Coimisiún na Scrúduithe Stáit

State Examinations Commission

LEAVING CERTIFICATE EXAMINATION 2013

PHYSICS

CHIEF EXAMINER'S REPORT

Contents

1. Introduction

1.1 Syllabus Structure

The current Leaving Certificate Physics syllabus was introduced in 2000 and first examined in 2002. The syllabus is designed to incorporate three components: pure physics (including principles, procedures and concepts), applications of physics and physics issues of concern to citizens. The first component has a 70 % weighting with the remaining 30 % allocated to the other two components in the ratio 3 to 1.

The syllabus is offered at two levels, Higher and Ordinary. Practical work is integral to both levels, with a number of mandatory student experiments listed at the end of each section of the syllabus – 22 in total at Ordinary level, 24 at Higher level. Differentiation between the levels is achieved in terms of depth of treatment and mathematical requirements, as well as structure and content: Higher level consists of the Ordinary level concepts, some additional concepts and either Option 1 (Particle Physics) or Option 2 (Applied Electricity).

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

1.2 Assessment Specification

The syllabus is assessed at both levels by means of a terminal written examination of three hours' duration. The examination is marked out of 400 marks.

The examination papers are divided into two sections – A and B.

Section A (30%) assesses the candidates in the experiments that are required to be completed by candidates during their course of study – three questions are to be answered from four given questions (40 marks each).

Section B (70%) assesses the candidates in general syllabus content, including principles, procedures, contexts, applications and practical work – five questions are to be answered from eight given questions (56 marks each).

Question 5 consists of ten short items, of which eight are to be answered. Question 12 consists of four parts or "half-questions", of which two are to be answered.

It has become the standard that Question 11 consists of a number of short items based on material contained within a short adapted passage of scientific writing. On the Higher level paper, the two optional topics are usually assessed in Question 10, as well as in item (*j*) of Question 5.

There are no compulsory questions.

1.3 Participation Trends

Table 1 gives the overall participation rates of candidates in Leaving Certificate Physics for the last five years. There has been no significant change in the percentage of the total Leaving Certificate cohort being examined in the subject over this time. (LCA candidature is excluded from the totals.)

Year	Physics Candidature	Total Leaving Certificate Candidature	Physics as % of Total
2009	6924	54196	12.8
2010	6745	54481	12.4
2011	6516	54341	12.0
2012	6373	52589	12.1
2013	6448	52767	12.2

Table 1: Participation in Leaving Certificate Physics, 2009 to 2012

There has however been a steady decrease in the number of Leaving Certificate students taking Physics since the first examination of the current syllabus in 2002. In that year 8651 candidates were assessed in the subject, 14.7 % of the total candidature at the time.

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

Year	Total Physics Candidature	Number at Higher level	Number at Ordinary level	% Higher	% Ordinary
2009	6924	4694	2230	67.8	32.2
2010	6745	4877	1868	72.3	27.7
2011	6516	4782	1734	73.4	26.6
2012	6373	4753	1620	74.6	25.4
2013	6448	4832	1616	74.9	25.1

Table 2: Number and percentage of candidates at each level, 2009 to 2013

Over the last five years there has been a steady decline in the number of Physics students opting for assessment at Ordinary level.

The gender breakdowns for Physics participation over the last five years at Higher level and Ordinary level are given in **Table 3** and **Table 4** respectively.

Year	Total Higher level	Female Candidates	Male Candidates	Female as % of total	Male as % of total
2009	4694	1296	3398	27.6	72.4
2010	4877	1380	3497	28.3	71.7
2011	4782	1320	3462	27.6	72.4
2012	4753	1279	3474	26.9	73.1
2013	4832	1243	3589	25.7	74.3

Table 3: Gender composition of Higher level cohort, 2009 to 2013

Year	Total Ordinary level	Female Candidates	Male Candidates	Female as % of total	Male as % of total
2009	2230	375	1855	16.8	83.2
2010	1868	309	1559	16.5	83.5
2011	1734	298	1436	17.2	82.8
2012	1620	302	1318	18.6	81.4
2013	1616	278	1338	17.2	82.8

Table 4: Gender composition of Ordinary level cohort, 2009 to 2013

While these tables indicate that the gender breakdown has been relatively stable over the last five years, some small changes have occurred over a longer period. For comparison, in 2002 – the first year the current syllabus was examined – the HL female candidature was 1769 (29.5 % of the total HL candidature for the subject) while the HL male candidature was 4228 (70.5 % of the total HL candidature). In 2002 the OL female candidature was 377 (14.2 % of the total OL candidature for the subject) while the OL male candidature was 2287 (85.8 % of the total OL candidature). Over this longer period there does appear to have been a general increase in the percentage of female candidates opting to be assessed at Ordinary level and a concomitant general decrease in the percentage of female candidates opting to be assessed at Higher level.

