PHYSICS TZ2 (IBAP & IBAEM)

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 15	16 - 27	28 - 39	40 - 49	50 - 58	59 - 68	69 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 25	26 - 38	39 - 49	50 - 58	59 - 68	69 - 100

Time zone variants of examination papers

To protect the integrity of the examinations, increasing use is being made of time zone 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 2008 examination session the IB has produced time zone variants of the Physics papers.

Internal assessment

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 9	10 - 15	16 - 21	22 - 27	28 - 31	32 - 37	38 - 48

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 9	10 - 15	16 - 21	22 - 27	28 - 31	32 - 37	38 - 48

The range and suitability of the work submitted

The majority of schools are offering an excellent range and complexity of investigations. Although some schools were moderated down and others up, there is solid evidence of the consistent and fair application of the IA criteria. There was also evidence of teachers reviewing the TSM on the OCC. However, many schools did not use the appropriate May 2008 version of the 4/PSOW form in which the student's signature is required. Some schools omitted teacher instructions and the 4/IA cover sheet.

The Group 4 Project is a collaborative enterprise, and hence is it not appropriate for assessment by the planning and the other moderated criteria. For the same reason students should not work in groups when their lab reports are to be assessed. There was evidence of students sharing data, graphs, even planning ideas and such work may be part of a good high school physics course but it is not appropriate for assessment. Students cannot work together on the IB exams and the same applies when practical work is to be assessed.

Planning (a) investigations require an open-ended teacher prompt. Teachers may provide the dependent variable but there must be a number of possible independent variables. The best planning topics concerns the relationship or function between variables, not specific values of physical quantities or the confirmation of know laws. Students should not research (textbooks, Internet, etc.) when designing a planning investigation.

There were a few cases of teachers telling students what data to collect and how to graph it. A few schools are still using worksheets (and then assessing DC and DPP). This is clearly inappropriate; it does not allow the student to earn full marks.

Candidate performance against each criterion

Planning investigations are occasionally over-marked by teachers and must be moderated down because the teacher provided too much information. Data collection was occasionally over-marked because students and teachers omitted an appreciation of errors and uncertainties. In physics, all measurements involve a degree of uncertainty. Under data processing and presentation, higher-level students often forget that minimum and maximum gradients are expected on linear graphs. Under conclusion and evaluation, students need a clear appreciation of each item of the three aspects. CE is probably the hardest criterion to earn all completes. When teachers under marked (and moderators increased the student's mark) it was because the teacher seemed to think that a complete means perfect. Each aspect needs to be appropriately addressed for a complete, but mistakes can be made and complete does not mean perfect.

The following contains specific details about the moderation of schools IA work.

When moderators mark down

Planning

(a) The moderator will mark down when the research question, hypothesis and/or independent and controlled variables are given by teacher. The moderator will mark the relevant aspect down to 'n'. A general aim is fine if the students have significantly modified the teacher prompt or question (e.g. made it more precise). The moderator will mark down when the hypothesis has not been explained or the explanation is clearly counter to theory as can be reasonably expected to be known by an average IB physics student. The moderator will award 'p' for second aspect.

(b) The moderator will mark down when a method sheet is given which the student follows without any modification or all students are using identical methods; here, moderators give n, n, n = 0. The moderator will mark down when teacher gives c, c, c but it is clear that the students have been told what apparatus and materials they require. The maximum moderators can award is n, c, c = 2.

Data Collection

The moderator will mark down when a photocopied table is provided with heading and units that is filled in by the students. The maximum the moderator can give is p, n = 0. If the student has not recorded uncertainties in any quantitative data then the maximum given by the moderator is ‘p’ for first aspect. If the student has been *repeatedly inconsistent* in use of significant digits when recording data then the most a moderator an award is ‘p’ for second aspect. In physics data is always quantitative. Drawing the field lines around a magnet does not constitute DC.

Data Processing & Presentation

The moderator will mark down when a graph with axes already labelled is provided (or students have been told which variables to plot) or students follow structured questions in order to carry out data processing. The most the moderator can give is c, n = 1. If there is no evidence of errors being propagated (HL only) or a total random error being estimated (SL) the maximum moderated mark is c, p = 2. Remember that a best fit line graph is sufficient to meet the requirement of error and uncertainty propagation.

Conclusion & Evaluation

If the teacher provides structured questions to prompt students through the discussion, conclusion and criticism then, depending on how focused the teacher’s questions are and on the quality of students’ response the maximum award is *partial* for each aspect the student has been guided through. The moderator judges purely on the students input. The moderator must mark down if the teacher gives c, c, c = 3 but the student has only indicated as a criticism that they ran out of time. The maximum the moderator can give is c, n, p = 1.

When moderators do not to mark down

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

Planning

(a) Dependent variable has been given by teacher or student has made no mention of dependent variable (surprisingly it is not featured in the descriptor of aspect 3). The moderator will not mark down if they disagree with the explained hypothesis but feel that it is a reasonable application of IB level knowledge. Wrong physics is not penalized. The hypothesis explanation is simplistic but the only one possible within the framework of the task. In this case the moderator will support the student but will provide feedback to teacher as to the poor suitability of the task for a meaningful hypothesis generation. Moderators do not mark down when the independent and controlled variables have been clearly identified in the 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 procedure which is independent and which are controlled.

(b) Moderators do not mark down when similar (not word for word identical) procedures are given for a narrow task. The moderator will make a comment though on the poor suitability of the task on 4/IAF form. Moderators do not only mark equipment list. They give credit for equipment clearly identified in 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 DC. 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 teacher's stance here.

