PHYSICS TZ1 (IBNA / IBLA)

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 15	16 - 28	29 - 39	40 - 49	50 - 59	60 - 69	70 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 25	26 - 36	37 - 45	46 - 56	57 - 65	66 - 100

Internal assessment

Component grade boundaries

Higher level

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

Standard level

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

General comments

The IB's expectations are being meet by the majority of schools. Teachers understand the IA criteria and are marking in a consistent and appropriate manner. Most schools required very little or no moderation. Many of the 4/PSOW reveal very good practical programs.

Often candidates were assessed by all three criteria in the same investigation. This allows for trial and error and the possible revision of the initial design ideas. This is good scientific practice. Assessing all three criteria in one investigation also allows candidates to better appreciate the IA expectations in the conclusion and evaluation.

There were several examples of the use of ICT in assessed work. This is good news and the IB encourages the use of ICT.

Some teachers are asking candidates for a hypothesis in their Design section, and although this is not penalized, a hypothesis is not required. Moreover, the lack of a hypothesis allows for a truly open-ended investigation. Perhaps a physical interpretation (along the lines of a hypothesis) could come into the first aspect of CE for the achievement level of complete.

On a more critical note, there are some trends that need correction. First, a noticeable number of schools are marking only two investigations or each criterion only twice. Sometimes, these are the first two labs listed on the 4/PSOW. This is unfair to the candidate who should have a number of chances at achieving their best two IA marks. Second and this is related to the first item, there are a number of candidates with noticeable low IA totals awarded by teachers. These have been checked and rechecked by moderators, and the low marks are truly justified. This is not encouraging. Teachers need to structure the teaching of IA in a way that allows candidates to improve, to learn from their mistakes, and do their best. In fact, the IB expects candidates do perform well on IA. For issues of guidance see the *Physics Course Guide* “Guidance and authority” pages 19-20.

Another critical point concerns graphs. Some teachers are accepting graphs that have hand drawn axes and estimated number lines as well as estimated data points. This is unacceptable at high school level. Candidates need to use printed graph paper for hand drawn graphs. Free graph paper software is readily available online. These candidates should be allowed a second chance at DCP. The majority of candidates, however, are successfully using graphing software.

A few teachers have little idea of what the Design criterion is about. For instance, there were examples of assessing Hooke’s law for Design, confirming Ohm’s Law, group work for assessment, and so on. The prompt “Investigate the relation between the current and the voltage for a metallic conductor, a filament lamp and an electrolyte” was given and then assessed on Design. The teacher also gave a handout with all the relevant theory and equations. This is a worthwhile investigation but it is not appropriate for assessment under the Design criterion.

Continuing this last critical point, there is the perennial problem of teachers assessing Design for an investigation that is already thoroughly understood by the candidate. In such cases, the candidate knows the relevant theory and equations. If teachers assess Design investigations where there is a standard textbook theory and relevant equations, such as the simple pendulum or the resistance of a wire, then it is essential that the labs be assigned before the relevant theory is covered in class. Too often candidates quote the relevant equation (and so there is no clear opportunity to select variables).

Under DCP, there were several cases of the teacher giving the candidate data tables with units, and the instructions of what to graph. This may be a good exercise but it is not appropriate for assessment.

Some teachers are giving ‘completes’ for DCP aspect 3 when graphs do not appreciate uncertainties; error bars and minimum and maximum gradients for linear graph lines are normally expected.

The range and suitability of the work submitted

The transition to the revised IA structure went very well. The majority of schools understood the requirements. Teachers continue to demonstrate an improvement in selecting appropriate labs for each criterion.

Problems occurred, however, when teachers assigned two clearly defined variables for design, or assessed design when determining a specific quantity, such as gravity.

The rule of thumb is to look for a function or relationship between two variables. Candidates need to make decisions and different candidates should come up with slightly different investigations given the same teacher prompt. Although hypothesis is no longer required under the planning of an investigation, some teachers are asking candidates for this. It should be noted that assessment does not address hypothesis. However, some physical interpretation may occur in CE, and hypothesis might appear here, but it is not required.

Data collection and presentation was done well. Occasionally teachers awarded full marks when units and uncertainties were absent, and of course these are required. Occasionally teachers would mark DCP when no graph was drawn. Under DCP candidates are expected to process data by graphing. Teachers need to access investigations that are appropriate to the criteria.

The majority of schools offered a diverse practical program with investigations ranging from low tech to the use of sophisticated equipment. Most schools covered a wide range of topics, but more than a few schools failed to provide candidates with practical experience on both options studied. Teachers are reminded that investigations on physics topics not in the syllabus can be appropriate for learning experimental skills. The majority of schools completed the required hours. There were a few suspicious cases, however, where (for example) a school claimed 4 hours of IA time for a thought experiment on gravity, and another school claimed 5 hours investigating Hooke's law. Moderators often question such claims.

DCP and CE are usually inappropriate for assessment when candidates work with simulations, such as radioactive decay using dice or a computer model of Snell's law. These are learning exercises but they are not appropriate for assessment. Standard textbook labs with standard classroom equipment are not usually appropriate for assessment under CE.

Candidate performance against each criterion

Design

The majority of schools are assigning appropriate design topics. The key to success under the design criterion is the teacher's prompt. It needs to direct a candidate toward a research question without doing the candidate's thinking for them. Variables need operational definitions. If a candidate says she will measure the size of a crater, then she needs to explain what the size is. Is it the width measured from rim tops, the depth measured from the level surface or just what? The terms independent, dependent and controlled variables need to be clearly understood by candidates.

Controlling variables was properly addressed in most cases but there were occasions where candidates needed to be more specific. Just saying, “I will measure the period of a pendulum” is not sufficient. Attention to detail is expected for a complete. Similarly, sufficient data requires an appreciation of the scope and range of values, as well as repeated measurements.

Most candidates are addressing these issues. Occasionally teachers over-mark this aspect. Teachers are reminded that moderators only know what is written out in the candidate’s report.

Data Collection and Processing

This criterion tends to earn the highest marks for candidates. The expectations are clearly spelled out in the IA descriptors. Teachers are reminded that the expectations for the treatment of errors, uncertainties and graph gradients are detailed in the Physics Course Guide syllabus. There were only a few instances where candidates were told what to graph. Teachers are reminded to read the clarifications in the Physics Course Guide under DCP for what is expected from the candidate. A few candidates drew free-hand graphs. The IB expects candidates to use graph paper or preferably graphing software.

A complete in DCP aspect 3 requires candidates to present processed data appropriately (without mistakes or omissions). The clarifications in the course guide state that a relevant graph will have appropriate scales, axes with units, properly plotted data points, a best-fit line, and that error bars and minimum and maximum gradients will be used to determine the uncertainty in the gradient. Section 1.2 of the syllabus gives the details of what is expected. Candidates may use more sophisticated methods of error analysis, such as standard deviation and other statistical methods, but the course guide explains the minimum level of error and uncertainty appreciation.