2. Performance of Candidates

2.1 Higher Level

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
2009	20.5	29.1	23.3	72.9	19.3	5.1	2.4	0.3	7.8
2010	20.8	28.8	23.7	73.3	19.8	5.2	1.4	0.4	7.0
2011	20.2	25.9	26.9	73.0	18.9	5.8	1.7	0.4	7.9
2012	19.9	29.7	24.9	74.5	18.1	5.6	1.3	0.4	7.3
2013	20.4	29.0	23.9	73.3	19.5	5.0	1.8	0.4	7.2

Table 5: Percentage of candidates awarded each lettered grade in Higher level Physics, 2009 to 2013

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2009	10.6	9.9	10.1	10.1	8.9	8.6	8.6	6.1	7.2	5.8	6.3	5.1	2.4	0.3
2010	8.8	12.0	8.4	10.8	9.6	9.2	9.4	5.1	8.8	6.0	5.0	5.2	1.4	0.4
2011	8.9	11.3	7.0	9.3	9.5	9.0	8.8	9.1	7.4	5.6	5.9	5.9	1.7	0.4
2012	9.7	10.1	10.3	9.7	9.8	8.8	8.4	7.8	6.7	5.4	5.9	5.6	1.3	0.4
2013	10.1	10.3	9.9	9.8	9.3	8.2	8.1	7.6	7.0	5.8	6.7	5.0	1.8	0.4

Table 6: Percentage of candidates awarded each sub-grade in Higher level Physics, 2009 to 2013

These results show that there has been no significant change in the results in Higher level Physics over the last five years. For example, in each of the last five years, 20.4 ± 0.5 % of the candidature achieved an A grade.

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
2009	11.0	13.0	10.5	10.8	9.6	8.6	8.2	5.2	7.9	5.5	4.2	4.0	1.5	0.2
2010	8.6	15.0	9.4	11.4	9.6	9.3	7.9	4.9	8.0	4.4	4.9	4.9	1.4	0.4
2011	8.4	11.6	8.1	9.9	9.5	10.1	9.0	9.8	7.2	4.5	5.4	5.3	0.8	0.4
2012	8.5	10.0	10.8	8.8	11.8	9.9	7.7	7.8	6.5	4.7	6.0	6.6	0.8	0.1
2013	10.3	10.0	10.7	11.3	9.2	8.4	8.6	7.2	7.8	6.0	5.1	3.6	1.4	0.3

Table 7: Percentage of female candidates awarded each sub-grade in Higher level Physics, 2009 to 2013

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2009	10.5	8.7	10.0	9.9	8.6	8.6	8.8	6.4	7.0	5.9	7.2	5.5	2.7	0.4
2010	8.8	10.9	8.1	10.5	9.6	9.2	9.9	5.2	9.2	6.6	5.0	5.3	1.3	0.4
2011	9.1	11.1	6.6	9.1	9.5	8.6	8.7	8.8	7.5	6.1	6.2	6.2	2.1	0.5
2012	10.2	10.1	10.1	10.0	9.1	8.4	8.7	7.8	6.8	5.7	5.8	5.3	1.6	0.5
2013	10.1	10.4	9.6	9.3	9.3	8.1	7.9	7.7	6.8	5.8	7.2	5.4	2.0	0.4

Table 8: Percentage of male candidates awarded each sub-grade in Higher level Physics, 2009 to 2013

There is no evidence of any significant change in pattern with regard to the breakdown of these results by gender over the last five years.

