of Question12(c), which, as expected, was both popular and well answered, required candidates to recognise and match seven terms with seven definitions. In answering Question 1, most candidates were unable to provide the required short response to parts (i) or (l), both of which were based on electricity and magnetism. Question 7 (f) and Question 11 (*Give one other major source of methane.*), both of which required simple recall in a short response, were frequently omitted or answered incorrectly. As is annually observed, candidate knowledge of electricity and magnetism and of organic chemistry is poor.

Other questions were more demanding, necessitating longer answers with greater detail for full marks. Examples include Question 1(g) (*State Boyle's law.*), Question 4(a) (*What is Brownian motion*?) and Question 7(e) (*Define electronegativity.*). Candidates were often unable to provide the detail and accuracy required for their answers to questions on definitions and laws. Ordinary level candidates also frequently omitted answers to question subparts like those mentioned above, revealing gaps in their learning.

Questions related to social, (Questions 1(f), 3 and 11), technological, (Questions 1(n) and 12(a)), and environmental (Question 11) aspects of physics and chemistry gave candidates opportunities to demonstrate a range of learning across different units of the syllabus and different contexts. Candidates' answers provided evidence of learning of applied aspects as well as theory of physics and chemistry.

Several question parts assessed comprehension of basic chemical principles and methods and ability to report experimental procedures, by asking for explanations or restatements of concepts in candidates' own words. These included Questions 3 (*Give one use for a curved mirror in a shop and explain why it is used instead of a plane mirror.*), Question 6(d) (*What property of an alpha-particle causes it to be deflected when it enters a magnetic field?*) and

Question 9(b) (*Will the addition of carbon dioxide gas increase or decrease the pH of the water? Give a reason for your answer.*).

Although Ordinary Level candidates are not required to write long answers to any questions, many explanations were awarded only partial marks because they lacked the necessary term or detail required and some answers were too brief or inaccurate or failed to give coherent explanations.

Application and Analysis

In general, few Ordinary level candidates demonstrated high achievement in their ability to apply and analyse learned material.

Calculations in Question 2 (mechanics) and Question 4 (thermometers) presented difficulties for most candidates, despite the structuring of the questions to help lead them through the steps of the calculations. Difficulties observed by examiners in answers to Question 2 included candidates failing to write down any equation of motion, candidates' inability to substitute the given data correctly into an equation of motion if one was given and candidates' inability to solve for the unknown in a substituted equation. In Question 4, candidates were unable to perform the sequence of mathematical instructions given in the question. Question 10 was very popular and reasonably well answered, but many candidates omitted the calculation part (e). In Question 12(a), most candidates experienced difficulties with calculations involving the molar concept. Those who attempted Question 6(a), 6(c) and 7(l) managed the momentum, Ohm's law and percentage mass calculations quite well, apparently benefitting from their expectation of calculations of these types based on past papers. There was evidence of candidates' ability to carry out learned procedures to solve some predicted types of mathematical problems, but poor achievement in solving relatively straightforward but less predictable problems. Many candidates appeared to make no use or limited use of the *Formulae and Tables* booklet.

Analysis based on prior learning was required in Question 6(c) (*Which lamp will glow brighter? Give a reason for your answer.*) and in Question 8 (*Why do* ${}^{6}_{3}Li$ *or* ${}^{7}_{3}Li$ *have the same electron configuration?*). Examiners reported that more candidates were able to demonstrate an ability to analyse where the question required drawing of conclusions and recognising patterns than in questions that involved analysis based on calculations.

Synthesis and Evaluation

While candidates had little difficulty when required to interpret completed ray diagrams (Question 1(d)), and readily comprehended given balanced equations (Questions 9(b) and 12(a)), they demonstrated poor attainment in the construction of ray diagrams (Question 3 and Question 6(b)) and in writing balanced equations (Question 7(i) and Question 10(d)). Candidates also struggled when required to draw the structure of molecules from formulae, e.g. Question 1(n) and 12(c). Thus there was indication of poor candidate achievement even at these rudimentary forms of synthesis.

Question 8 (*The relative atomic mass of lithium is 6.941. Which of its two isotopes,* ${}^{6}_{3}Li$ *or* ${}^{7}_{3}Li$*, exists in greater abundance? Give a reason for your answer*) was a relatively difficult question where evaluation of the significance of given data and justification of a conclusion were required yet most candidates were able to answer it well.

