May 2015 subject reports

Physics Timezone 2

To protect the integrity of the examinations, increasing use is being made of timezone variants of examination papers. By using variants of the same examination paper candidates in one part of the world will not always be taking the same examination paper as candidates in other parts of the world. A rigorous process is applied to ensure that the papers are comparable in terms of difficulty and syllabus coverage, and measures are taken to guarantee that the same grading standards are applied to candidates' scripts for the different versions of the examination papers. For the May 2015 examination session the IB has produced timezone variants of Physics HL and SL papers 1, 2 and 3.

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0–17	18–32	33–44	45–53	54–63	64–72	73–100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0–16	17–30	31–42	43–52	53–61	62–71	72–100

Higher and standard level internal assessment

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0–8	9–16	17–22	23–27	28–33	34–38	39–48

The range and suitability of the work submitted

The scope and range of practical work was impressive. Most schools had a comprehensive practical program and teachers were assessing appropriate high school level investigations. The quality of most candidate's work was good, and even schools where the candidates were academically weak still demonstrated enthusiasm and determinism with their investigations. The majority of candidate reports were word-processed and graphs were drawn using graphing programs. There was a good use of ICT in various investigations. Overall, the majority of schools are doing an exemplary job of implementing a practical programme.

Candidate performance against each criterion

Design (D)

Most teacher's prompts were in line for appropriate Design investigations. There were many examples of tried and true prompts, like the cantilever and ball bounce investigations. There were also genuinely new investigations where the teacher's prompt was non-directive, such as investigate something you like. Weakness arrived only in a few cases where quantities could not be quantified, like bouncing a ball off different surfaces (where a histogram was used instead of a linear graph) or where the teacher assessed Design for a well-established investigation, like Boyle's law or the speed of sound using a resonant tube filled with water.

Data Collection and Presentation (DCP)

As expected, candidates often earn high marks under the DCP criterion. Raw data always has uncertainty, if no other value than least count, and candidates should easily address expectation. Moderators are looking for a brief statement to why the candidate gives a particular value of uncertainty, and this holds for both raw and processed data. When assessing DCP candidates are expected to have produced graphs. Graphs allow the detection of outliers and systematic errors in the data trend line. There were some cases where graphs would have been relevant but candidates just made calculations. There were a few cases of graphs without error bars and without the determination of the gradient uncertainty. Again, candidates easily achieve these if they realize the appreciation of uncertainties is expected. Examples like this cannot earn complete for DCP aspect 3. Scatter graphs should graph best-fit lines (linear or curved) and not point-to-point lines. Finally, there were a few cases of scatter graphs that clearly described curves, but candidates forced a linear line. Teachers should guide candidates away from this.

Conclusion and Evaluation (CE)

This continues to be the most difficult criterion for candidates. Under CE aspect 1, candidates need to think beyond the given data in order to provide a justification based on a reasonable interpretation of the data. Such insight might look at the extremes of the data range, the origin of the graph, the *y*-intercept, for some physical meaning. Candidates might even give the overall relationship some physical interpretation (perhaps a hypothesis). If candidates perform a standard and well-established physics lab, and CE is assessed, then it is unlikely that they can really come up with weaknesses or improvements. CE is also best assessed when candidates have designed and performed the investigation themselves.

Recommendations for the teaching of future candidates

The November 2015 examination session will be the last session with the current IA criteria. The May 2016 examination session will include new internal assessment criteria and expectations. The current candidate knowledge of design, data collection and analysis, graphing and error propagation, and conclusion and evaluation will be of great help with the new IA. It is recommended that throughout the course the teacher can enrich candidate's experience by suggesting possible extensions to this or that classroom investigation. Doing so can help encourage candidates to think about their own IA. It is also recommended that teachers clarify and enforce the idea of academic honesty. The Group 4 Project will be a good place to teach research skills as well.

Further comments

The current IA system has become all too familiar to teachers, and many are cutting corners with just two investigations that assess each criterion. The time has come for a new approach to IA, and in May 2016 new criteria will be used. Teachers and candidates need to plan well ahead for the expectations and requirements of the new IA.

There were some alarming cases of candidates earning zero points under all three IA criteria. Even when this is the case, teachers must submit the work that earned zeros. There was a case where the teacher awarded zero under Design but was moderated up.

Higher and standard level paper one

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0–10	11–15	16–20	21–23	24–27	28–30	31–40

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0–7	8–10	11–14	15–17	18–19	20–22	23–30

General comments

A proportion of questions are common to the SL and HL papers, with the additional questions in HL providing further syllabus coverage.

Every year there are occasional comments from teachers that either paper 1 or paper 2 is unbalanced in terms of syllabus cover. It should be noted, however, that these two papers *together* aim to provide valid assessment of the complete syllabus, both in content and skills. The specific skills that need to be engendered in the candidates in order to succeed at multiple choice questions are described in the final section of this report.

A pleasing number of centres returned G2's this session. For SL there were 112 responses from 844 centres and for HL there were 168 responses from 812 centres. While we would like to thank those who took the trouble to provide G2 feedback, we would urge all centres to contribute. Comments from teachers are carefully considered and inform the process of setting realistic and fair grade boundaries given the nature of the paper.

The replies received indicated that the May 2015 papers were generally well received, with many of the G2's received containing favourable comments. Negative comments included a feeling that there was not enough time, and that many of the questions were too "tricky". This will be dealt with in the final paragraphs of this report. The statistics showed that 48% of the respondents thought that the HL paper was of similar difficulty to last year's with 36% judging it to be a little more difficult. The SL paper was deemed to be of similar standard to last year's paper by about 60% of the respondents with the remaining evenly split between “a little more difficult” and “a little easier”. The mean score for both the SL and HL was very similar to last year (HL 22.3 as against 22.8; and SL 15.9 as against 15.6)

With few exceptions, teachers thought that the presentation of the papers and the clarity of the wording were either satisfactory or good.

Statistical analysis

The overall performance of candidates and the performance on individual questions are illustrated in the statistical analysis of responses. These data are given in the grids below. The numbers in the columns A–D and Blank are the numbers of candidates choosing the labelled option or leaving the answer blank.

The question key (correct option) is indicated by a shaded cell.

The difficulty index (perhaps better called facility index) is the percentage of candidates that gave the correct response (the key). A high index thus indicates an easy question. The discrimination index is a measure of how well the question discriminated between the candidates of different abilities. In general, a higher discrimination index indicates that a greater proportion of the more able candidates correctly identified the key compared with the weaker candidates. This may not, however, be the case where the difficulty index is either high or low.

Higher level paper one item analysis

Number of candidates: 6737

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	557	472	4830	839	39	71.69	0.37
2	5182	1048	315	180	12	76.92	0.28
3	4699	1386	331	314	7	69.75	0.44
4	350	420	4928	1013	26	73.15	0.42
5	48	6324	267	94	4	93.87	0.14
6	239	1058	873	4526	41	67.18	0.37
7	180	396	5185	968	8	76.96	0.25
8	3441	1684	841	722	49	51.08	0.25
9	409	1232	4628	455	13	68.70	0.47
10	386	167	1349	4822	13	71.57	0.21
11	4850	753	863	265	6	71.99	0.44
12	1180	4940	432	167	18	73.33	0.13
13	1180	3494	1319	712	32	51.86	0.49
14	838	5507	184	188	20	81.74	0.36