It is expected when assessment is made under DCP that candidates construct graphs. However, there may be exceptions to this, where DCP is appropriate for assessment but a graph is not appropriate. For example, perhaps candidates are using time-lapse photographs of a moon orbiting Jupiter and gather data to determine the gravitational constant, G. There would be raw and processed data, and raw and processed uncertainties. The final value of G would have an uncertainty range (and it would be compared to the accepted value) and yet no graph would be relevant. Such an investigation could earn a complete under DCP aspect 3.

There may be other examples of assessed work under DCP without graphs. In such cases the moderator must assess the type of investigation and determine if a high school candidate could have and should have constructed a graph. If a graph would have been relevant but one was not used, then a complete cannot be awarded to DCP aspect 3.

For example, in a simple pendulum experiment to determine g, a candidate may have processed data and found an average for gravity. Without a graph a possible systematic error (perhaps of wrongly determined length of the pendulum) would not have been revealed. In an example of a Boyle’s law experiment, the dead space in the pressure gauge would not be revealed without graphing the data. Or, when measuring the speed of sound with an open-ended resonance tube, only appropriate graphing reveals the end-effect. In all these cases the moderator could not accept a complete for DCP aspect 3 without a graph.

Finally, there is a type of experiment that may or may not be appropriate for graphing. In an experiment to measure the specific heat capacity of water, a candidate may process data and uncertainties correctly and then calculate a numerical value of c. However, it may be relevant to construct a graph in this experiment because of an experimental error in the heating process. A graph of temperature against time (for constant electrical power source) would reveal a non-linear temperature increase with time, hence revealing an important experimental error. In this case a graph is relevant and hence required for the work to earn a complete under DCP aspect 3.

When a candidate's investigation is assessed for Design as well as DCP then a graph is most certainly required. This is because, under Design, candidates should be looking for a function or relationship between two variables. These variables would then be appropriately graphed.

The conclusion from the above observations is that in the majority of investigations, a graph is expected. Teachers are advised that when assessing DCP graphs should be involved. However, there are exceptions. The moderator needs to determine whether or not the intentions of the physics syllabus statements about error analysis have been achieved without a graph and whether or not the candidate's investigation should have involved a graph.

Conclusion and Evaluation

CE aspect 1 achievement level 3 requires candidates to 'justify' their reasonable interpretation of the data. Going beyond a partial requires something more than summarizing the graph. Perhaps some physical theory, or at least some physical interpretation or meaning is required here. Candidates should ask themselves what the gradient of the graph means, what (if anything) a systematic shift in the graph might mean, and what the scatter of data points might mean. Aspect 1 is probably the most difficult of all IA to achieve a complete. Candidates often confuse the words "linear" with "proportional" when talking about a graph's line.

Recommendations for the teaching of future candidates

- Teachers should make sure that all assessed work is appropriate for assessment by the relevant criterion. This may sound obvious but there are numerous cases where candidates were denied possible marks because the teacher assessed inappropriate tasks. Remember that only a fraction of all the hours attributed on the 4/PSOW form need to be assessed.
- Although only the two highest marks per criterion are used to establish a candidate's IA grade, candidates need a number of opportunities at assessed work in order to improve and do their best. Some schools are marking only two sets of work, and this is unfair to the candidate.
- Teacher's are reminded to use only the most recent version of the 4/PSOW form (the current one has spaces for the moderator's and senior moderator's marks), and to include the 4/IA cover form. The PS mark is established with the group 4 projects but no evidence of the project is required for moderation. Remember to send only the lab samples that are to be moderated. Some schools are sending entire portfolios. Finally, candidates and teachers must sign and date the 4/PSOW form.
- There is ample evidence of the use of ICT. The IB encourages this. The majority of candidates are word-processing their lab reports, and many schools are using graphing software. The other ICT requirements are being met.

- Teachers are reminded of the teacher support material (TSM) that is available on the Online Curriculum Centre (OCC) physics pages. See Assessment, Internal Assessment, and then TSM. The material here covers issues of design, errors and uncertainties, MS and it includes 10 candidate labs that are marked with moderator comments.
- Teachers are allowed to respond to candidate questions as they do their experimental work and as they write up their reports. However, teachers must not grade a draft of a lab report, and teachers should respond to questions only by directing candidates routes of inquiry (and not answering questions directly). In assessing candidate work using IA criteria, teachers should only mark and annotate the final draft. See the section of the Physics Course Guide called "Guidance and authenticity" for more detail.
- It is essential when work is to be assessed that candidates work on their own. There cannot be a set of common data or identical results if the work is to be assessed.

Further Comments

This last section contains the advice that is given to physics IA moderators. Overall, moderators normally keep the teacher's marks, but occasionally they raise or lower marks. If the teachers have applied the criteria to appropriate tasks in good faith then the moderation system should support them. Moderators are not here to apply their own pet theories and practices as teachers, but to ensure that the schools are using the criteria within acceptable bounds according to the official descriptors. In other words, moderators are **looking for the systematic error beyond the random error in the application of the aspects of the criteria**. The following advice is given to the moderators.

When moderators mark down

Design

The moderator will mark down when the teacher gives a clearly defined research question and/or the independent **and** controlled variables. The teacher may give the candidate the dependent variable (as long as there are a variety of independent variables for the candidate to identify). Giving the candidate the general aim of the investigation is fine if the candidates have significantly modified the teacher prompt or question (e.g. made it more precise, defined the variables). The moderator will mark down when a method sheet is given which the candidate follows without any modification *or* **all** candidates are using identical methods. Standard laboratory investigations are not appropriate for assessment under Design.

Data Collection and Processing

The moderator will mark down when a photocopied table is provided with headings and units that are just filled in by candidates. If the candidate has not recorded uncertainties in any quantitative data then the maximum given by the moderator is 'partial' for the first aspect. If the candidate has been *repeatedly inconsistent* in the use of significant digits when recording data then the most a moderator an award is 'partial' for the first aspect. In physics data is always quantitative. Drawing the field lines around a magnet does not constitute DCP.

The moderator will mark down when a graph with axes already labelled is provided (or candidates have been told which variables to plot) or candidates follow structured questions in order to carry out data processing. For assessment under DCP aspect 3, candidates are expected to construct graphs.

For a complete, the data points on the graph should include uncertainty bars, and the uncertainty in the best-straight line gradient needs to be calculated. The method for this is often the minimum and maximum gradients using the first and last data points.