Indirect Assessment of Practical Skills

The general comments made earlier about indirect assessment of practical skills by means of a written examination paper apply also at Ordinary Level.

Question 7(g), (*Name the gas detected if it causes a chemical reaction with limewater as shown in Figure 15*) asked candidates about observations and conclusions made when carrying out experiments. Question 4(a) (*How can Brownian motion be demonstrated?*), which was well answered, required candidate knowledge of experimental procedures. Question 12(b) (*Why should this preparation only be carried out in a fume cupboard?*) required knowledge about how to perform experiments safely, but was not popular and was poorly answered by those who attempted it. In Questions 5(a) and 8(b), candidates were required to describe experimental procedures in a concise, accurate and comprehensible way. As Question 5 was not popular and those who attempted it had poor knowledge of capacitors, descriptions of procedures for discharging a capacitor were poor. Most candidates described rinsing the titration flask in Question 8(b) with deionised water but some also described further and incorrect rinsing with the solution it was to contain.

The examination also assessed the extent of engagement with and attainment of the key syllabus objectives of interpretation of experimental data and assessment of the accuracy of experimental results. In Question 4(b) and again in Question 10(e), candidates were required to interpret experimental results, apply rules or formulae (not provided) to the data supplied, perform calculations and manipulate units. As mentioned above, candidates who attempted Question 4 had difficulties with the calculations in part (b), but there was a better standard of answering in part (a) where no mathematical applications or analysis was required. While Question 10 was popular and reasonably well answered, many candidates omitted the volumetric analysis calculation in Question 10(e).

4. Conclusions

Candidates at both Higher and Ordinary levels were tested across the range of cognitive skills, on the reporting of experimental procedures, and on the interpretation of experimental data, as described above. At both Higher and Ordinary levels, only those who had demonstrated good engagement and attainment across all of those skills were awarded high grades.

Higher Level

Good knowledge and understanding of basic physics and chemistry facts and concepts was demonstrated by most candidates. Most candidates were able to attempt the calculations and other numerical analyses, but some candidate work indicated deficiencies that might be attributable to insufficient practice. Fewer candidates were awarded marks where generalisation or applying learned material in new situations was required. Diagrams produced by candidates, other than ray diagrams, were good.

Many candidates whose work was of a reasonable standard in some respects nonetheless displayed a lack of appreciation of the precision of language expected in answering. Some candidates' answers, such as statements of definitions and laws, lacked detail or accuracy. Application of theory was weaker than candidates' ability to perform calculations.

Electricity and magnetism and organic chemistry constitute a significant part of the syllabus but are significantly less popular than other topics at Higher level. Since the level of difficulty of the associated questions is similar to the level of difficulty of the other questions on the examination paper, it can be concluded that candidates do not possess the knowledge required to attempt them, presumably because they have not studied these topics and perhaps have not been taught them.

Many candidates attempted surplus questions – on average 0.85 surplus questions per candidate. This suggests reasonably good coverage of the syllabus (with the exceptions mentioned above) in school and in study. It also suggests that time does not represent an issue in completing the examination.

In general, candidates followed instructions correctly and presented their work in a satisfactory manner. Some candidates made poor use of the Formulae and Tables booklet in their examination.

Ordinary Level

Many candidates whose work was of a reasonable standard in some respects nonetheless displayed a lack of knowledge of basic physics and chemistry, such as laws and definitions. Many candidates had evidently placed insufficient emphasis on acquiring the fundamental knowledge of facts underlying the subject.

Analysis demonstrated by candidates in text-based responses ranged from good to poor but average performance in applications involving calculations or handling numerical data was weaker. Some routine calculations were not as well executed as might be expected, suggesting a lack of practice, and frequently candidates did not attempt them.

Electricity and magnetism and organic chemistry constitute a significant part of the syllabus but are significantly less popular than other topics at Ordinary level

In general, most candidates followed instructions correctly but a significant percentage of the cohort did not attempt the minimum number of questions. At Ordinary level it is not uncommon for candidates to answer fewer than the required number of questions in each section.

5. Recommendations to Teachers and Students

The comments below refer to both levels unless otherwise specified; the depth of detail and understanding required of candidates at Ordinary level is obviously less than that expected at Higher level.