15	787	1024	2032	2871	23	42.62	0.49
16	784	931	1575	3442	5	51.09	0.60
17	576	1822	2739	1568	32	40.66	0.54
18	3033	1216	2130	325	33	76.64	0.11
19	623	2847	2003	1219	45	42.26	0.37
20	2434	2834	785	650	34	36.13	0.20
21	607	1377	1539	3191	23	47.37	0.48
22	2553	505	3233	401	45	47.99	0.38
23	1028	4222	1062	414	11	62.67	0.51
24	491	1816	642	3755	33	26.96	0.26
25	2925	2298	816	681	17	43.42	0.32
26	965	1936	3576	232	28	53.08	0.41
27	471	5054	525	660	27	75.02	0.39
28	1940	1088	2166	1512	31	32.15	0.26
29	2524	2487	645	1022	59	36.92	0.53
30	2163	1099	683	2736	56	40.61	0.51
31	1196	3124	1409	919	89	46.37	0.41
32	860	578	3880	1382	37	57.59	0.37
33	3826	2548	124	216	23	56.79	0.28
34	2928	1145	1026	1584	54	43.46	0.53
35	508	748	2245	3202	34	33.32	0.26
36	1735	2417	2437	75	73	35.88	0.23
37	537	453	142	5569	36	82.66	0.23
38	289	698	1625	4090	35	60.71	0.28
39	1733	2354	1219	1304	127	25.72	0.36
40	4355	708	920	649	105	64.64	0.46

Standard level paper one item analysis

Number of candidates: 5088

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	226	1912	890	2053	7	40.35	0.56
2	1608	389	3021	59	11	59.38	0.50
3	3437	1096	207	340	8	67.55	0.36
4	2697	1501	400	480	10	53.01	0.50
5	559	2303	1657	555	14	45.26	0.41
6	215	4437	207	223	6	4.38	0.00

7	99	4408	395	173	13	86.64	0.28
8	519	174	4273	119	3	83.98	0.27
9	1834	947	2200	96	11	36.05	0.57
10	254	922	741	3149	22	61.89	0.36
11	227	549	3383	917	12	66.49	0.44
12	2879	964	831	408	6	56.58	0.56
13	1067	2844	769	392	16	55.90	0.51
14	1658	1011	462	1944	13	32.59	0.47
15	2316	1266	1109	386	11	45.52	0.54
16	1268	283	3094	431	12	60.81	0.36
17	1054	903	1340	1782	9	35.02	0.63
18	955	812	1922	1375	24	15.96	0.05
19	853	1163	590	2469	13	48.53	0.59
20	526	1026	1658	1864	14	36.64	0.42
21	2180	741	1537	605	25	30.21	0.26
22	116	408	4344	213	7	85.38	0.30
23	543	3359	480	667	39	66.02	0.47
24	269	204	4477	126	12	87.99	0.21
25	2637	2072	111	247	21	51.83	0.35
26	637	3688	277	472	14	72.48	0.35
27	1626	1064	983	1376	39	31.96	0.48
28	506	688	1742	2132	20	34.24	0.33
29	1330	3419	182	139	18	67.20	0.50
30	540	408	323	3791	26	74.51	0.32

Comments on the analysis

Difficulty

The difficulty index varies from about 25% in HL and 4% in SL (relatively “difficult” questions) to about 93% in HL and 87% in SL (relatively “easy” questions). The papers gave an adequate spread of marks while allowing all candidates to gain credit. The 4% question at SL (question 6) was unusual – 28 of the 30 SL questions had difficulty indices over 30%

Discrimination

All questions except SL Q6 had a positive value for the discrimination index. Ideally, the index should be greater than about 0.2. This was achieved by all but two questions in each of the papers. However, a low discrimination index may not result from an unreliable question. It could indicate a common misconception amongst candidates or a question with a high (or a very low) difficulty index.

"Blank" response

In both papers, there were a number of blank responses throughout the test with a slight increase towards the end. This may indicate that some candidates had insufficient time to complete their responses, while others left the questions they were unsure of. Candidates should be reminded that there is no penalty for an incorrect response. Therefore, if the correct response is not known, an educated guess should be made. In general, some of the "distractors" should be capable of elimination, thus increasing the probability of selecting the correct response. If candidates concentrate on selecting the correct response – instead of working out the correct answer (as they might in paper 2) – then there should be adequate time to complete all the questions and check the doubtful ones.

The strengths and weaknesses of the candidates in the treatment of individual questions

Candidate performance on the individual questions is provided in the statistical tables above, along with the values of the indices. For most questions, this alone will provide sufficient feedback information when looking at a specific question. Feedback will be given only on selected questions, ie those that illustrate a particular issue or drew comment on the G2's.

Higher level and standard level common questions

SL Q10 and HL Q6

If candidates have an understanding of specific heat capacity in terms of the "reluctance to change temperature" then D is the only possible answer. Candidates should not need to do any algebraic manipulation.

SL Q21 and HL Q22

Candidates knew it was either A or C, but clearly were not able to use their left hand correctly. If the directions are awkward, then they can always change the orientation of the paper. This was an easy question and it was surprising seeing so many choosing the incorrect A.

SL Q25 and HL Q33

Candidates should be aware of worldwide energy generation. There were some comments from teachers that this question was unfair, but it clearly asks about the world's energy needs – not those of a particular country.

SLQ28 and HLQ35

Many candidates clearly thought that the sea was more reflective than the desert. Its colour is deep blue…and its albedo is about 0.1 compared to 0.4 for the desert

Higher level questions

Q10

The liquid changes direction so B is impossible. We are told it oscillates, so A must be incorrect. The difference between C and D is that D is damped. Anyone who has seen liquid oscillating in a tube will know that it is damped – it is not necessary to say that the situation is "frictionless". This did not confuse many candidates but there were some teachers who thought that C was a possibility. It must be stressed that it is the best answer that is required.

Q12

Reflection of waves at boundaries is clearly on the syllabus despite a view held by some G2 respondents. The statistics show that the candidates had no problem in selecting the correct response.

Q15

Many candidates selected C, presumably as they did not know that violet light has a shorter wavelength than red light. Comparative knowledge of electromagnetic wavelengths should be common knowledge to candidates.

Q17

It is common for examiners to observe that candidates have no intuitive "feel" for circuit electricity. This was a case in point. When the slider is at P_1 then the voltmeter is measuring the potential across a conducting wire – clearly zero. One would have thought, then, that A and C would be the common options, but about half the candidates chose B or D. When the slider is at P_2 then its reading must be less than 6V as some potential will be dropped across each resistor.

It is always a mistake to teach candidates $V = IR$ before they have a reliable conceptual understanding of what V and I refer to. This question is an example of the type of question they should be able to solve before they are able to do any circuit calculations.

Q18

Some teachers pointed out that the direction of a positive current was not defined in the stem, leaving both A and C as possible correct responses. Both were accepted. The examiners suspected, however, that those selecting C had not learnt any mnemonic associated with Lenz's law – just as they did not know how to use their left hand in question 22.

Q20

Electric field strength decreases with the distance from a charge according to an inverse square rule. So the ratio of the distances of the required point to P and Q should be $\sqrt{2}$. This is clearly not the case for B, the most popular response.

Q24

Candidates frequently confuse the field strength at a point with the potential at that point. These two concepts need to be carefully introduced and reinforced. Here the question asks about the potential, ie the work done per unit mass to bring a mass from infinity to P. It is clearly not zero (although the force on an object placed there would be zero). Yet over 50% of the candidates opted for D.

Have the candidates never stood on a high mountain (where the potential is high) but on level ground (where there is no force pulling them downhill).

Q25

Since charges generate equipotentials in an analogous manner to masses, if I is correct then II must also be correct. This leaves A and D as the only possible options. As the equipotentials are symmetrical with respect to the two sources the answer must be A.

Q28

The statistics show that the candidates were very confused by this question. Examiners have also noticed a confusion with similar questions in paper 2.

Here the source emits the same number of photons per second, but with the light changing from red to blue. (This means that the intensity of the light has increased, as intensity refers to the power of the light and each “blue” photon carried more energy than a “red” one.)

As has been observed with reference to question 15, candidates need to know that blue light has a shorter wavelength/higher frequency than red light and therefore each photon carries more energy. So the photoelectrons will have more kinetic energy and the stopping voltage will be greater. So it is either A or C. But as there are the same number of incident photons per second there will be the same number of photoelectrons per second at saturation. Hence C.