Conclusion and Evaluation

If the teacher provides structured questions to prompt candidates through the discussion, conclusion and criticism then, depending on how focused the teacher's questions are and on the quality of candidates' response the maximum award is *partial* for each aspect the candidate has been guided through. The moderator judges purely on the candidates input. The difference between a partial and a complete for CE aspect 1 involves the justification of their interpretation of the experimental results. This is a difficult task, and it can involve physical theory.

When moderators do not mark down

In the following cases the moderator will support the teacher's stance, as they are aware of their own expectations of the candidates.

Design

Moderators do not mark down when the independent and controlled variables have been clearly identified in procedure but are not given as a separate list (we mark the whole report and there is no obligation to write up according to the aspect headings). Moderators do not mark down when there is a list of variables and it is clearly apparent from the procedures which is independent and which are controlled.

Moderators do not mark down when similar (but not word for word identical) procedures are given for a narrow task. The moderator will make a comment though on the poor suitability of task on 4/IAF form. Moderators do not only mark the equipment list, they give credit for equipment clearly identified in a stepwise procedure. Remember moderators look at the whole report. Moderators do not insist on +/- precision of apparatus to be given in the apparatus list. This has never been specified to teachers and the concept of recording uncertainties is dealt with in DCP. Moderators do not downgrade a teacher's mark if something as routine as safety glasses or lab coats are not listed. Some teachers consider it vital to list them each time and some teachers consider them such an integral part of all lab work that they go without saying. Moderators support the teacher's stance here.

Data Collection and Processing

In a comprehensive data collection exercise possibly with several tables of data the candidate has been inconsistent with significant digits for just one data point or missed units out of one column heading, then the moderator will not mark this minor error down. If the moderator feels the candidate has demonstrated that they were paying attention to these points and made one careless slip then the moderator can still support maximum marks under the 'complete not meaning perfection' rule. This is an important principle since good candidates responding in full to an extended task unfairly get penalized more often than candidates addressing a simplistic exercise. The candidate is not marked down if they have not included any qualitative observation(s) and the moderator cannot think of any that would have been obviously relevant. The moderator does not mark down if there is no table title when it is obvious what the data in the table refers to. Often candidates do all the hard work for DCP and then lose a mark from the class teacher because they did not give the table a title. Except for extended investigations it is normally self-evident what the table refers to.

The expectation for the treatment of errors and uncertainties in physics is described in the Course Guide and the TSM. Both standard level and higher-level candidates are assessed on the same syllabus content and the same standard of performance. All raw data is expected to include units and uncertainties.

The least count of any scale or the least significant digit in any measurement is an indication of the minimum uncertainty. Candidate may make statements about the manufacture's claim of accuracy, but this is not required. When raw data is processed, uncertainties need to be processed (see the Course Guide, syllabus section 1.2.11)

Candidates can estimate uncertainties in compound measurements (± half the range), and they can make educated guesses about uncertainties in the method of measurement. If uncertainties are small enough to be ignored, the candidate should note this fact.

Minimum and maximum gradients should be drawn on linear graphs using uncertainty bars (using the first and last data points) for only one quantity. This simplified method becomes obscured when both graph quantities contain uncertainty bars. Other uncertainty analysis is expected when graphs are non-linear.

If the candidate has clearly attempted to consider or propagate uncertainties then moderators support the teacher's award even if they may feel that the candidate could have made a more sophisticated effort. If propagation is demonstrated in part of the lab then full credit can be awarded even if error analysis is not carried through in every detail (as long as the candidate has demonstrated an appreciation of uncertainty then they can earn a complete). Moderators **do not** punish a teacher or candidate if the protocol is not the one that you teach i.e. top pan balance uncertainties have been given as +/- 0.01g when you may feel that if we consider the tare weighing then it should be doubled. Moderation is not the time or place to establish the favoured IB protocol.

Conclusion and Evaluation

Moderators often apply the principle of 'complete' not meaning perfect. For example, if the candidate has identified the most sensible sources of systematic error then the moderator can support a teacher's award even if the moderator can identify one more. Moderators are a bit more critical in the third aspect that the modifications are actually relating to the cited sources of error. If the moderator feels a task was too simple to truly meet the spirit of the criteria, then comments on the 4IAF as to the unsuitability of the task giving full justifications will be provided in feedback but the moderator will not necessarily downgrade the candidate. This does mean that candidates could get high DCP marks for some quite brief work on limited data but, if they have fulfilled the aspect's requirements within this small range, then the moderator will support the teacher's marks.

The most challenging aspect of CE is the differentiation between a partial and a complete under aspect 1: "States a conclusion, with justification, based on a reasonable interpretation of the data." A justification may be a mathematical analysis of the results, one that includes an appreciation of the limits of the data range, but it might also be an analysis that includes some physical meaning or theory, even a hypothesis (though a hypothesis is not required). It is difficult to earn a complete in CE (aspect 1) because serious and thoughtful comments are required, something beyond "the data reveal a linear and proportional relationship". See the last paragraph in the Conclusion and Evaluation comments in section B above.

Paper one

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 14	15 - 19	20 - 23	24 - 26	27 - 30	31 - 40

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 11	12 - 15	16 - 17	18 - 20	21 - 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.

Only a small percentage of the total number of teachers or the total number of Centres taking the examination returned G2's. For SL there were 21 responses from 437 Centres and for HL there were 15 responses from 236 Centres. Consequently, general opinions are difficult to assess since those sending G2's may be only those who feel strongly in some way about the Papers. The replies indicated that the May 2010 papers were generally well received, with many of the G2's received containing favourable comments. The majority of the teachers who commented on the Papers felt that they contained questions of an appropriate level and of a similar standard to last year's paper.

With few exceptions, teachers thought that the papers gave satisfactory or good coverage of the syllabus. When commenting on coverage, it should be borne in mind that this must be judged in conjunction with Paper 2. Most teachers also felt that the presentation of the papers was either satisfactory or good.

There was clearly, however, an issue with the clarity of the wording which was judged to be poor by just over half of the HL respondents. Comments indicated that questions where two things are being tested simultaneously (e.g. SL Q23 or HL Q14) are confusing despite these being a common feature of past papers.

There were also quite a few comments that there were too many definitions being tested. We would stress, however, that definitions should be learnt by candidates and that Paper One is an appropriate place for the nuances of these to be tested. Similarly, certain facts (e.g. the size of a proton or the wavelength of red light) do need to be memorized and candidates can expect these facts to be assessed in Paper One.

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 an asterisk (*). 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.