2.2 Ordinary Level

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
2009	17.0	32.7	24.6	74.3	15.7	5.7	3.3	1.0	10.0
2010	17.4	31.6	23.8	72.8	15.6	5.8	4.2	1.6	11.6
2011	14.8	29.5	27.9	72.3	16.6	7.6	3.2	0.4	11.2
2012	15.2	31.6	25.3	72.1	17.2	6.4	3.2	1.0	10.7
2013	14.5	31.2	27.0	72.8	18.0	5.4	2.8	1.1	9.2

Table 9: Percentage of candidates awarded each lettered grade in Ordinary level Physics, 2009 to 2013

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2009	5.7	11.3	9.3	9.9	13.5	8.2	8.2	8.2	5.4	4.5	5.8	5.7	3.3	1.0
2010	8.0	9.4	9.0	9.8	12.8	7.5	7.2	9.1	3.9	4.4	7.3	5.8	4.2	1.6
2011	6.0	8.8	6.2	10.6	12.7	6.7	10.3	10.9	4.4	6.2	5.9	7.6	3.2	0.4
2012	5.3	9.9	8.3	10.5	12.8	8.1	8.6	6.6	4.5	6.4	6.4	6.4	3.2	1.0
2013	6.0	8.5	7.4	11.6	12.3	8.9	8.0	10.0	4.2	5.8	8.0	5.4	2.8	1.1

Table 10: Percentage of candidates awarded each sub-grade in Ordinary level Physics, 2009 to 2013

These results show minor fluctuations in grade and sub-grade percentages at Ordinary level Physics over the last five years. For example, in each of the last five years, 31.1 ± 1.6 % of the candidature achieved a B grade. Such minor fluctuations are not unexpected with a relatively small candidature.

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
2009	10.9	12.0	8.5	10.9	16.3	6.9	7.2	5.9	6.4	4.0	3.5	4.5	2.7	0.3
2010	13.9	9.1	7.8	9.1	15.9	7.8	6.8	10.4	1.9	3.9	4.9	3.9	3.9	1.0
2011	10.1	12.4	5.7	11.1	12.4	5.0	10.1	9.7	4.7	4.7	5.7	6.7	1.3	0.3
2012	8.9	11.3	8.6	8.9	10.6	10.6	7.9	8.6	3.0	5.6	4.6	5.6	5.0	0.7
2013	10.4	9.4	9.0	14.7	14.1	6.8	5.8	9.0	3.6	3.2	5.8	4.0	3.6	0.4

Table 11: Percentage of female candidates awarded each sub-grade in Ordinary level Physics, 2009 to 2013

Year	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
2009	4.7	11.2	9.4	9.7	13.0	8.4	8.4	8.7	5.2	4.6	6.3	5.9	3.4	1.1
2010	6.9	9.4	9.3	9.9	12.2	7.4	7.2	8.9	4.3	4.6	7.8	6.2	4.2	1.7
2011	5.2	8.1	6.3	10.5	12.7	7.0	10.4	11.1	4.4	6.5	5.9	7.7	3.6	0.4
2012	4.5	9.6	8.2	10.8	13.4	7.5	8.8	8.6	4.9	6.5	6.8	6.6	2.8	1.1
2013	5.1	8.4	7.0	10.9	11.9	9.3	8.5	10.2	4.3	6.4	8.4	5.7	2.6	1.2

Table 12: Percentage of male candidates awarded each sub-grade in Ordinary level Physics, 2009 to 2013

There is consistent evidence that a larger percentage of the female candidature achieves an A grade, relative to the male candidature.

3. Analysis of Candidate Performance

3.1 General Commentary on Engagement and Performance

Table 13 is a summary based on an analysis of a random selection of 320 scripts (≈ 6.6% of all scripts) from Higher level Physics candidates in 2013.

Q	Response Rate (%)	Response Ranking (Section)	Response Ranking (Examination)	Mean Mark	Mean Mark (%)	Mark Ranking (Section)	Mark Ranking (Examination)	Topic
1	87.2%	1	2	26.3	65.8%	4	5	Laws of Equilibrium
2	79.7%	3	5	32.7	81.8%	1	1	Boyle's Law
3	84.7%	2	3	31.8	79.5%	2	2	Concave Mirror
4	35.6%	4	11	30.3	75.8%	3	3	Current & Voltage
5	91.6%	1	1	34.6	61.8%	4	8	Miscellaneous
6	67.2%	4	7	32.8	58.6%	7	11	ISS & Gravitation
7	53.8%	7	10	29.5	52.7%	8	12	Sound Waves & Resonance
8	34.4%	8	12	33.2	59.3%	6	10	Current Electricity
9	60.9%	5	8	35.0	62.5%	3	7	Radioactivity
10	70.4%	3	6	38.5	68.8%	1	4	Options
11	58.8%	6	9	33.9	60.5%	5	9	Seismic Waves
12	81.9%	2	4	35.3	63.0%	2	6	Miscellaneous
10a	68.8%	1	-	38.7	69.1%	1	-	Particle Accelerators
10b	1.6%	2	-	28.4	50.7%	2	-	Moving Coil Galvanometer
12a	62.5%	1	-	17.7	63.2%	2	-	Conservation of Energy
12b	47.5%	2	-	15.0	53.6%	4	-	Dispersion of Light
12c	47.5%	2	-	16.7	59.6%	3	-	Coulomb's Law
12d	41.3%	4	-	19.8	70.7%	1	-	Thermometric Properties