Q31

Candidates are required to know about the mass spectrometer. The particles entering a mass spectrometer all have constant speed (after having passed through crossed fields which select an appropriate velocity). Hence the only answer can be B. It would seem that many candidates were confusing the mass spectrometer with the cyclotron.

Q36

Both B and C were chosen by roughly the same number of candidates. The graphs show that the two bodies have their peak intensity at the same wavelength. Wien’s law relates this λ_{max} to temperature. Hence the two bodies have the same temperature. Since both X and Y have the same surface area the higher peak for X can only mean that X has greater emissivity.

Standard level questions

Q6

This question generated some quite bizarre statistics. Sankey diagrams show energy transformations at every location in the working of a machine. They therefore need to be read carefully without jumping to conclusions. Here there were two sources of energy “loss” – in the pulley and in the motor. The question asked about the efficiency of the *motor*. The diagram shows that 75% of the electrical energy supplied to the motor does work on the surroundings. D must therefore be the correct answer.

Perhaps the problem is that Sankey diagrams are not explicitly taught – they are just assumed by most teachers and candidates to be obvious.

Q9

Internal energy relates to both the potential energy of the molecules (which increases with a change in state) and the kinetic energy of the particles (which increases with the temperature). Hence A.

The most popular option was C, indicating perhaps, that the candidates are not familiar with the concept of internal energy, confusing it with temperature.

Q14

D was the most popular option. This situation is analogous to traffic flow, water flow in rivers as well as electricity. In all cases the frequency of “things” passing per second does not change although the speed does. So the answer must be A.

Q15

It was good to see that A, the key, was also the most popular option. This question was a very good discriminator with the best candidates seeing that the two pulses could never combine to make B.

Q18

Candidates must read the question carefully and not jump to the most familiar-looking graph. The most common response was C, as if the circuit was set up to test Ohm’s law, but the question clearly states that R is variable.

Q19

Some teachers did not like the use of 10 $N kg^{-1}$, but this did not confuse the candidates, for whom the most popular choice was the correct D.

Q24

The confusion over the definition of half-life is always evident in paper 2. The best strategy is to define it in terms of the activity of the sample. If, however, candidates wish to talk about what happens at the atomic level, then they must specify (as this question does) that the sample is a pure radioactive sample. (Normally radioactive samples are not pure). It was good to see that almost 90% of the candidates got this right. The track record in paper 2 is not quite as good.

Recommendations and guidance for the teaching of future candidates

Multiple choice items are an excellent, motivating and highly time-efficient way of testing and promoting learning as a course is being taught. They can be used as warmers to stimulate discussion as well as for quick tests and should never be regarded as add-ons to be practised, a paper at a time, solely for the final examination session.

Multiple choice questions test a different skill to structured questions. In paper 2 candidates are expected to display their knowledge in a logical and communicative fashion. But multiple choice questions test quick thinking (without a calculator), insight and problem solving.

Teachers frequently comment on unfair “tricky” questions, but the physical world has a history of tricking scientists into false conclusions. In order not to be “tricked”, candidates must read the question very carefully to visualise the situation. The questions are carefully created to communicate the problem unambiguously and in as few words as possible; the words are both necessary and sufficient. After they have made their selection the candidates should make a habit to check back that they have indeed answered the question. Only then should they move on. There is evidence that many candidates are not “back-checking” once they have made their selection.

There is no single most successful strategy with MCQs, so flexibility of thinking is needed. Candidates should be encouraged to develop strategies for spotting the correct answer – rather than working it out as they would in a paper 2. Among the strategies leading to successful completion of multiple choice questions are:

- Eliminate the clearly wrong responses.
- Consider the units. There is much evidence that candidates are not being taught the power and necessity of units. They are there to help the candidate not to burden them and will often lead to the identification of the correct response.
- If two responses are logically equivalent then they must both be wrong.
- Exaggerate a variable – this will often point the candidate in the correct direction, especially if a variable is in the denominator in one response and the numerator in another.
- Draw the situation while reading the stem. A simple sketch will aid in understanding the stem and often lead the candidate to the correct response. This is particularly important for those candidates with weak language skills.
- Distinguish between cos and sin functions – mentally making the angle 90° will show which is correct.

- Use proportion: new quantity = old quantity × a fraction, where the fraction depends upon the variables that have changed.
- Notice the axes on graphs and use units to attach meaning to the gradient and the area.
- If all else fails, make an intelligent guess.

Candidates should make an attempt at every item. It should be emphasised that an incorrect response does not give rise to a mark deduction.

Graphs, force diagrams and other means of illustration are a fundamental way in which physicists seek to model and understand the world. Candidates should be encouraged to sketch their answers to problems before they plunge into calculations. There is evidence, also from the written papers and extended essays, that this is not a skill shared by many candidates.

The stem should be read carefully. Inevitably some questions may appear at first sight similar to past questions, but candidates should not jump to conclusions. It appears that some candidates do not read the whole stem but rather, having ascertained the general meaning, they move on to the options. Multiple choice items are kept as short as is possible. Consequently, all wording is significant and important. They should also bear in mind that they are asked to find the best response. Sometimes it may not be strictly 100% correct but physics candidates should be used to identifying and ignoring quantities that have negligible impact.

Candidates should consult the current Physics Guide during preparation for the examination, in order to clarify the requirements for examination success. Teachers should be aware that questions are constructed from the requirements of the syllabus – not from previous papers.

The Guide does invite the candidates to recall certain simple facts, although most of physics is process orientated. Such facts lend themselves to multiple choice questioning so the teachers should not be afraid to require their candidates to occasionally memorise information. Definitions (which are universally poorly given in written papers) are perhaps best learned and tested with simple multiple choice questions.

Candidates can expect the proportion of questions covering a particular topic to be the same as the proportion of time allocated for teaching that topic, as specified in the Physics Guide. The common knowledge that most people have about certain areas of the Guide is not always sufficient to answer questions, which are not trivial.

Higher and standard level paper two

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0–13	14–26	27–35	36–44	45–52	53–61	62–95

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0–6	7–12	13–17	18–22	23–27	28–32	33–50

General comments

At HL, only 192 centres out of 812 provided feedback on the G2 forms this session. These comments are very useful in the design of future examination papers and teachers are encouraged to provide timely feedback via their IB coordinator. There was general satisfaction with the syllabus coverage; 88% of centres thought the paper was of appropriate difficulty, 11% thought it too difficult and the remaining 1% thought it was too easy. 59% of centres thought the paper was of similar difficulty to last year, 30% thought it more difficult and 8% thought it a little easier. 80% of centres thought the clarity of the wording was good to excellent, 16% thought it fair and 4% thought it poor or very poor. 89% of centres thought that the presentation of the paper was good to excellent, 10% thought it fair and 1% thought it poor.

At SL, only 130 centres out of 844 provided feedback on the G2 forms this session. There was general satisfaction with the syllabus coverage; 93% of centres thought the paper was of appropriate difficulty, the remaining 7% of centres thought it too difficult. 62% of centres thought the paper was of similar difficulty to last year, 20% thought it more difficult and 15% thought it a little easier. 85% of centres thought the clarity of the wording was good to excellent, 14% thought it fair and 1% thought it poor. 94% of centres thought that the presentation of the paper was good to excellent and the remaining 6% thought it fair.

The paper revealed that the best candidates have a sophisticated understanding of the physical world and are able to apply their knowledge of Physics accurately in problem-solving.

There are far too many candidates who have a poor sense of numbers when applied to everyday physical situations. Many wires had subatomic dimensions and wind turbines possessed blades a few kilometres in length! For such candidates there is a serious disconnect between the world in which they live and the answers they commit to paper. All areas of the examination suffered in this way.

Only the best candidates displayed a sense of rigour in the presentation of their answers. It must be stressed that the object of problem solving is not merely to produce a final answer. The candidates must show how that answer was obtained, displaying their reasoning logically and clearly. Too often numbers and equations are scattered around the answer box with no obvious connection between them on display. Examiners cannot be expected to guess what numbers refer to – it is the candidates' duty to make the solution plain.