HL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	1322 *	619	366	172	12	53.07	0.24
2	752	700	114	924 *	1	37.09	0.52
3	133	370	322	1665 *	1	66.84	0.20
4	208	1184 *	330	767	2	47.53	0.34
5	420	1242 *	165	663	1	49.86	0.39
6	197	56	2189 *	48	1	87.88	0.26
7	356	361	1455 *	316	3	58.41	0.37
8	755 *	607	120	1005	4	30.31	0.28
9	1804 *	67	135	481	4	72.42	0.34
10	368	202	1816 *	103	2	72.90	0.21
11	307	943 *	313	925	3	37.86	0.29
12	922 *	786	124	655	4	37.01	0.49
13	656	930 *	490	409	6	37.33	0.26
14	109	211	69	2101 *	1	84.34	0.27
15	79	402	1652 *	355	3	66.32	0.45
16	297	338	1703 *	149	4	68.37	0.30
17	256	1528*	542	159	6	61.34	0.29
18	257	906	1174 *	150	4	47.13	0.32
19	550	689	420	821 *	11	32.96	0.24
20	1344 *	458	254	431	4	53.95	0.33
21	475	120	312	1571 *	13	63.07	0.46
22	588	300	1046 *	538	19	41.99	0.40
23	424 *	463	427	1170	7	17.02	0.09
24	857 *	1321	223	83	7	34.40	0.53
25	196	1019 *	491	776	9	40.91	0.25
26	750	637 *	199	901	4	25.57	0.29
27	119	242	1950 *	168	12	78.28	0.37
28	2112 *	156	131	85	7	84.79	0.30
29	1295 *	596	402	174	24	51.99	0.53
30	645	782	213	848 *	3	34.04	0.36
31	354	468 *	1467 *	186	16	77.68	0.28
32	519	1711 *	119	134	8	68.69	0.39
33	411	248	1717 *	103	12	68.93	0.37
34	739	992 *	501	212	47	39.82	0.18
35	510	1403 *	190	378	10	56.32	0.49
36	52	120	129	2182 *	8	87.60	0.23
37	158	349	1136	839 *	9	33.68	0.42
38	1517 *	108	669	185	12	60.90	0.38
39	1653 *	618	107	109	4	66.36	0.50
40	223	379	141	1742 *	6	69.93	0.47

Number of candidates: 2491

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	2558 *	1080	1078	586	11	48.15	0.25
2	1263	2360	340	1342 *	8	25.26	0.37
3	870	3097 *	1232	110	4	58.29	0.34
4	765	450	2934 *	1158	6	55.22	0.37
5	693	2066 *	848	1698	8	38.89	0.19
6	981	813	259	3256 *	4	61.28	0.61
7	2079	1542 *	499	1190	3	29.02	0.14
8	705	188	4254 *	163	3	80.07	0.40
9	113	164	747	4287 *	2	80.69	0.40
10	1014	1838 *	1082	1367	12	34.59	0.28
11	1454 *	2129	358	1367	5	27.37	0.37
12	381	1133	2995 *	797	7	56.37	0.47
13	760	795	3320 *	408	30	62.49	0.37
14	793	2756 *	1396	359	9	51.87	0.32
15	989 *	3675	211	435	3	18.61	0.03
16	214	1802	2625 *	624	48	49.41	0.44
17	2693	239	168	2207 *	6	41.54	0.09
18	863 *	1348	1216	1878	8	16.24	0.03
19	1185 *	3243	667	193	25	22.30	0.37
20	155	3505 *	232	1404	17	65.97	0.38
21	372	2007	368	2552 *	14	48.03	0.21
22	310	1092	622	3277 *	12	61.68	0.53
23	431	628	3763 *	465	26	70.83	0.35
24	1106	3010 *	554	626	17	56.65	0.60
25	665	393	3826 *	424	5	72.01	0.43
26	195	429	380	4296 *	13	80.86	0.31
27	3095 *	308	1374	521	15	58.25	0.40
28	3213 *	1495	287	299	19	60.47	0.51
29	798	991	487	3011 *	26	56.67	0.58
30	256	4472 *	310	258	17	84.17	0.30

Number of candidates: 5313

Comments on the analysis

Difficulty

The difficulty index varies from about 17% in both HL and SL (relatively ‘difficult’ questions) to about 88% in HL and 84% in SL (relatively ‘easy’ questions). The majority of items were in the range 30% to 70%. Thus, the Papers provided ample opportunity for all candidates to gain some credit and, at the same time, gave an adequate spread of marks.

Discrimination

All questions had a positive value for the discrimination index. Ideally, the index should be greater than about 0.2. This was achieved in the majority of questions. However, a low discrimination index may not result from an unreliable question. It could indicate a common misconception amongst candidates or a question with an extreme difficulty index.

'Blank' response

In both Papers, the number of blank responses tends to increase towards the end of the test. This may indicate that candidates did not have sufficient time to complete their responses, despite a lack of comments from teachers to this effect. Candidates should be reminded that there is no penalty for an incorrect response. Therefore, if the correct response is not known, then an educated guess should be made. In general, some of the 'distracters' should be capable of elimination, thus reducing the element of guesswork.

In general we would advise against candidates leaving a response blank in the hope that they will be able to return to it.

Comments on selected 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, i.e. those that illustrate a particular issue or drew comment on the G2's.

Please note that the rubric invites the candidates to select the 'best' answer and that the question stem is kept as short as possible given this requirement.

SL and HL common questions

SL Q2 and HL Q2

A majority of candidates clearly had not translated the absolute uncertainties into percentages.

SL Q10 and HL Q11

D was a common distracter indicating that many candidates were unfamiliar with expressions such as 'a mole of water' or 'a mole of marbles'.

SL Q18 and HL Q23

At both levels the most popular response was D, with A, the correct answer, being the least popular. It must be stressed that candidates are expected to learn rigorous definitions.

SL Q19 and HL Q24

The inverse square law means that halving the radius of a planet results in quadrupling the gravitational field strength at its surface.

SL Q27 and HL Q38

Only in certain reactors does the moderator also have the role of cooling the reactor down. The best answer is therefore A.

SL Q28 and HL Q39

Some teachers argued correctly that a photovoltaic cell was a type of solar panel. In the context of this question, though, it is clear that a solar *heating* panel is meant. The response options allowed only A to be correct.

HL Questions

Q6

The vast majority of candidates gave the correct response, assuming the particle to be travelling in a straight line. Some teachers reasoned that the correct response could have been C if the particle were travelling in a circular orbit. But the candidates are invited to give the *best* answer, which they clearly did in this case.

Q8

Gravitational potential is defined in terms of moving a *small* mass. This is, yet again, a matter of candidates learning their definitions.

Q13

B is clearly the best response even though it does not read ‘very low pressure’.

Q25

If eddy currents are induced in the copper sheet, then there will clearly be damping of the oscillations. Hence B is the only possible answer.

Q31

Many candidates answered C which was, on reflection, accepted alongside the intended correct response of B. The Bainbridge mass spectrometer is indeed usually used to compare the masses of isotopes, although it does this by measuring the masses of the respective ions.