Table 13: Popularity of and average mark for each question, Higher level Physics 2013

In the Higher Level examination, the mean mark per question in Section A was 30.3 marks (75.7%) with a standard deviation of 2.4 marks (6.1%). The most popular question in the section (Question 1) was the least well answered question in the section.

In Section B the mean mark per question was 34.1 marks (60.9%) with a standard deviation of 2.4 marks (4.3%). The best answered question was Question 10. As in all but one of the previous Higher level examinations of this syllabus, Question 10 allowed candidates to answer either Question 10a on Option 1 (Particle Physics) or Question 10b on Option 2 (Applied Electricity). As in previous examinations, the proportion of those answering the Particle Physics option was significantly greater than those answering the Applied Electricity option; in 2013 almost 98% of those who answered Question 10 chose the Particle Physics option. The mean mark achieved by those students who did answer Question 10b was 50.7%, the lowest mark for any question (or "half-question") in any section on this year's examination. It seems that a huge majority of candidates are either not engaging with Option 2 during their studies or are choosing not to answer examination questions on this topic.

Of the four "half questions" that constitute Question 12, the significantly most popular one was Question 12a, on mechanics. The most popular question in Section A was also in the area of mechanics (Question 1, on the Laws of Equilibrium). In Section B, excluding the three questions with internal choice (Questions 5, 10 and 12), the mechanics question (Question 6, on gravitation) was also the most popular. Yet despite this popularity of mechanics questions among candidates, these questions were not necessarily well answered: Question 1 was the least well answered question within Section A and Question 6 was the second least well answered question within Section B.

Questions 4 and 8 were the least popular questions with candidates, with both questions attempted by approximately a third of candidates only. This exemplifies candidates' lack of engagement with topics within the area of electricity.

Table 14 is a summary based on an analysis of a random selection of 160 scripts (≈ 9.9% of all scripts) from Ordinary level Physics candidates in 2013.

Q	Response Rate (%)	Response Ranking (Section)	Response Ranking (Examination)	Mean Mark	Mean Mark (%)	Mark Ranking (Section)	Mark Ranking (Examination)	Topic
1	90.6%	1	2	25.6	63.9%	4	6	Acceleration due to Gravity
2	82.5%	2	4	31.9	79.7%	1	1	Specific Latent Heat of Fusion
3	60.6%	4	9	27.7	69.3%	3	3	Refractive Index
4	63.1%	3	8	29.7	74.3%	2	2	Resistance of a Thermistor
5	92.5%	1	1	36.9	65.9%	1	4	Miscellaneous
6	67.5%	5	7	28.0	50.1%	6	10	Momentum & Force
7	58.8%	6	10	27.2	48.5%	7	11	Sound Waves
8	45.0%	8	12	20.8	37.2%	8	12	Electricity & Magnetism
9	73.8%	4	6	34.5	61.6%	4	8	Heat Transfer
10	49.4%	7	11	30.1	53.7%	5	9	X-rays
11	83.8%	2	3	35.0	62.5%	3	7	Transmission of Electricity
12	78.8%	3	5	36.2	64.7%	2	5	Miscellaneous
12a	45.0%	2	-	17.9	64.1%	3	-	Pressure
12b	53.1%	1	-	18.7	66.8%	1	-	Dispersion of Light
12c	33.1%	4	-	16.2	57.8%	4	-	Electroscope
12d	43.1%	3	-	18.5	65.9%	2	-	Nuclear Fission

Table 14: Popularity of and average mark for each question, Ordinary level Physics 2013

In the Ordinary level examination, the mean mark per question in Section A was 28.7 marks (71.8%) with a standard deviation of 2.3 marks (5.8%). As in the Higher level examination, the most popular question in the section was Question 1, which was again based on an experiment from within the mechanics section of the syllabus. At this level too, this mechanics experiment question was the least well answered question in the section.