Candidates showed evidence of patchy memorisation of half-forgotten definitions and concepts when invited to give explanations of physical phenomena. Many verbal explanations were woolly and often incomplete. It is clear that many candidates do not understand the conceptual basis of the subject preferring a rote-learning approach that does not work with questions set at the highest assessment objective.

Candidates continue to lose marks through inattention to units.

Despite G2 comments, there was no evidence that the paper was too long as most scripts contained complete attempts at all questions.

The areas of the programme and examination which appeared difficult for the candidates

- An understanding of the relationship between a graph and the equation that represents it.
- Clear descriptions of thermodynamic quantities.
- Momentum calculations and descriptions.
- Representations of wave function.
- Calculations and understanding of electrical theory.
- Determination of weight components.
- Recalling the shape of the graph of binding energy per nucleon against nucleon number.

The areas of the programme and examination in which candidates appeared well prepared

- Calculations involving combining percentage uncertainties.
- Descriptions of interference effects.
- Describing the enhanced greenhouse effect and discussing the advantages and drawbacks of wind turbine technology.
- Describing the mechanism by which information is read from a DVD.
- Calculating energy changes during a change of state.

- Calculating the energy of a system undergoing simple harmonic motion.
- Calculating a decay constant and mass of isotope at a given time.

The strengths and weaknesses of the candidates in the treatment of individual questions

Section A

Q1 HL and SL

This data-analysis question scored better than in previous years. Many candidates scored 6 or more out of the available 11 marks. The question was criticised in the G2 comments for its complexity, but candidates rose to the challenge very well.

(a) Although the majority could determine the fractional uncertainties of the two values, a significant minority subsequently subtracted them to arrive at their estimate of fractional uncertainty. Only a small fraction of the total entry could make little headway with the problem.

(b)(i) Roughly three-quarters gave a convincing demonstration of this simple problem. Those who failed did so because they fudged the result or because they ventured into attempts to derive the result numerically; this could not gain credit.

(b)(ii) The best-fit line was carelessly completed even by those who gained the mark. The work of candidates continues to be poor in this area. Lines should be drawn with a thin pencil, work should be well presented. Double, kinked or thick lines are penalised and inadequacies in this respect are obliged to have implications for later work that relies on data derived from the graph.

(b)(iii) Candidates must always use a sufficiently large triangle for the determination of a gradient. A good rule of thumb is to use at least half the length of line drawn. Read-offs should be accurate and – for experimental data of this type – must be specified to an appropriate number of significant figures. Poor work here was characterised by read-offs that were more than half a square out, and final values expressed to only one significant figure.

(b)(iv) Candidates were required to extrapolate their line to the appropriate axis and then read off on the *y*-axis. Those who do not extend a line or make any appropriate marking on the question paper cannot expect to gain this mark.

(b)(v) Many candidates realised that a calculation was required here and in general these were well done. However, some failed to appreciate that the intercept took a negative value even though the calculation indicated this clearly; this was penalised.

(b)(vi) This was poorly done. All candidates had to do was to square the value from (b)(v). However, many used a convoluted calculation including a value for *g* of $9.8\,m\,s^{-2}$ that candidates assumed to be correct. It was not, this was experimental data and, to use a calculation from derived data, candidates needed to calculate the *g* value.

HL Q2 and SL Q4 part 2

Explanations and definitions were poor. Candidates failed to read questions carefully and lost marks through not addressing the points required.

(a) Too many gave a loose and ill-considered definition of binding energy – they were not asked to discuss mass defect which many did.

HL (b)(i) and SL (d)(i) Given that this is a simple task straight from the Guide, this graph was badly drawn. The maximum point was misplaced – even candidates who wrote Fe-56 at the maximum placed it well away from there. The graph was poorly drawn at high nucleon number and the region from nucleon numbers 1 to 30 poorly rendered. Candidates had failed to commit the details of this important plot to memory.

HL (b)(ii) and SL (d)(ii) Candidates were told to refer to the graph but no more than one-third did so. Explanations were confused and incoherent with many candidates simply making random remarks about fission. It was clear that there is major confusion about the nature of fission (and indirectly, fusion) and the origin of the energy that is released as a result of its occurrence.

HL only (c)(i) The vast majority were able to quote the equation correctly. Failures include assuming the presence of an incoming neutron and inabilities to sum correctly.

HL only (c)(ii) The calculation of the initial mass of the element was well done by many. The numbers using the exponential equation and those calculating the half-life and using $2^{\text{half-life}}$ were about equal.

(c) and (eii) SL only These are two commonly asked questions but most candidates are still unable to produce precise and correct answers. Candidates should be aware that a “radioactive sample” will contain both decayed and undecayed nuclei. Half-life is always easiest to define in terms of the activity of a sample, rather than what is actually going on inside.

SL only (e)(iii) This was well done, although many of the weaker candidates just divided 5.6 mg by the three half-lives, instead of doubling it for each half life.

Q2 SL only

(a) Most were able to calculate the weight (although many just wrote down 85×10 with no introduction or units). But there were far too many candidates confused between cos19 and sin19. Candidates should know that $\sin 0 = 0$ so that if the road is horizontal and there is no component “down the hill”, then sine is the relevant function to use. Similarly in part (ii) we know that the normal reaction force increases as the angle decreases, so cosine must be used.

(b) Over half the candidates seemed not to realise that the bicycle will be decelerating and that they therefore should expect a negative acceleration leading to a positive distance. This was another case where candidates were hurrying to an answer without giving time to reflect upon what was going on.

Q3 HL and SL

(a) Candidates were offered a command term at objective level 3; this should indicate to them that a high level answer is needed. 3 marks were available; this should tell candidates that three physics points are required. An overwhelming majority offered a contrast between thermal energy and temperature without offering a third point – this was the comparatively simple statement of the relevant units. Candidates are advised to use *all* the information that the question paper provides. About 50% scored 2 marks.

(b)(i) The calculation in numerical terms was well done. However, in a question where powers of ten are likely to be an issue it is vital that the candidate offers a unit. The answer of 2.5×10^6 J kg^{-1} can be expressed in a number of ways (2.5 MJ kg^{-1}, 2500 kJ kg^{-1}, etc). However if the candidate offers no unit the examiner must penalise the candidate.

(b)(ii) It was very clear from the answers that candidates had failed to comprehend the nature of the experiment. Many indicated that "heat was lost to the kettle". This was implausible because the situation was one of steady-state as the water had reached the boiling point before the experiment began. Consequently marks were relatively poor in this part.

Q4 HL only

(a) Examiners saw many competent attempts to explain the situation and it seemed at this point that candidates were comfortable with the experimental details. Interference effects were described and there were careful descriptions of the phase/path differences that cause the minima positions.

(b) However, when it came to the calculation many candidates went adrift. A simple approach was allowed so that when one of the reflecting sheets moves, so does the interference pattern. Examiners saw many examples of a simple use of $c = f\lambda$, however. This was not worthy of credit. Even those who understood what was happening often assumed that the examiner did too and failed to explain exactly why they were dividing the distance between minima by 2. A small handful of candidates provided a Doppler effect approach. This was usually incorrect because they did not recognise that the moving sheet B is a moving "observer" and then a moving "source". Consequently they did not refer to the concepts of beats between the original and detected signals in the answer.

(c)(i) The quality of communication was poor in this question. Candidates must understand the need to make phenomena clear to an examiner. Diffraction does not lead to a "bending" of a wave – that is, at best, refraction. Examiners were looking for a clear sense that the wave spreads out. Many candidates who drew a clear diagram scored both points here relatively easily.

(c)(ii) Most were able to arrive at the angle required. However, those who wrote 0.533° clearly did not understand what was happening in their calculator and were penalised for this. Equally the question did not indicate that a circular aperture was involved and the use of a factor of 1.22 was unjustified.

(d) Most scored 1 out of 2 here as the logic often did not join up. A worrying minority think that sound waves are electromagnetic and transverse (or worse, electromagnetic and longitudinal).