SL Questions

Q7

This question refers to the total energy of the system. Many candidates answered as though it were referring only to the kinetic energy of the system.

Q15

This question highlighted a common confusion between *displacement* and *amplitude*.

Recommendations and guidance for the teaching of future candidates

Candidates should make an attempt at every item. Where they cannot provide the correct response, then they should always choose that option which, to them, appears to be most likely. It should be emphasised that an incorrect response does not give rise to a mark deduction.

The stem should be read carefully. 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.

Having decided on the correct response, candidates should check that all other options are not feasible.

Candidates should consult the current Physics Guide during preparation for the examination, in order to clarify the requirements for examination success.

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 Guide. Ample time should be apportioned to the teaching of such topics as Global Warming and the Greenhouse Effect. The common knowledge that most people have about these areas of the Guide is not always sufficient to answer questions on these topics, which are not trivial.

Paper two

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 21	22 - 30	31 - 40	41 - 51	52 - 61	62 - 95

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 5	6 - 10	11 - 14	15 - 19	20 - 24	25 - 29	30 - 50

Only 28 G2’s were received from SL teachers and 7 from HL teachers. In both tests, 50% of teachers found the examination to be of a similar standard to last year’s paper. One-third of HL teachers found the paper a little easier in comparison, whereas 20% found that SL was a little more difficult.

The vast majority of teachers found the papers to be of an appropriate level of difficulty, and were either satisfied with the syllabus coverage, clarity of wording and presentation of the paper or found these essential elements to be good.

15% of SL and HL teachers thought the syllabus coverage was poor.

General comments

Some of the issues noted last year are still apparent. Candidates are relying on background reading rather than the development of a good physics understanding. Teachers are strongly advised to give the full weight to each topic as dictated by the syllabus Guide.

Definitions continue to be poorly learnt and poorly expressed.

The comment about poor expression extends also to written explanations. Candidates should take the opportunity to pause for a moment to consider their answer before committing to paper.

In questions that involve the command terms “show that” and “determine”, candidates must be aware that a logical and complete solution will be required for full marks. Bald answers never attract full credit when the command terms come from the objective 3 group.

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

- giving definitions clearly and accurately
- presenting calculations in a clear and logical way
- calculations in the general area of Topic 8.
- physical mechanisms in descriptions of charge-coupled devices
- descriptions of wave interference
- projectile motion, especially taking and re-combining horizontal and vertical components
- atomic physics
- use of a ruler in drawing or completing diagrams

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

- calculations involving simple mechanics
- simple electrical calculations

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

A1 Data analysis

a) Candidates were at a loss as to how to use data from the graph to confirm the hypothesis. This was simply a matter of showing that the product of R and T values for two or more data points did not produce the same value.

b) (i) There was no real evidence that candidates misunderstood the term lg (for $\log_{10}$) as many were able to carry through the calculation at the end of this part. However there was some comment about this on G2 forms. Teachers should note that the lg form is quoted in the Guide in the mathematical requirements (p130) at both examination levels and will continue to be a requirement at both Hl and SL.

Most candidates failed to use the quoted equation and to make it clear to the examiners that they understood how the three terms in it have a bearing on the equation of a straight line.

(ii) b should have been derived from a calculation of the gradient of the line. Too many were content to substitute into the equation using data points *that did not lie on the line*. This will always be penalised either in method terms or because it leads to an answer that will generally lie outside the range accepted by examiners.

A2 Forces

Significant figure errors and unit omissions or errors were common throughout this straightforward part of the syllabus. Candidates must take much more care in this respect.

a) Most candidates were able to evaluate *F* correctly, but too many took the component of 470 N again.

b) Some candidates were unable to identify which force value to use.

c) There are two issues involved in the explanation of energy changes when the athlete drags the load uphill. The friction remains constant and there is an additional force required to allow the increase in gravitational potential energy. It was rare to see both points made despite the clear indication that there are two marks for the question.

A3 Solar heating panels

Some G2 forms complained that the phrase “solar heating panels” was not continued throughout the question. This was not necessary in this context as the topic was clearly indicated in the first line of the question. Question writers have to strike a balance between brevity and completeness but in this case there was no problem. Some teacher comments remarked on the lack of the term “heating panels” in the part (b), but candidates could have answered either in terms of water heating (which most did) or photovoltaic cells to gain credit.

a) Many candidates produced correct – if sometimes confused – solutions although a small number could gain only two marks maximum because they evaluated the area of panel required for one house. Units were surprisingly poor in this part.

b) Most candidates gave one convincing disadvantage, the other tended to be very vague.

A4 HL only Generator and emf

a) There were very few correct definitions of electromotive force. Candidates either do not understand this or they are learning the wrong idea.

b) The calculation was well done by many, but the graph sketch was poor both in terms of physics and presentation. Most candidates at this level should be able to draw an acceptably shaped sine curve. The physics both in terms of sketch and explanation showed only a weak understanding of Faraday’s law. Most were able to refer to the obvious point that halving the speed of rotation doubles the time for one period of rotation of the generator. The point that this also reduces the maximum emf was widely ignored; equally, the explanation for this was usually missing. This was an “explain” question and was the first question where candidates did not fully appreciate the requirements of the examiners.

A5 HL only Ideal gas

a) Candidates could easily identify the isochoric change and go part way to use data from the graph. However, in this part (ii) most only looked at two data points (using the end points of AB) rather than the three that are required to be entirely confident that the change is isothermal. It was rare to see candidates who understood when thermal energy was transferred to the gas. The calculation of work done by the gas was straightforward and well done.

b) The calculation was generally well done and explained.

c) Explanations for the difference in behaviour between temperature changes at constant volume and pressure were weak with some having an unsuccessful recourse to the laws of thermodynamics.

B1 Part 1 HL and SL Solar radiation

a) Answers often omitted a consideration of the temperature units.

b) (i) Weak answers often omitted the 4π factor in the calculation.

(ii) This standard calculation eluded many and perhaps indicates that this topic is not frequently rehearsed.

(iii) The reasons stated for the variation in power absorbed at the Earth's surface were weak and it was clear that candidates were giving vague answers rather than basing their work on solid physical effects.

(iv) This was a "show that" and candidates usually failed to do this convincingly. It was rare to see a considered statement *in words* of the energy balance.

c) and (d) These parts revealed how poor is candidates' understanding of the greenhouse effect and the enhanced greenhouse effect. There was little discussion of the essential wavelength shift and this was rarely related to temperature. Although candidates recognised (in (d)) that there were increases in the levels of greenhouse gases, these were not usually taken further. Discussions were vague and inconclusive. These topics do not appear well understood.