In Section B the mean mark per question was 31.1 marks (55.5%) with a standard deviation of 5.2 marks (9.3%). The best answered question in the section was Question 5 (which was also the most popular question on the examination paper), followed by Questions 12 and 11.

Of the four “half questions” that constitute Question 12, the least popular and least well answered was Question 12c, on a topic within the area of electricity. Question 8, also an electricity question, was the least popular and least well answered question on the examination paper. This further exemplifies candidates’ lack of engagement with the section of the syllabus on electricity, as was also the case for the Higher level candidature.

3.2 Meeting of Specific Syllabus Objectives

The Physics Syllabus identifies five specific categories of objectives; these are common to both levels.

The categories of syllabus objectives are:

1. Knowledge
2. Understanding
3. Skills
4. Competence
5. Attitudes

The syllabus document states that the subject “will be assessed under the headings knowledge, understanding, skills and competence. The attitudinal objectives will be assessed where feasible.”

The success of candidates in meeting each of the syllabus objectives is examined by an analysis of the standard of candidate responses to specific parts of questions on both examination papers. Such analysis is made possible by information captured by examiners during their work.

3.2.1 Knowledge

Most candidates demonstrated good levels of achievement when asked to recall basic physical principles, terminology, facts and methods. At both levels, this knowledge is fundamental to the success of candidates in the examination.

At Ordinary level, basic knowledge questions were usually very well answered. Examples of such questions included the recalling of the name of the scientist associated with the discovery of the structure of the atom (Question 5c), the definition of momentum and force and the statement of the principle of conservation of energy (Question 6), the naming of the units of current (Question 8) and the definition of pressure (Question 12a).

At Higher level, while students performed well when asked to recall standard pieces of knowledge, such as the name of a device used to vary the potential difference across a conductor (Question 4), or Newton’s law of universal gravitation (Question 6), they performed less well when asked to recall slightly less standard facts, such as the definition of the becquerel (Question 9) or the coulomb (Question 12c). It is recommended that candidates give due attention to the definition of fundamental physical units.

It was noted that Higher level candidates showed an improvement over previous years in their ability to recall the nuclear equation relevant to the Cockroft and Walton experiment (Question 10a).

3.2.2 Understanding

While the syllabus objectives do not make reference to some of the higher order cognitive skills, the capacity to engage in such forms of cognition is encapsulated by the notion of depth of understanding. The syllabus indicates that understanding includes the capacity to solve problems and engage in various forms of higher order thinking, particularly when taken in combination with the objectives specified under "skills" and "competence".

Questions which assess understanding are ones in which many Higher level candidates usually demonstrate reasonably high levels of achievement, but which can cause significant difficulties for many Ordinary level candidates.

Higher level candidates, for example, showed a good understanding of resonance and how it could be demonstrated in the laboratory (Question 7), of the forces acting on an object at rest (Question 11c) and of the application of the principle of conservation of energy (Question 12a); they showed little understanding, however, of why occupants of the International Space Station experience apparent weightlessness (Question 6vi) – with many vague answers appearing here – or of how charged particles generated an electric field (Question 12c). Questions which were novel or dissimilar to those typically appearing in the commonly used second-level educational resources proved to be challenging for all but the highest achieving candidates. Such questions test deeper levels of understanding, as they require candidates to display understanding of relationships between concepts and to apply their understanding in unfamiliar situations.

Similarly, while Ordinary level candidates demonstrated a clear understanding of the principles behind a standard, practiced experimental technique, such as that to measure the acceleration due to gravity (Question 1), less standard questions proved more problematic. Examples of the latter include Question 6vi (where candidates showed poor ability to determine the physical concepts involved in the use of a driver's airbag and to apply their understanding of these concepts to this context), Question 7iii (where candidates had difficulties in demonstrating an understanding of how interference occurs in waves) and Question 10vi (where many candidates did not evidence an understanding of the purpose of high voltage across an X-ray tube).