Q5 HL only

(a) This question was pleasingly done, pulling together as it does two areas of the subject. Most identified $F = Blv$ as the appropriate expression to use and were able to use a kinematic equation of motion to calculate v. However, weaker candidates were completely at sea in terms of the physics and were struggling unsuccessfully to use versions of Faraday's Law to arrive at a result. Again, powers of ten errors were possible and examiners needed to see the unit (V, mV, μV and so on) before they could judge the correctness of the numerical answer.

(b) Explanations of the effect were good, many scoring 2 out of 3. It was common to see the continuity of the coil leading to charge flow, and a discussion of Lenz's law and its consequences; however the link to increased time was poor. Most gave an incomplete description of the force acting – it is upwards, and candidates need to specify such directions unequivocally. Talking about opposition is no more than an extended Lenz statement.

Section B

HL Q6 Part 1 and SL Q4 Part 1

(a)(i) Despite the relatively common appearance of variants of this problem, candidates still demonstrate considerable weakness in working through data. It was common to see solutions that omitted the presence of five turbines, or the 30% efficiency of each turbine or both. Considerable numbers gave the radius not the diameter. These are not trick questions. Candidates at the level of the Diploma should be able to read a question carefully and determine what is required.

(a)(i), (ii), (iii) and (iv) Candidates were lead through a series of questions about the suitability and placement of wind turbines in the specific case of a small community. Again, there were too many stock statements from candidates who had failed to think through what the consequences and issues are for this particular case.

(b)(i) Many were able to work this simple problem through.

(ii) The question asked the candidates to focus on the wind issues. Instead many gave responses focussed on the coal-fired station.

(iii) Many candidates now have the message about the physics of the greenhouse effect and are using the terminology correctly and appropriately.

Q4 Part 2 HL only

(c) About half were able to write convincingly about the trade-off between gravitational potential energy and the kinetic energy of the rocket. Weak answers featured discussion of the orbital characteristics (candidates were not told that the rocket was in orbit).

(d) The calculation was well done. Both approaches featured in the mark scheme were seen, but candidates often failed to score both marks because they did not clearly indicate that the value of the acceleration that they had determined was numerically the same as the gravitational field strength.

(e)(i) Many gained 2 out of 3 here. The most common failure was to assume the relationship between mg' and GMm/r^2. Otherwise the equating of kinetic energy and potential energy was well shown and the manipulations were good. Candidates who used a centripetal force approach could gain little credit given that (again) no circular motion was involved.

(e)(ii) Many were able to use their value from (d) to determine a rocket speed (errors were allowed to be carried forward) and the answer statement followed directly.

(f) Only a relatively few could not explain that the satellite also has a speed component from its presence on the space station.

SL Q6 Part 2

(d) A very common question which was very poorly answered.

(e)(i) This was another "show that" question so candidates were expected to spell out very clearly the reasoning that leads them to the equation given.

(ii) Mostly correctly done.

(iii) It was pleasing to see how many candidates realised that four charges cancel each other out. This needs to be spelt out, though. Examiners are not psychic.

HL Q7 Part 1 and SL Q5 Part 1

Candidates showed great skill in this question and clearly have a good understanding of the principals involved.

(a) Many were able to score 1 or 2 in showing that k was related to m and ω^2.

(b)(i) Almost all correctly calculated the frequency.

(ii) Although many understood what was going on, full expressions of the logic were sometimes lacking; the full chain of argument was required. Frequency or period is the same so ω is the same, springs are identical so k is the same.

(iii) This scored poorly because candidates did not get to the heart of the word "confirm". Examiners were looking for a statement of what had to be confirmed – the definition of SHM which most knew – and how the candidate was proposing to do this. This second point was weak; candidates simply did not have the language to describe how they would take the graph and manipulate it to show what was required.

(c)(i) and (ii) These were well done by many. Common faults were the placement of the maximum of B and its endpoints. Most scored 2 out of 3 in (ii) with one or other of these faults.

(d) The calculation was well done by a large number of candidates.

HL Q7 Part 2

(e) and (f) Both were competently answered.

(g)(i) This was usually half answered: either "work done by the engine" or "work done in one cycle". Many thought that the fluid was doing work over the whole cycle.

(g)(ii) A simple question that was well done by many. Failure points included arriving at a fraction that was greater than 1 and using incorrect energy values for the fraction.

(g)(iii) This was well answered, many gaining both marks.

(h) Although a statement that $\Delta Q = 0$ was common, many solutions led to a negative sign because candidates misunderstood the symbols in the first-law equation. This was incorrect and penalised.

HL Q8 Part 1 and SL Q6 Part 1

(a) As in previous sessions, candidates do not give full statements of the conservation of linear momentum. It is not sufficient to write "momentum is conserved".

(b)(i) The candidature was split 50:50 as to the answer here. Some remembered that the initial momentum is half the momentum change and arrived at the correct value of $0.96\,\text{kg m s}^{-1}$; those who did not obtained twice the value and lost a mark.

(b)(ii) The sign of the acceleration was frequently ignored in this part and was penalised. Most candidates used their knowledge of the force (though sadly the maximum force, not the more appropriate average) and the mass to yield the numerical value.

(b)(iii) This was a difficult question at the top end of the assessment objective spectrum and candidates probably did not give themselves long enough to think about it. Many gained 1 or 2 marks but it was rare to see all 3.

HL Q8 Part 2

(d) Although candidates obviously understand what a least-significant bit is, putting this into appropriate vocabulary on an examination paper is clearly beyond them. Many described it as the right-hand bit – or worse, the left-hand bit. There are two parts to the statement (and 2 marks available): what is meant by bit, and what is it that makes it the least significant. Candidates can usefully practise matching question to available marks as part of their training.

(e) Many candidates were able to demonstrate partial competence in answering this question. Generally, they forgot one aspect of the calculation, usually the relationship between reading rate and number of bits in the sample.

(f) Again many candidates were able to show partial but not total competence here. A score of 3 out of 4 was common with one element of the description omitted. This often centred on the need to make it clear that the reflection is jointly from the pit–land edge, or to discuss the path difference clearly. Good diagrams drawn and labelled with care were often very useful to candidates. There are reasons why space is provided on the question paper.

HL Q9 Part 1

(a)(i) The inevitable failures to manipulate equations and allow for the radius/diameter issue were seen. The most common mark was 1.

(a)(ii) This was an unusual and tricky calculation of a synoptic character and it was well carried through by many (an ECF from (a)(i) was allowed). A large majority were able to negotiate the force/acceleration step that ends the calculation even if they had made slips earlier.

(a)(iii) On the other hand, candidates did not come to terms with this question. It was clear that they had never considered the issue that, although electrons are subject to an electric field in a conductor, they do not continuously accelerate. Statements about energy change were rare; candidates usually confined themselves to a discussion of collisions in terms that were simplistic and often non-physical.

(b)(i), (ii) and (iii) Candidates who are well practised in manipulating electrical equations and who have a good conceptual understanding of the topic found little difficulty here. Those whose appreciation of circuit theory is shaky (sadly, the majority of candidates) found great difficulty in proceeding beyond (i).

(i) Usually well done.

(ii) and (iii) These gave a greater challenge with misunderstandings very evident. It was common to see statements that the potential difference across a component was 24 V (in a circuit with a 12 V supply). Here and elsewhere, candidates commonly write down figures that have no basis in fact without any critical thought.

HL Q9 Part 2

(c) This was well understood.

(d)(i) and (ii) These were stock calculations and gave candidates few problems.

(d)(iii) This was a question that demanded more thought than candidates gave it. Many (though not all) recognised that the graph had to be periodic in nature but few thought to connect their (correct) answer to (d)(ii) to the problem. Equally the end point of 2 nm was not recognised either and graphs extended beyond this point.

(d)(iv) An easy conclusion was missed by many with waffle produced and many returns to the answer to part (c) without definitively stating the relationship to the *y*-axis of the graph.