B1 Part 2 HL Charge-coupled devices

a) Expressions of the advantages of the use of CCDs continue to be too vague and non-physical.

b) The calculation was often well done, but too many weaker candidates cannot find their way through a multi-step calculation such as this.

c) Candidates were asked to outline the production of a voltage signal. There was little discussion of the role of capacitance. They were then expected to outline the storage of the information. There was little attempt to give a coherent description of the way in which the potentials on the pixels are recovered systematically.

B1 Part 2 SL Mechanics

a) Too many are continuing to use kinematic equations in an inappropriate context rather than comparing kinetic and gravitational potential energies at different points in the motion.

b) This was well done by many.

c) There was a general failure to recognise the importance of centripetal motion in the changes in tension in the string. Few could get beyond evaluating the tension force in the string when the system is stationary in part (ii).

B2 Part 1 HL and SL Wave motion

a) [HL] The statement of the nature of a travelling wave was very poor.

b) [HL] and a) [SL] The data collection from the graph and subsequent calculations were well done.

c) and b) The diagrams of the wavefronts were only moderately completed. Generally, large numbers of candidates fail to use a ruler to draw straight lines whether on graphs or diagrams. Taken to extremes this will lose marks. Examiners were looking for parallel lines as part of one of the marks available. It is difficult to see how a candidate can be awarded this mark when the line is non-straight, thick or ill-drawn.

d) and c) Discussions of the formation of regions of minimum disturbance were well done, but often candidates forgot to mention the link between the increase in oscillation frequency and decrease in wavelength in part (ii).

B2 Part 2 HL Projectile motion

This detailed projectile-motion question left many struggling because they do not fully understand that horizontal and vertical motion in a gravitational field are independent. The question was in the unusual context of a set of time-lapse photographs and candidates simply did not read the question thoroughly enough to get understand how to proceed. There was also a failure to recognise that the final speed (part b)) is made up of two components.

B3 Part 1 Hl and B2 Part 2 SL Nuclear processes

a) Examiners were surprised to find that very many candidates cannot identify proton and nucleon numbers.

b) Reasons for the motion of the alpha particle and radon nucleus after a radium disintegration were poorly expressed and only rarely convincingly related to the conservation of momentum.

c) The majority knew what ionization was but in the ensuing calculations often had problems when dealing with the units expressing the answer in eV (partial credit given).

d) [HL] and c) [SL] The reasons for the differences in range in air between beta and alpha particles were poorly linked. Candidates often discussed the mass or charge or speed differences but rarely indicated why these factors are important.

B3 Part 2 HL Radio waves

a) Candidates usually calculated the frequency shift with some success and went on to identify the direction of the shift. However, the lack of frequency change when the satellite and shuttle are at the closest point of approach was rarely seen.

b) The Rayleigh criterion was recognised as relating to resolution but it was unusual to see a clear description of it. The calculations were very mixed, most candidates got one of the two calculations incorrect but could continue to make a correct judgement of resolution from incorrect figures.

B4 Part 1 HL and B3 Part 2 SL Electrical heater

a) The calculations were well done by many candidates who are clearly well rehearsed and at home with the physics.

b) Few candidates obtained all 3 marks with their diagrams which were in general poor in quality. The direction of the field was often correct, but the shape of the field in 3D was usually poor. Many candidates think that the field has a helical shape. Discussions of the attraction or repulsion of wire turns were also incomplete with sometimes simple bald unexplained statements of the overall effect.

B4 Part 2 HL Hydrogen atom

a) Many could calculate the energy of the photon of light with ease.

b) Candidates focussed their answers on the absorption of the light, with some success. However, they usually failed to consider the re-emission of the light in directions other than that of the emergent beam.

c) Good discussions of the Schrodinger model of the hydrogen atom were rare. Many were able to give low-level statements about wave probabilities but these were rarely linked to the discrete energy states of the electrons.

B3 Part 2 SL Latent heat changes

a) Few could give consistent suggestions as to why the energy of melting is less than that associated with boiling.

b) Likewise in the next part, distinctions between evaporation and boiling were vague and ill-expressed. Many could get half way through the calculation by calculating the energy released by the steam, but then omitted the energy released by the steam in cooling from 100°C to 80°C. Reasons expressed for the underestimate in the mass of steam required were good and thoughtful.

Recommendations and guidance for the teaching of future candidates

- Invite candidates to learn correct definitions.
- Ensure that candidates understand the meaning and requirements of the command terms.
- Ensure that candidates understand the physical principles that underpin Topic 8 subjects
- Insist on calculations being set out in a logical and communicative fashion.

Paper three

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 21	22 - 26	27 - 32	33 - 37	38 - 60

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 3	4 - 6	7 - 10	11 - 14	15 - 18	19 - 22	23 - 40

General comments

The majority of candidates appeared to find the Paper accessible with many examples of good understanding of the material. There was no evidence that candidates were short of time to complete their work.

The feedback from teachers on the G2 forms for SL and HL is summarized as follows. However, it should be realised that fewer than 20 Centres submitted G2 forms at SL and fewer than 10 at HL!

Standard Level

- 56% found the paper to be of a similar standard to last year, 6% easier, 28% a little more difficult and 6% much more difficult. Overall, 70% found the paper to be of an appropriate standard and 30% thought it too difficult.
- about 30% found the syllabus coverage satisfactory, but 70% thought it was poor.
- about 60% found the clarity of wording satisfactory and 25% found it good with 15% finding it poor.
- about 55% found the presentation satisfactory and 35% found it good whereas 10% found it poor.
- The most popular option by far was A (Eye, sight and wave phenomena), followed by G (Electromagnetic waves), B (Atomic, nuclear and quantum physics) and E (Astrophysics) in roughly equal numbers.

Higher Level

- about 43% found the paper to be of a similar standard to last year, 29% found it much easier and 14% too difficult. Overall, 88% found the level of difficulty appropriate and 12% thinking it too difficult.
- about 57% found the syllabus coverage satisfactory and 43% good.
- About 57% found the clarity of wording satisfactory, 29% found it good and 14% found it poor.

- about 43% found the presentation satisfactory and 57% thought it was good.
- The most popular options were E (Astrophysics) and H (Relativity) in roughly equal numbers followed by G (Electromagnetic waves). There was a marked absence of scripts in the new options F (Communications) and J (Particle physics). Medical physics (Option I) was also underrepresented.