3.2.3 Skills

In the current Physics syllabus, the skills objective refers in the main to candidates' abilities to measure physical quantities, use scientific equipment appropriately, follow instructions, work safely in a laboratory, use experimental data appropriately and – in the case of the Higher level students – plan, design, analyse and evaluate experiments. While a number of these skills cannot be directly assessed in a written examination, their indirect assessment is primarily achieved in Section A at both levels. (The appropriate and safe use of laboratory equipment is assessed, for example, by asking candidates to describe – by text and/or diagram – the arrangement of apparatus for a particular experiment and by asking candidates to state or explain specific safety precautions.)

Ordinary level candidates showed excellent levels of response to questions designed to assess their experimental skills. Questions 2, 3 and 4 were, statistically, the three best answered questions on the examination paper. Candidates showed excellent skills in explaining the proper use of equipment, as manifested in their drawings of experimental apparatus set up to take appropriate measurements. Candidates showed limited skills however in the manipulation and use of experimental data. This was most especially true in Question 1 where many students struggled to explain how they might calculate a value for g from their measurements, with many candidates supplying irrelevant and inappropriate formulae for g, such as some of those provided on page 56 of the *Formulae and Tables* booklet.

At Higher level, Questions 2, 3 and 4 were also the three best answered questions on the examination paper. In Question 2, on Boyle's Law, candidates showed evidence not only of the standard skills of appropriate arrangement and use of apparatus, but also – as part of a novel question format – evidence of knowledge of appropriate units for the quantities measured. In Question 3, on determining the focal length of a concave mirror, candidates again showed evidence of the skills required to correctly use the relevant apparatus. However in answering the final part of the question – which asked how a student could have found an approximate value for the focal length of the mirror before starting the experiment – many candidates neglected to mention the concept of *measuring* the correct distance.

At Higher level it is usual for some of the questions in Section A to require candidates to draw appropriate graphs. In the 2013 examination, Questions 2 and 4 explicitly required the candidates to draw appropriate graphs; those attempting Question 3 were also able to use a graphical method if they chose to do so. It is commendable that almost all candidates use graph paper when answering graphical questions in Section A. Students and teachers are asked to note, however, that not only are marks lost for unlabeled or incorrectly labelled axes, but also for incorrectly plotted points, for poor distribution of the line or curve about points and for inappropriate scales. Such inappropriate scales include those where the overall dimensions of the graph are unacceptably small and those where each large unit (or "box") on the scale is equivalent to a number not easily divisible by factors of 10.

3.2.4 Competence

The examinations assess the levels of candidate competence in solving numerical problems, explaining the science behind observations and phenomena, presenting information in diagrammatic and graphical form and suggesting scientific explanation for familiar and unfamiliar facts. The assessment of such competencies allows for a significant degree of discrimination between candidates of high, moderate and low levels of achievement in the subject.

At Higher level, most candidates demonstrated the competence to use standard physical formulae in familiar contexts to solve numerical problems. A typical example of such a question is in Question 3 where candidates are asked to use all of the data provided to calculate a value for the focal length. (Most candidates used each pair of *u* and *v* values to calculate a value for *f* and then determined the mean; some candidates determined a mean from the intercepts of line-of-best-fit on an appropriate graph; a common mistake was to calculate mean values for *u* and *v* to determine a single value for *f*.)

However, the ability of candidates to solve numerical problems in an unfamiliar context (such as the calculation of the angular and linear velocities of the International Space Station in Question 6) or to use familiar formulae in novel ways (such as the calculation of the mass of the Earth, also in Question 6) was found to be much less prevalent. The part of Question 7 where candidates were asked to use appropriate diagrams to show how overtones are produced in an open pipe was also poorly answered, with apparent confusion between the composition of standing waves in open and closed pipes; there was also a general failure to correctly label the diagrams drawn in answering this question.

In Question 9, it was noted that candidates generally showed a greater ability to determine the correct nuclear equation for the beta-decay of an isotope than in previous years. However, the widespread failure later in the question to convert from years to seconds in the calculation of decay constant (and, hence, number of active caesium–137 atoms present) was disappointing.