SL Q5 Part 2

(d)(i) This was a very standard calculation but there are far too many candidates unable accurately to deal with the arithmetic manipulation involved. Common mistakes were: confusing the diameter with the radius of the wire, not translating from millimetres to metres, not knowing the area of a circle.

(ii) Common sense (based upon simple mental imagery) dictates that as the diameter of a wire increases then its resistance must decrease. But many graphs showed a positive correlation.

(e) It was rare to find candidates who identified electrons as charge-carriers that moved under the influence of an electric field (hence setting up a current).

(f) The answers given showed that the vast majority of the candidates had not taken time to understand the circuit and what was being asked. It seemed as if they used the first equation that came to hand and substituted values with no clear reasoning.

Recommendations and guidance for the teaching of future candidates

- Candidates should learn definitions as an aid to the understanding of concepts.
- Candidates should be encouraged to set out calculations in a logical and presentable fashion and to use units correctly.
- Candidates should recognise the implications of the command words used in a question.
- Candidates should be encouraged to use appropriate scientific vocabulary.
- Candidate should be encouraged to link their studies to their everyday lives.
- Candidates should recognise that a numerical answer alone, without its unit, is incomplete.

Higher and standard level paper three

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0–10	11–20	21–29	30–34	35–40	41–45	46–60

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0–6	7–12	13–18	19–21	22–25	26–28	29–40

General comments

Most candidates made a serious effort to attempt the required number of questions and appeared to have ample time to complete the paper. Clearly many centres provide plenty of past papers as questions which had occurred previously were well answered.

Relatively few candidates allowed answers to flow outside the boxes provided on the question paper. However, there are still too many candidates who do not know how to present answers in a concise and organised way. This session saw a noticeable decrease in the number of extension sheets used compared to 2014.

There were frequent occasions when poor handwriting made marking difficult. In particular powers of ten and decimal points were not always clear. Very often examiners had difficulty in deciphering the candidate’s reasoning within a calculation – and frequently this reasoning was completely absent. Errors with units and powers of ten were alarmingly frequent. Physics departments need to be aware that in examinations from May 2016 topic 1 of the new Subject Guide will be significantly tested. (See section on recommendations at the end of this report).

At HL, 192 out of 812 centres provided G2 feedback on this examination. This is a very welcome increase compared to last year. These comments are very useful in the design of future examination papers and teachers are encouraged to provide timely feedback via their IB coordinator. There was general satisfaction with the syllabus coverage. 94% of schools thought that the paper was of appropriate difficulty. 64% of schools thought the paper was of similar difficulty to last year; 13% thought it more difficult, 20% thought it was easier. The overall comments on the individual options suggests that the majority of schools responding were delighted with the balance and facility of the paper. In fact the mean score was about 3 marks higher than in M14. 90% of schools thought that the clarity of the wording or the presentation of the paper was good to excellent. 95% commented that there was no significant cultural, religious or ethnic bias.

At SL, 130 out of 844 centres provided G2 feedback on this examination. There was general satisfaction with the syllabus coverage. 95% of schools thought that the paper was of appropriate difficulty. 70% of schools thought the paper was of similar difficulty to last year; 16% thought it more difficult, 11% thought it was easier. The overall comments on the individual options suggests that the majority of schools responding were satisfied with the balance and facility of the paper. The mean score was about 1 mark higher than in 2014. 90% of schools thought that the clarity of the wording or the presentation of the paper was good to excellent. 95% commented that there was no significant cultural, religious or ethnic bias.

The areas of the programme and examination which appeared difficult for the candidates

General weaknesses in this and recent examinations.

- Highlighting key phrases or data in a question.
- Knowing what the symbols represent in a data book formula or equation.
- Powers of 10 and unit multipliers. (The most common cause of accidental mark loss.)
- Careless arithmetic and algebraic errors. Calculator mistakes are common.
- Showing working in full in “show that” questions. Proof of calculation is required.
- General layout of working in numerical questions – needs to be planned and methodical.
- Use of a ruler in drawing diagrams.
- Paying little attention to the number of marks awarded for each part question. Often candidates provide fewer key facts than required.
- Paying little attention to specific command terms – determine, explain, estimate, etc…
- Sequencing the presentation of facts to support an explanation or description.
- Definitions were generally poor.

Weaknesses specific to the higher level M15 question paper.

- Referring to remnant mass when quoting the Chandrasekhar limit.
- Referring to stars or “objects” rather than galaxies when describing expansion.
- Correct use of the conventional units for Hubble’s constant.
- Explaining time-division multiplexing.
- The difference between attenuation and dispersion.
- Using negative gain for an inverting amplifier.
- The mechanisms for light absorption and scattering.
- Relativistic kinematics, especially simultaneity.
- Relativistic mechanics, especially the use of the units MeV, $MeVc^{-1}$ and $MeVc^{-2}$.
- Lack of reference to geodesics.

- Dosimetry calculations.
- The charge on the various quarks.
- Use of the available energy equation for particle collisions.
- The need for charge neutral vertices in Feynman diagrams.

Weaknesses specific to the standard level M15 question paper.

- Peak wavelength of the spectral response of rod cells.
- Finding the wavelength of a standing wave from the length of the air column.
- Explaining observations from the photoelectric effect using the light particle theory.
- Converting photon energy to eV.
- Outlining how the half-life can be determined experimentally.
- Incorrectly referring to stars or "objects" rather than galaxies when describing expansion.
- Describing the meaning of AM.
- Explaining time-division multiplexing.
- Not using negative gain for an inverting amplifier.
- Dependence on resolution on wavelength
- The mechanisms for light absorption and scattering.
- Relativistic kinematics, especially simultaneity.
- The charge on the various quarks.

The areas of the programme and examination in which candidates appeared well prepared

Very few candidates answering fewer or more than 2 options.

Keeping responses within the answer box provided.

Some improvement in knowledge or understanding were seen with the following syllabus areas:

- Operational amplifier circuits – proof of gain formula
- Identifying peak wavelength in a black body graph
- Describing the meaning of AM
- Ray diagrams
- Simultaneity – some improvement, but it is still a major weakness
- Kinematic calculations involving the Lorentz factor, gamma
- Pair formation energetics
- Colour of quarks and baryons
- Single slit diffraction
- Electron transitions

The strengths and weaknesses of the candidates in the treatment of individual questions

HL: Approximate percentage popularity

E 70%; G 60%; I 30%; H 25%; F 10%; J 5%;

SL: Approximate percentage popularity

A 45%; B 40%; C 10%; D 5%; E 45%; F 10%; G 45%

Option E — Astrophysics

The most popular option. Most often in combination with option G.

1 HL and 13 SL Stars in an HR diagram

In part (a) nearly everyone could name the types of stars. In (b) the ratio of star radii was usually correct, with the square root missed by many candidates. The apparent brightness and power of a star in (c)(i) were usually correctly stated. Mistakes usually involved stating power per second or energy. Part (c)(ii) was done well also, although arithmetic errors were common. In (d) nearly all candidates found the star's peak wavelength and drew a suitable graph. Overall a very well answered question.

2 HL and 14 SL Eclipsing binary stars

Part (a) produced a variety of positions for the orbital position of the second star. Many placed it on the wrong circle. In (b) the condition for observing eclipsing binaries is that the stars orbit in the plane containing the earth. This was not well known. In part (c) many did not realise that there will be two unequal narrow minima every 10 years.

3 HL and 15 SL Expansion of the universe

In (a) far too many candidates just repeated the question rather than stating that expansion refers to galaxies moving further apart. CMB radiation was usually mentioned in (b)(i). The fact that CMB was a specific prediction of the Big Bang model, long before its discovery, was sometimes mentioned in (b)(ii). Most were able to refer to cooling and wavelength increase of CMB as being consistent with the Big Bang model.