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

Even though this was the third time the new syllabus was examined teachers still stayed, mainly, with the old option topics. For the remaining options the areas identified by the examination team as being difficult were as follows:

- The definition of critical density in Astrophysics.
- Calculations with apparent brightness and luminosity in Astrophysics.
- FM modulation in Communications.
- Dispersion in Communications.
- Advantages and disadvantages of geostationary and polar satellites in Communications.
- The mobile phone system in Communications.
- The operational amplifier in Communications and Digital technology.
- The explanation of the red atmosphere during sunsets in Electromagnetic waves.
- The explanation of the characteristic spectrum of X – rays in Electromagnetic waves.
- The explanation of coloured soap films in Electromagnetic waves.
- The identification of a proper time interval in Relativity.
- The twin paradox in Relativity.
- The explanation of the gravitational redshift in Relativity.
- The understanding of NMR and magnetic resonance imaging in Medical Physics.
- The definitions of the basic quantities of radiation dosimetry in Medical Physics.
- The definition of a virtual particle in Particle physics.
- The discussion of the uncertainty principle in Particle physics.
- The bubble and wire chambers in Particle physics.
- Explanations of the mater – antimatter asymmetry in Particle physics.
- Understanding and use of the Doppler effect in Sight and wave phenomena.
- Polarization and stress analysis in Sight and wave phenomena.
- Discussion of an experiment to verify de Broglie's hypothesis in Quantum and nuclear physics.
- Calculation of the distance of closest approach in Quantum and nuclear physics.

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

Simple mathematical calculations were often done well by the majority of candidates. In fact, it was good to see that candidates were able to choose the correct formula and substitute in it correctly. Many candidates appeared well prepared and able to produce some excellent answers that showed a good understanding of the concepts, particularly in options E, F, H and G.

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

SL only

Option A – Eye, Sight and Wave phenomena

A1 Eye and sight

Very many candidates were able to score points by correctly defining and explaining accommodation. There were mixed responses to how the visual impression of temperature is achieved.

A2 The Doppler effect

There were few correct answers explaining the factors of 2 and $\cos\theta$. The formula for the frequency shift does contain *c*, the speed of the wave and the speed of the wave was clearly stated in the question. Candidates must learn that there is a variety of ways in which symbols can be assigned to various quantities and the context of the question decides what that assignment is, provided the question is read carefully. Many candidates took *c* in the question to mean the speed of light and so obtained a very large speed for the blood cells (that did not appear to cause any thought for reconsidering the answer). The markscheme allowed for these answers.

A3 Polarization

There were poor and vague answers about what is meant by polarized light. There were very few correct answers to the use of polarization in stress analysis. Many candidates answered in terms of psychological stress in humans (often the teacher of the candidate) caused by shining polarized light at them. Candidates clearly were underprepared for this. Whereas the examining team recognizes that the allocation of six marks to this question was perhaps excessive, the topic examined is firmly in the syllabus.

Option B – Atomic, Quantum Physics and Nuclear Physics

B1 The de Broglie hypothesis

The first part of the question was done reasonably well with many candidates. However there was almost a complete absence of any reasonable discussions of an experiment to verify the de Broglie hypothesis. Calculations of the de Broglie wavelength were generally good but as often happens when the answer is given, there were many scribbled numbers out of which the final answer mysteriously appeared.

B2 Alpha particle scattering

This was poorly done. Even the most essential point of this question, the conversion of the kinetic energy of the alpha particle into electrical potential energy was missed by many candidates. There were problems in the conversion of the MeV into joules as well as in identifying the charges of the particles involved.

B3 Radioactive decay

This was the question in this option that candidates answered well, particularly part (b) that required use of the radioactive decay formula. The first part, requiring an explanation of how the neutrino accounts for the continuous positron spectrum was not as well done. Candidates often referred to the “missing energy” without explaining what they meant by this phrase.

Option C – Digital technology

C1 Storing information

There were straightforward questions in this part of the option and candidates did manage to collect points but the answers were often vague and general. Clear reasons were not given as to why digital storage is replacing analogue storage of information. There is also a misconception that digital storage is storage of information that can *never* lead to loss of the information.

C2 The operational amplifier

This question was identical to question F5 in option F and the reader is referred to the comments in that question.

C3 The mobile phone system

This question was identical to question F4 in option F and the reader is referred to the comments in that question.

Option D – Relativity and particle physics

D1 Relativistic kinematics

This question was similar to question H1 in option H and the reader is referred to the comments in that question. The difference is that the SL question did not contain part (c) of the HL question.

D2 Fundamental interactions

This question was identical to question J1 in option J and the reader is referred to read the comments for that question.

SL and HL combined

Option E – Astrophysics

E1 Properties of a star

The first part of this question dealt with the parallax method for determining distances to stars and was generally well answered but perhaps not as well as in past years. Many candidates missed the point that two measurements, six months apart had to be made and comparison of the positions of the star in the two photographs relative to the distant stars had to be made. Part (b) required the luminosity ratio of Wolf to the Sun given the ratio of the apparent brightness of the two stars. As is usually the case this is an all or nothing type of question. Candidates who have practiced this type of questions do well and those who haven't get confused with meaningless strings of numbers. Parts (c) and (d) were well answered for the most part.

E2 Density of the Universe

It was clear that many candidates had a good idea of what was happening here but lack of precision in the answers prevented them from collecting many points. Most defined critical density as that density for which the Universe was flat but the definition of flatness was omitted. Most could produce the correct graphs in part (b) with the occasional mistake of getting the densities the wrong way around.

E3 [HL only] Stellar evolution

Stellar evolution in this syllabus is such a standard topic for examinations that it is surprising that it is not studied more thoroughly. Most candidates missed the crucial point of the conversion of gravitational potential energy into kinetic energy as the gas contracted. In part (c) the question asked for the end products of a nuclear fusion reaction and not end products in stellar evolution. This is a case where reading the question carefully pays.

E4 [HL only] Galactic motion

This standard question was well done by most candidates who could also identify the difficulty in measuring distances as the main cause for the uncertainty in the Hubble constant.

Option F – Communications

F1 Frequency modulation

This was a straightforward question on the basics of FM modulation but it was not answered well except for a handful of candidates. The concept of frequency deviation appeared to be unknown to the candidates and most could not state that the modulated wave has a constant amplitude.

F2 Optic fibre transmission

Part (a) dealt with attenuation and signal noise and this was generally well done but part (b) that asked for the reasons of the increased duration of the signal was not answered clearly, with very few references to dispersion.

F3 Satellites

There were surprisingly very many confused answers to what a geostationary satellite is. It was disappointing to see answers where it was stated that a geostationary satellite is "stationary". There were few correct answers in stating (let alone in explaining) the advantages of the two types of satellites.

F4 [HL only] The mobile phone system

This was a very poorly done question with candidates unable to score many points other than the point that the "base station sent a signal to the cell phone".

F5 [HL only] The op amp

As in the last two exams on the new syllabus, questions on the op amp are very poorly done. It is clear that candidates have not had any substantial exposure to this topic and have not spent much time doing problems with op amp circuits.

Option G – Electromagnetic waves

G1 The compound microscope

It was extremely disappointing to see so many incorrect answers to what should have been a straightforward question to anyone who studied the microscope at some level of detail. Questions on lenses, ray diagrams and optical instruments continue to be a weak point for the majority of candidates. The part on spherical aberration was answered relatively well but chromatic aberration seemed to have been beyond the capabilities of most candidates.