The provision of the *Formulae and Tables* booklet to all examination candidates has significantly changed how students approach the subject. There is no longer the need to learn physical formulae by rote, as may have happened previously. However, it is to be noted that many candidates evidence a lack of familiarity with correct use of the booklet. In some cases, candidates appear to copy into their answer booklet every formula that might possibly be relevant to the question asked. Such a “scattershot” approach to choosing the correct relevant formula will not generally meet with any success. There is consistent evidence of candidates inserting the data given in a question into the correct formula, but without converting the data to the correct SI units, as mentioned above in relation to Question 9. There is also evidence of some candidates not knowing what physical quantities are represented by the various symbols in the formulae. The clearest example of this last phenomenon was found in Question 7, where candidates were asked to determine the tension in a wire, usually denoted as *T*. Formulae found in candidate responses to this question included those for the period, *T*, of satellite or periodic motion, for the torque, *T*, of a couple and even for the thrust, *T*, on an immersed plane surface.

So, while some may argue that the provision of the *Formulae and Tables* booklet makes certain questions easier than heretofore, the reality is that it shifts the emphasis of the task from recalling information to the skills involved in knowing that there is a relevant formula, identifying what one is required, knowing where to find it, understanding it, and being able to apply it. This is an important skill in an age where information is constantly available close at hand, and the difficulties described here indicate that it is far from trivial.

The levels of competence required at Ordinary level are significantly less than those required at Higher level. Ordinary level candidates show evidence of good ability to present information in a graphical form, as in Question 4. When they are asked to solve numerical problems, they demonstrate a reasonable ability to carry out calculations involving standard formulae. Examples of this include the pressure calculation using $p = h\rho g$ in Question 12a and the energy calculation using $E = mc\Delta\theta$ in Question 7vii, although many failed to convert three minutes to 180 seconds in this latter case. Candidates generally show lower levels of ability in performing less standard calculations, such as the subsequent power rating calculation in Question 7viii.

3.2.5 Attitude

The syllabus objectives which are least open to direct assessment are those relating to attitude. The type of "appreciation" of physics described in the syllabus can only occur with knowledge and understanding, and it is these that are more directly tested for in the examination Most of the questions which seek to do this are those requiring knowledge of the applications of physics, of the relationships between physics and technology and of the contributions of physics to society.

At Ordinary level, candidate awareness of how physics manifests itself in the societal and technological landscapes are best assessed in Question 11, where candidates answer a number of questions contextualised by a piece of scientific writing aimed at an appropriate level. In 2013, the text was adapted from a publication by *Eirgrid* on the subject of the National Grid. Parts a, b, d and f were found to be exceedingly well answered. Question 12d tested candidates' engagement with the physics and technology of nuclear fission power stations. Part v, which asked for a hazard of nuclear reactors, was particularly well answered, perhaps as a result of student interest in historical and contemporary examples of problems related to nuclear power, such as those at Chernobyl, Sellafield and Fukushima.

Question 9 of the Higher level examination paper made specific reference to the 1986 accident at Chernobyl. STS (science, technology and society), along with candidate understanding of the applications of physics in the everyday world, are also assessed in Question 5d (storage heaters) and 5i (fossil fuels and nuclear power), both of which were answered quite poorly. Other questions which related physics to modern technology included Question 8 (mobile phone chargers) and Question 11 (seismometers). In both these cases candidates showed some difficulties in applying their knowledge of physics to complex practical contexts.

4. Conclusions

- The overall standard of answering was similar to previous years' standards, at both levels.
- Examiners noted that many candidates attempted extra questions, especially at Higher level.
- Candidates showed strength in answering Section A on the required experimental work. The responses of some candidates, however, showed a lack of specificity and detail.
- Very few candidates used data-logging methods in answering questions within Section A.
- Candidates showed strength in answering standard questions on definitions and statements of physical principles and laws.
- Candidates showed a preference for answering questions on topics within mechanics, although the standard of answers in mechanics questions was not noticeably higher than the standard for other topics, and was in some cases of a lower standard.
- Candidates at both levels showed a general lack of engagement with questions on topics within the syllabus section on electricity.
- Candidates at Higher level showed a clear and unambiguous preference for Option 1: Particle Physics over Option 2: Applied Electricity. This is in line with previous years' examinations.
- Candidates appeared to have difficulty applying knowledge of physical principles and laws to practical contexts, whether familiar or unfamiliar.
- Many candidates show a lack of familiarity with correct use of the *Formulae and Tables* booklet and an inability to connect the relevant symbols with the correct physical variables.
- Candidates appeared to have difficulty in expressing their understanding of physical principles and applications in clear and unambiguous language, often leading to at best partial credit for candidate responses.
- Many candidates showed a poor knowledge of the units of physical quantities and were not able to manipulate these units when carrying out calculations.
- Candidates who performed poorly showed at best a partial understanding of physical principles, a poor ability to manipulate formulae and a weakness in solving numerical problems. Some poorly performing candidates did not attempt the required number of questions.
- Candidates who performed well showed a high level of achievement on each of the syllabus objectives and showed a clear ability to
    - provide definitions and statements of physical principles and laws
    - explain the details of mandatory and demonstration experiments
    - apply physical principles to everyday life and technology
    - derive and manipulate physical formulae
    - solve numerical problems
    - draw and use graphical representations of data
    - give logical and coherent explanations of physical phenomena.