5.1 Preparing for the examination

While students should learn and be able to recall key facts, laws and definitions accurately, understanding is essential to being able to engage fully with most questions. Appreciation of the interdependence of disparate pieces of information is crucial to high achievement.

Study time should be devoted to the key syllabus topics that underpin the subject, namely, mechanics (including gravitation), the properties of light and waves (including ray diagrams), atomic structure (paying particular attention to the distinction between shell, sub-level and orbital), the structure and trends in the periodic table and bonding. Students should practise writing explanations of complex concepts in their own words.

The topic electricity and magnetism constitutes a significant element of the discipline physics and, similarly, organic chemistry constitutes a significant element of the discipline chemistry. At both Higher and Ordinary levels, these two topics continue to be unpopular and poorly answered. Teachers' and students' attention is drawn to the fact that omission of the teaching and learning of electricity and magnetism and organic chemistry detracts from the usefulness of this subject as a preparation for third level science and engineering courses. Despite the choice in the examination paper, an appropriate amount of class time and study time should therefore be devoted to these topics.

Practical activities associated with topics specified in the syllabus should be carried out. When revising, students should give consideration to the *reasons* for experimental procedures and ensure that they understand the relevant theory in addition to memorising the arrangement of apparatus, reagents and methods.

Students should become familiar with the layout of the *Formulae and Tables* booklet and how it should be used in the examination.

Students should learn how to correctly round off decimals in a calculation and should include the correct units in all relevant answers.

The skills of interpreting and drawing graphs should be acquired by practice; these include manipulation of data prior to graphing, choice of scales, labelling axes, accurate plotting of points, drawing appropriate lines or curves with good distribution of points, finding slopes and giving the unit for the slope. Students should use graph paper and draw graphs that take up most of the page.

Appropriate use should be made of past examination questions as a guide to question style and scope.

- A review of past examination papers will show that certain facts and statements of laws and definitions feature frequently because of their fundamental importance in physics and in chemistry.
- Past examination papers can be used to practise problem-solving questions.
- Past examination papers can be used to practise the time-management skills required to do well in an examination.
- Past examination questions show the scope of questions that can be posed on a particular topic and can be used to encourage thorough revision. While there is some predictability of the theme of certain questions from year to year in the two sections of the *Physics and Chemistry* examination paper, the exact topic, emphasis or style of the component parts of any question is not predictable. For example Question 2 usually features mechanics but the topic could be, amongst others, accelerated linear motion, momentum, gravitational force or a combination of topics. Students should expect some material to be examined in a novel way every year and should study all sections of the syllabus and be prepared to answer any style of question on a given topic.

Marking schemes may be used to inform teachers and learners of solutions to problems and the main points of answers to previous examination questions. However, the notes to teachers and students at the front of the published marking schemes about their use should be carefully taken into consideration.

5.2 In the examination

Candidate understanding of physics and chemistry principles should be expressed using clear, concise and correct language. Some answering in examinations has insufficient detail.

At both Ordinary and Higher levels candidates are expected to elaborate sufficiently to include essential details in their answering in order to achieve full marks. Questions containing the cues ‘describe’ or ‘explain’ generally require an answer in the form of a sentence or sentences. Answers in the form of a phrase or a word are rarely sufficient for full marks in such questions.

It is recommended that candidates write in black or blue ink.

Where diagrams are required, large, clear, labelled diagrams should be included. Pencil is recommended for drawing diagrams and graphs.

Other diagrams may be and should be used to help describe concepts, but a diagram alone is not sufficient for full marks when the question requires a description or an explanation.

Candidates should label their answers to correspond with the question and present their work clearly in terms of legibility and layout.

Candidates should not attempt surplus questions at the expense of spending sufficient time on the questions that they anticipate will contribute to their final mark.

Ordinary level candidates in particular are encouraged to engage as fully as possible with the examination paper as follows:

- use the full three-hour examination time
- attempt at least three questions from each section
- consult the Formulae and Tables booklet throughout the examination
- understand that any attempts to answer parts of questions may earn marks and that partial marks are generally awarded for partially correct answers
- after writing an answer to a question that says ‘explain’ or ‘describe’, review it and see whether any further details could be added
- do not rush the completion or labelling of diagrams
- do not rush through calculations – marks are awarded for attempts that show partial knowledge or understanding and for work that is *part* of the solution.