4 HL only Stellar evolution

In part (a) most candidates correctly referred to the mass–luminosity equation and used it to determine the luminosity range for the star. Part (b)(i) was answered well by many, but there were also many who did not refer to the remnant or core mass being below the Chandrasekhar limit. In (b)(ii) there were far too many candidates who referred to fusion continuing in a white dwarf. In part (b)(iii) carbon or oxygen were almost always correctly stated. In (c) it was expected that electron degeneracy pressure would be mentioned, many did so but fusion radiation pressure was also incorrectly mentioned.

5 HL only Hubble's law

In part (a) there were almost no incorrect answers. In part (b) far too many candidates lost 1 mark because they used the wrong power of ten for velocity in Hubble's constant.

Option F — Communications

Chosen by few candidates

6 HL and 16 SL Amplitude modulation (AM)

Part (a) was answered rather better than in previous years, but few remembered to say that AM is a way of transferring data/information. In part (b) the bandwidth and power spectrum were almost always correct. Most knew that both devices in (c) were amplifiers.

7 HL and 17 SL Sampling

In (a) the sampling frequency was often multiplied by 16 instead of 32 to find bit rate. In (b) most candidates could state that the sampling rate or bit rate needed to increase, but could not explain why. The inverse of bit rate was often used in part (ii). But the question asked for the time of one sample. In (c) a minority of candidates used the diagram space to explain time division multiplexing.

8 HL and 18 SL Optical fibres

Total internal reflection was not usually well explained. Far too many candidates gave disorganised accounts and were unsure which angle was the critical angle.

The value of critical angle was frequently wrong in part (b) as the wrong pair of refractive indices was used. In (c) there was often confusion between attenuation and dispersion.

9 HL and 10 SL Operational amplifier (op-amp)

Infinite input impedance and zero output impedance were the most popular answers to (a). Part (b) is frequently asked and many can now give a convincing proof for the gain. In (c)(i) the gain is –12, but many omitted the negative sign. However ECF was applied for use of the previous wrong answer in part (ii) and (iii).

Option G — Electromagnetic waves.

The second most popular option after Astrophysics.

10 HL and 19 SL The nature of electromagnetic (EM) waves

In (a) candidates usually mentioned: transverse, perpendicular E,B oscillations, speed c in a vacuum. They were generally less sure about absorption and scattering in (b) – many effectively saying absorption is absorption and scattering is scattering. Interaction with energy levels in atoms or molecules was often ignored. Virtually everyone could think of one application of lasers in (c).

11 HL and 20 SL Magnifying glass and telescope

The magnifying glass ray diagram was almost always correct in (a). All candidates knew that the image was virtual, but often gave vague statements about what this means. Part (b) was also done well with only a few candidates making POT errors when finding the angular magnification of the telescope.

12 HL and 21 SL Two slit interference

In part (a) diffraction at each slit, followed by a path difference and subsequent constructive or destructive interference was very often given, but sometimes in a clumsy fashion. It is evident that not all candidates take 30s to plan the order in which they are going to present the steps in their argument. Part (b) was not difficult, but many lost 1 mark for not using n = 3. Highlight this fact in the stem and these kind of careless errors can be avoided.

13 HL only X-rays

In (a)(i) there were 3 marks for the annotation of the X-ray spectrum diagram. Not all candidates realise that this means they should be looking for three features in their answer. In part (ii) the decrease in λ_{min} and increase in intensity were usually correct. Part (b) was a very easy substitution into the equation for λ_{min}. Part (c) caused quite a few problems. Many mistakenly assumed that using n = 2 would give the angular separation of n = 1 and n = 3 X-ray maxima. Many forgot the factor of 2 in the Bragg formula. However there were many correct answers.

Option H — Relativity

14 HL and 11 SL Relativistic kinematics

Part (a) was answered very well. This year almost nobody worked in seconds and so the answers were easily obtained. As usual there were candidates who got time dilation the wrong way round. The time interval for the Earth clocks is dilated (longer) but some candidates think that the time interval on the “moving” clock is dilated. It is best not to think of motion, but to realise that the single clock at both events records the shortest time interval. In (b) a very common misconception with proper length is to just say that the object must be measured in the same frame of reference as the observer. Well this is always true of course, but only if the object is at rest in the observer’s frame is it proper length. Everything is in everything else’s frame. Gradually more and more candidates are answering simultaneity questions correctly. This year almost 3% could correctly explain why light B emits waves before light F as perceived from the spacecraft frame. The other 97% thought that the question was asking about which light the spacecraft observer sees first.

15 HL only The Michelson–Morley experiment

Both parts (a) and (b) were answered well by large numbers of candidates. The main difficulty seems to be with understanding the reason for the 90° rotation of the interferometer.

16 HL only Relativistic mechanics

In part (a) the KE was usually easily identified and added to the proton rest energy. Part (b): In any question with units expressed in terms of MeV and c there is enormous potential for confusion. However an increasing number of candidates are able use the relativistic energy – momentum equation ($E^2 = (mc^2)^2 + p^2c^2$) correctly as they realise that it becomes a Pythagorean $E^2 = m^2 + p^2$ when using the simpler units. The commonest mistake was to try to make use of the value of "c" in the calculation instead of just sticking with the values given. In (c) gamma was frequently found correctly and converted to a speed, but ECF was often necessary.

17 HL only Gravitation

Rather surprisingly candidates could explain the warping of spacetime and the shortest path followed by a planet but could not explain gravitational force providing centripetal motion.

18 HL only General relativity

In part (a) most candidates drew a projectile path for (ii) but thought that light would travel horizontally for the rocket observer in (i). Part (b) was an easy substitution into the gravitational frequency shift formula. Many forgot to square the speed of light or failed to give a negative value for Δf.

Option I — Medical Physics

19 HL only The ear

Part (a) was 4 marks, so a detailed answer was expected with reference to named physical processes – not just biologically named parts. However many made a good effort and there were more than 4 marking points available. In (b) most candidates knew that intensity was power per square metre, but made mistakes with μW and mm^2 even though ignorance was bliss on this occasion. POT errors are the most common cause of accidental mark loss. Part (b) was well answered, but ECF was often applied. In part (c) the logarithmic response of the ear was sometimes mentioned, and many spotted the identical intensity ratios. Not many could convincingly link the two ideas.

20 HL only X-ray/CT imaging

Part (a) contains two standard questions and was well answered. In comparing the processes of computed tomography (CT) and conventional X-ray imaging many candidates did well. Common problems included not mentioning the fact that CT images are taken at all angles during rotation and that CT involves a far greater absorbed dose.

21 HL only Ultrasound

Part (a) was an easy mark, although the speed of light was mentioned too often. In (b)(i) many candidates ignored the data and answered using existing knowledge. The reflection coefficient was usually correctly calculated in (b)(ii). Part (b)(iii) was poorly answered. Most candidates did not take the time to analyse what was happening. Two attenuations and one reflection, so $I = 0.4 \times 0.34 \times 0.4 I_o$ for 3 marks – but very few correct answers were seen.

22 HL only Radiation therapy

Part (a) was an easy 2 marks. In (b)(i) many just defined normal half-life without saying it applied to the activity within the patient. The dose equivalent calculation was not done well in (b)(ii) as many overlooked the 8h time period or could not convert MeV to J. Unit multipliers also caused problems.

Option J — Particle Physics.

Relatively few candidates chose this option.

23 HL and 12 SL Particles and interactions

In (a)(i) the fact that antiparticles have equal mass was often not mentioned. Most realised that antineutrons and neutrons were not identical as they had different quark structure or opposite baryon numbers. Part (b)(i) was usually partially correct. Few mentioned that exchange particles were bosons. Parts (ii), (iii) and (iv) were answered correctly only if candidates knew the charges on the various quarks in the Feynman diagram. About half did know. The simple substitution into the data book equation allowed the majority of candidates to determine the mass of a pion in part (c).