G2 Scattering of light

The majority of candidates failed to correctly answer this basic question. Most made references to refraction, diffraction and every other wave phenomenon except the role of scattering and its dependence on wavelength. Few candidates seemed to know approximate values for blue and red wavelengths of light.

G3 Two source interference

This part was generally well done (most could do the numerical calculation of the fringe separation) but the explanation of why an interference pattern forms on the screen (a basic point) was not well done. The effect of reducing the intensity in one slit was partially done by candidates: most could see that the bright fringes would decrease in intensity but not many cared to comment on the dark fringes.

G4 [HL only] X-rays

The calculation of the minimum wavelength was well done by most candidates but the majority of those who got the answer correctly missed that the question asked for the range of the wavelengths produced in the tube. Part (b) asked for an explanation of the origin of the characteristic spectrum and this was poorly done. There was a lack of detail as to which electrons get knocked out of the atom and what happens consequently.

G5 [HL only] Thin films

Many could draw the rays correctly but the explanation of why the film appeared coloured escaped most candidates. This was another example that certain topics in the syllabus are barely touched in any detail by very many candidates.

HL only

Option H Relativity

H1 Relativistic kinematics

As has often been the case in the past candidates have a very difficult time identifying when a time interval is a proper time interval. Most candidates said that Ann measured the proper time interval but often gave incorrect reasons for this. The most common reason given was that Ann was at rest in her frame of reference or that she was at rest with respect to the events. Both of these are incorrect and in fact the second reason is even meaningless. This has been pointed out in very many past subject reports but these answers continue to appear. The answer to part (iv), the time taken by a radio signal to arrive to Earth, is 26 years after its emission by Ann. This leads to an interesting and crucial observation for part (c) that only applies to HL.

(c) **HL only** This part dealt with the twin paradox. There were reasonably good answers to what is meant by the twin paradox. But few candidates seem to be aware that the pertinent resolution of the "paradox" is the fact that Ann has to change inertial reference frames for her return trip. The point from (iv) is that the signal she sends to Earth takes 26 years to arrive to Earth by Ann's clock but she herself will only take 6.6 years to return to Earth! Even though the question does not deal with this apparent new "paradox" (is Ann moving faster than light?) it is worthwhile for teachers to discuss it in class when dealing with time dilation and the twin paradox.

H2 [HL only] Relativistic energy

This question was answered well by most candidates. It must be pointed out, however, that the concept of mass increasing with speed has been taken out of the new syllabus. Whereas most think that it is mostly a question of taste as to whether we do or do not refer to mass increasing with speed, there is plenty of evidence to suggest that using relativistic mass leads to confusion and inconsistencies. Einstein himself used the concept in his first paper but later on abandoned it and never used it again. The fact that no particle can reach the speed of light can easily be answered, without reference to relativistic mass, simply by realizing that to do so would require an infinite amount of work to be done which is impossible.

H3 [HL only] Black holes

This question was generally well done. Candidates did much better in the calculation of the distance of the probe from the centre of the hole compared to the performance on a similar question last year but missed the last point that asked for the distance of the probe above the surface. There were, however, few correct explanations of gravitational redshift.

Option I – Medical physics

This was a much less popular choice among candidates compared with recent years.

I1 Hearing

This was well done by most who attempted it.

I2 Ultrasound imaging

This standard question suffered from a major flaw in that the equation for the intensity reflection coefficient was not given in the examination paper. The markscheme was modified substantially to allow credit for anything reasonable that the candidates had to say and it is the belief of the examination team that no candidate was disadvantaged by this.

I3 NMR

This was a very poorly answered question. Even the most basic points about magnetic resonance imaging were missing and it is clear that candidates did not really study this part of the syllabus in any depth or any level of understanding.

I4 Radiation

Candidates still have difficulty defining quantities correctly and the basic quantities of radiation dosimetry were no exception. It was common to define exposure as “the time one is exposed to radiation”. It is therefore not a surprise that answers to part (b) were confused. One cannot do the calculation unless one understands what exposure means. Part (c) was well done.

Option J – Particle physics

More candidates attempted this option compared to last year but in substantially smaller numbers than options E, G and H.

J1 Fundamental interactions

There were generally good answers to parts (a), (b) and (c). The problems appeared in the definition of a virtual particle in (d) and the more sophisticated question in part (e) where they had to explain how the energy – time uncertainty relation applies to the interaction in (c). The calculation of the uncertainty in energy was well done but surprisingly, many candidates missed the unit in the final answer.

J2 Particle detection

Answers to this question revealed only a superficial study of this topic. Most candidates had no idea of how a bubble chamber works and that the advantage of proportional wire spark chambers over bubble chambers is the elimination of dead time in between photographs and, especially, the digital images obtained. This means that the laborious and time - consuming examination of photographs, that used to be done by humans, is now done by computer. In part (c) few candidates could correctly point to the energy loss by the particles as the reason for the spiral paths. The connection (from core material) between radius of the path and the momentum was not appreciated by many candidates.

J3 Mesons and baryons

This was perhaps the most accessible part of this option for most candidates with generally good answers. In part (c) many candidates did not refer to baryon number conservation but improvised a bit by considering the number of quarks and anti – quarks in the initial and final states to help them deduce whether particle X was a baryon or a meson.

J4 Pair production

The calculation of the temperature at which pair production of electrons and positrons takes place was well done. There were occasional errors in incorrectly converting the MeV into joule. The explanation in part (b) was less successful however.

Recommendations and guidance for the teaching of future candidates

Recommendations from the examination team included the following ideas:

- Candidates should be given more opportunities during the course to practice examination style problems, look at past papers and markschemes. At the same time it must be emphasized that not all new questions will be similar to past ones!
- Candidates should be provided with, and given assistance with, the list of action verbs as specified in the syllabus. It is clear that many candidates do not recognise the difference between, for example, the stating and the explaining of an answer.
- When using a diagram to help answer a question, candidates should be encouraged to pay attention to the precision of the diagram. The axes in graphs, at the very least, must be labelled.
- The definitions given must be precise. Candidates would be greatly helped if they made their own glossary of terms in the course of their studies and learned it well for the exam.
- Enough time should be devoted to cover in depth the Options chosen. This is especially true of the new options in particular option F (Communications) and option J (Particle physics). There are excellent resources for Particle physics listed on the OCC. For those doing option F or option C, practice with op amp questions is essential.
- Whereas candidates appear to be doing well when what is required is the substitution of numbers in a formula, much more work must be done to be able to answer conceptual questions, and in general questions using the command term “explain”.
- Candidates must be discouraged to study options on their own. The options must be covered in full in the classroom.