5. Recommendations to Teachers and Students

- Students should be encouraged to approach the subject of physics not as a body of disparate pieces of information to be memorised, but rather as a series of interdependent and mutually reinforcing principles to be understood so that they may be applied to a wide variety of contexts.
- Teachers and students are encouraged to engage with a wide variety of teaching and learning methodologies, with particular emphases on hands-on experimental work (including experiments supplemental to those prescribed on the course), the use of ICT and dynamic computer simulations of physical phenomena and the constant linking of syllabus material to common applications of physics.
- Teachers and students should be encouraged to engage fully with all parts of the syllabus, with the exception, at Higher level, of one or other of the Options. The omission of any part of the course severely limits students' ability to achieve a satisfactory grade in the examination. Such omissions will significantly restrict student choice. This is especially evident when considering the synoptic structure of a number of questions, where question elements are drawn from a number of topics across the syllabus.
- It is recommended that students give due regard to precision of expression and clarity of textual and diagrammatic responses to questions.
- It is recommended that candidates' responses should be in black or blue ink wherever possible. The use of red, green or purple ink is not recommended as these colours are used by examiners in assessing candidates' work.
- Teachers and students should give due attention to the development of the skills involved in drawing of appropriate graphs, in particular when graphing experimental data. Relevant skills include: proper manipulation of data prior to graphing; choice of scales; labelling of axes; correct plotting of points; correct selection and drawing of appropriate lines or curves, with a good distribution about the data; use of lines or curves of best fit, including interpolation, extrapolation and the calculation and use of slopes; understanding the correct units of slopes.
- Students are recommended to draw clear, unambiguous and reasonably sized diagrams, and to label <u>all</u> diagrams appropriately.
- Students attempting extra questions in the examination are reminded that, while all candidate responses to questions will be marked (with the lowest scoring supplementary question(s) excluded in each section), it is apparent from a scrutiny of answer booklets that *some* candidates might have been better served by the candidate spending more time reviewing and clarifying their answers to eight questions rather than attempting nine or more.
- All candidates are encouraged to attempt at least eight questions. In particular, Ordinary level candidates are advised to use all of the time available to them and are reminded that

while partially valid answers may merit some marks, unanswered question or parts of questions can never merit any.

- Question 5 is the most popular question at both levels; it is recommended that candidates answering this question should attempt all ten parts if possible. (The eight highest scoring parts will be counted in determining the overall mark for the question.)
- Teachers and students are encouraged to use the *Formulae and Tables* booklet in their everyday teaching and learning, so that, by the time of their examination, students will have appropriate familiarity with the location and use of formulae and data contained in the booklet. While the provision of this booklet has meant that candidates are no longer required to recall many physical formulae, candidates are required to select the correct formula from the booklet and to understand that formula so that they may apply it in the appropriate context.
- The use of previous examination papers and marking schemes may assist students in familiarising themselves with paper structure, question styles and answer guidelines. However, teachers and students are reminded that – as noted at the front of SEC marking schemes – assumptions about future marking schemes on the basis of past schemes should be avoided, as the details of the marking of a particular type of question may change in the context of the contribution of that question to the overall examination in a given year. It is also to be noted that in many instances the marking scheme will contain only key words – words which must appear in the correct context in the candidates' answers to merit marks. It is also to be noted that the descriptions, methods and definitions in the scheme are not exhaustive and that alternative valid answers are acceptable.
- Students should be encouraged to locate physics within the context of their everyday experiences and to relate their learning of physics to their learning of other subjects, with particular emphases on other science, technology and mathematical subjects.
- Students should be encouraged to apply their physics learning to areas of public discussion, ethical debate and general citizenship.