24 HL only Particle production and accelerators

Part (a) was quite well answered in terms of lower energy but less radiation loss in the LINAC. Part (b) was not well answered as many candidates did not know which energy to use for E_A or had the usual trouble with the units. Just stay in MeV units and forget the “c” is good advice here. In part (c) the loss of energy due to radiation was sometimes mentioned.

25 HL only The standard model and Pauli exclusion principle

Part (a)(i) was poorly answered as many just stated lepton number is not conserved. They needed to be specific. In (ii) a common mistake was to think that baryon number is not conserved when in fact it is charge that is not conserved. The Feynman diagram in (b) was rarely correct. Far too many candidates drew vertices that did not conserve charge. However partial marks were obtained for identifying the Z boson or for correct arrow directions. In (c)(i) Pauli’s exclusion principle was often incorrectly stated; it applies only to identical fermions. In parts (ii) and (iii) most candidates correctly referred to “colour” in their explanations. Hadrons are “white” was often stated rather than “colourless”.

26 HL only The early universe

Part (a) is a common question. The usual mistake was to use a single electron or work in mixed units. In part (b) many candidates made a good effort to explain why the formation of particle – antiparticle pairs became impossible as the universe cooled by referring to their previous answer. They were usually able to explain the annihilation of matter and antimatter. They were less certain about explaining the initial or subsequent imbalance.

Option A — Sight and wave phenomena

1 SL only Rod cells

In part (a) the general shape of the graph was correctly drawn but the wavelength at maximum sensitivity was not well known. Answers to part (b) were almost always half correct but the lack of sensitivity for cones in the red region was rarely mentioned. Very few candidates made an appropriate reference to the graph as mentioned in the question.

2 SL only Standing (stationary) waves

Part (a) was answered well by many, but the idea of superposition of incident and reflected waves was often expressed poorly. Candidates seemed to have memorised the definition of how a standing wave is formed but often struggled to see how it applied to this situation. Part (ii) was easy if the candidate knew that the wavelength was 4L. Many just used L or other multiples of L. Part (b) was also an easy 2 marks as long as it was remembered that the waves were longitudinal.

3 SL only Diffraction and resolution

Parts (a) and (b) on single slit diffraction were well answered. However there were fewer correct answers for part (c) where effect of the different wavelengths of red and blue light were sometimes confused and the smaller θ interpreted as poorer resolution. Often the ability to resolve was explained incorrectly in terms of the intensity of the graphs drawn.

4 SL only Polarization

In part (a) the definition was often not specific enough, the idea that the electric field vector is oscillating rather than just light was often omitted. In part (b)(i) many stated that the ray would be polarized, but failed to mention totally. Part (b)(ii) was an easy mark. Although the exact shape of the transmitted intensity graph was not necessarily correct in (iii) most candidates knew that the maximum transmission occurred at 0° and 180°.

Option B — Quantum physics and nuclear physics

5 SL only The photoelectric effect

In part (a)(i) many correct answers were seen, however there were quite a few mistakes in converting the photon energy to eV. Part (a)(ii) was easy, but some candidates thought that the KE of the electrons needed to be used. Candidates found (b) difficult as the answer is slightly counter intuitive. Very few candidates seemed to know that equal intensity of light means equal total photon energy per second. Many assumed it meant equal number of photons per second. The answers were mostly disorganised and did not reflect a logical scientific argument that would be expected at this level.

6 SL only The hydrogen atom

In part (a) almost everyone drew just two transitions out of the three possible. In part (b) many candidates were able to identify the transition.

7 SL only Radioactive decay

Most candidates were very uncertain about determining a very long half-life. Part marks were often obtained for stating how half-life was obtained from the decay constant, but determination of activity and number of sample atoms was not usually mentioned. Most candidates described how the half-life of a nuclide with a short half-life can be found. In (b) surprisingly few candidates know the easy way to calculate fraction remaining. Find the number of half-lives passed (n). Fraction remaining = 0.5^n. This works even when n is non-integer. Most obtained at least 1 mark for finding the decay constant or the number of half-lives. Quite a few candidates assumed a proportional relationship for the non-integer part of n.

Option C — Digital technology

8 SL only Digital signals

Virtually everybody answered (a) correctly. In part (b) many candidates overlooked the factor of 2 due to stereo sampling but ECF was applied so that part marks were obtained.

9 SL only Charge-coupled device (CCD)

Part (a)(i) should have been very easy, but many candidates made careless POT errors. Mistakes were also made in part (ii) where 2 pixel widths are used to obtain the minimum resolution value or when magnification was ignored. In part (b) there were many correct answers, but often the question was repeated (eg photoemission followed by charge build up). In (c) most knew that the image would be brighter, etc, but did not mention the advantage of shorter exposure time. General and insufficient statements such as better quality were often mentioned.

Recommendations and guidance for the teaching of future candidates

The option topics allow candidates to experience some of the more challenging and interesting areas of Physics. However the importance of the fundamental principles of the subject should not be underestimated. Definitions and statements of laws are sometimes poorly expressed or largely guesswork. In general candidates tend to perform less well on the descriptive parts of questions, these are often the cause of the difference between a mediocre and good grade. In setting private study exercises it is helpful for candidates to be given not only numerical questions but also plenty of extended response questions which are marked rigorously. It is encouraging to see more candidates organizing their responses by utilizing bullet points. This technique not only assists with the planning of an extended response, but makes the marking of the response more reliable. Very often extended responses in descriptive questions are too verbose. The concise use of bullet points is a way of reducing unnecessarily wordy answers.

A common misconception is that units do not matter – because the incorrect or missing unit in a final answer is often not penalised. This is a dangerous assumption because mistakes with units, within the calculation, will obviously lead to an incorrect numerical value or power of ten error. These mistakes **are** penalised. Rigorous treatment of units is a fundamental and essential part of any Physics course, but based on current evidence units are not well handled by a large percentage of candidates. Teachers are encouraged to set exercises involving the manipulation of units wherever possible and to ensure that units feature prominently in any worked examples provided. The new Subject Guide places greater emphasis on the teaching of units, unit multipliers and powers of ten. This will be reflected in examination papers from May 2016.

Even though the May 2016 examinations will be based on a revised syllabus, past papers provide the opportunity for essential practise with the style of questions candidates will face. Giving candidates model answers (as well as discussing past markschemes) allows them to understand the level of response that is expected. These are often provided in IB Physics textbooks. In many schools model answers to homework exercises are routinely provided. The marking of key phrases in a question should be encouraged as so often an instruction or piece of information is missed. The mark for a question, given in the margin of the paper, is a useful indicator of the detail required in a response.

All candidates can benefit from being given the new IB Physics Subject Guide and Data Booklet. Both are useful learning tools and revision checklists. The Subject Guide and Data Booklet can be provided in teacher-annotated form, with textbook page references, web-site links and past paper question references. Although time consuming, it is so easy to do since both documents are in digital format. If they cannot be provided in this form at the beginning of the course, then the annotations can be added by candidates as the course progresses. Teachers are advised to have sessions, during revision, to explain the use of every equation and all items of data in the Data Booklet. Now that future candidates will only be able to answer questions from one of the four options it is vital that schools select an option that is both popular and suited to the abilities of both candidates and teaching staff. Some option topics may include material that staff have never taught or even seen before. Physics departments may need to have in-service training sessions to decide on the best strategy for teaching this new material. These new option topics are set in stone for the foreseeable future, so now is a good time to develop revised or new schemes of work.

School G2 comments sometimes complain that questions test information that is not in the Subject Guide. It is important to remember that the Subject Guide provides a framework – a list of aims, objectives and assessment statements – it is not meant to be a definitive list of facts. There are several excellent IB textbooks that interpret the various objectives. Physics department's schemes of work will usually make use of many additional online sources of information. IBO's OCC, Wikipedia, Hyper physics, CERN, NASA, Physics.org, outreach.atnf.csiro.au, phys.unsw.edu.au, etc, etc, provide a wealth of relevant and inspirational material. These can be organized by teachers into a very valuable learning resource, to supplement textbooks, in the teaching of the options (as well as the Core).