Data Collection

In a comprehensive data collection exercise possibly with several tables of data the student has been inconsistent with significant digits for just one data point or missed units out of one column heading. If the moderator feels the student 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 perfect' rule. This is an important principle since good students responding in full to an extended task unfairly get penalized more often than students addressing a simplistic exercise. The student 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 students do all the hard work for DC and then lose a mark from the class teacher because they did not title the table. Except for extended investigations it is normally self-evident what the table refers to and the section heading Raw Data is sufficient. Once again 'c' does not mean perfect.

Data Processing & Presentation

The expectation for the treatment of errors and uncertainties in physics as described in the Course Guide and in TSM 1. Standard level candidates are not expected to process uncertainties in calculations. However, they can make statements about the minimum uncertainty, based on the least significant figure in a measurement, and can also make statements about the manufacturer's claim of accuracy. They can estimate uncertainties in compound measurements (± half the range at the measured end and at the zero end), 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.

Under DPP higher level candidates should be able to express uncertainties as fractions, and as percentages. They should also be able to propagate uncertainties through a calculation. Minimum and maximum gradients should be drawn on graphs using uncertainty bars (using the first and last data points) for only one quantity.

For both DC and DPP, if the student has clearly attempted to consider or propagate uncertainties (according to whether HL or SL) then moderators support the teacher's award even if they may feel that the student could have made a more sophisticated effort. Moderators do not punish a teacher or student if the protocol is not the one that you teach i.e. top pan balance uncertainties have 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 student 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 student. Yes, this does mean that students could get high DC or DPP 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.

Recommendations for the teaching of future candidates

- The current IA criteria will be replaced in the May 2009 examination session. The current IA schema will be moderated for the last time in the November 2008 examination session. Teachers preparing students for May 2009 must be following the new syllabus and the new IA criteria, including the combined SL and HL requirements for errors and uncertainties, the new ICT requirement, and the new Group 4 expectations.
- Schools examining in November 2008 will still follow the current Group 4 project structure. It is emphasized that the group project is not suitable to assessment under Pl (a), Pl (b), DC, DPP or CE.
- Research on the Internet for Planning (a) should not be encouraged. This applies to the new Design criterion. Students should do their own thinking on the given teacher prompt. If students know the equation describing the function under investigation then a planning lab (or Design lab) is not appropriate. Teacher prompts need to be open-ended. Determining the specific heat capacity of an unknown material or determining the value of gravity are not appropriate for the new Design criterion.
- The use of graph paper or computer-generated graphs is expected. There are examples of hand drawn axes and roughly plotted data points from a few schools. Students should not just make up error bars; they should make a fair estimate or calculation for error bars.
- Students need to experience a variety of assessed work over the two year course, and should not be expected to earn top marks on just two investigations early on in the course.
- Students as well as teachers are required to sign the 4/PSOW form; a 4/IA cover sheet is also required as well as a statement of the teacher's instructions for any assessed investigation. The new 4/PSOW form for May 2009 also has a column for the new ICT requirement.
- Student should be familiar with the IA criteria and have their own copy of it. Many teachers use a cover sheet, a checklist approach, to marking IA. This is useful to the teacher, the students and the moderators.
- The IB encourages the use of data logging in assessed work. The key axiom to be followed is that the students are to be assessed on their individual contribution to the assessed task. To judge this moderators have to be guided by the teacher who

knows exactly what the students had to do. The moderator applies the normal standards regarding expectations of data presentation (units, uncertainties, etc.) and graphs (best fit lines, axes labels, suitable scales, etc.). See the relevant section of the Teacher Support Material on the OCC for examples of assessed and non-assessed ICT in student investigations.

General comments on the written papers

IB multiple choice physics papers are designed to have, in the main, questions testing knowledge of facts, concepts and terminology and the application of the aforementioned. These Assessment objectives are specified in the Guide.

It should be noted that multiple-choice items enable definitions and laws to be tested without full recall, but requiring understanding of the underlying concepts.

Although the questions may involve simple calculations, calculations can be assessed more appropriately in questions on Papers 2 and 3. Calculators are therefore neither needed nor allowed for Paper 1.

In Papers 2 and 3, candidates are sometimes asked to write short paragraphs so that their understanding of topics may be assessed. It is clear that, from many answers, candidates have been trained to give definitions and to perform calculations, but have little understanding of the underlying physics. It is this lack of understanding that prevents candidates from achieving the higher grades.

Candidates should be encouraged to give precise definitions for physical quantities. Definitions given partly or totally in terms of units are not acceptable.

Paper one

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 15	16 - 21	22 - 25	26 - 28	29 - 32	33 - 40

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 11	12 - 15	16 - 18	19 - 21	22 - 23	24 - 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 example, at SL there were 51 responses from 475 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 2008 papers were generally well received. The majority of the teachers who commented on the Papers felt that they contained questions of an appropriate level. Only 4% of the G2 replies suggested that the Papers were more difficult than last year and all suggested that the Papers gave satisfactory or good coverage of the syllabus. Most teachers who replied on the G2's felt that the presentation of the Papers was 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 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	309	1826*	1083	248	8	52.56	0.27
2	2902*	241	76	246	9	83.53	0.28
3	226	2466*	545	236	1	70.98	0.36
4	316	305	1407*	1442	4	40.50	0.39
5	2632*	292	256	290	4	75.76	0.25
6	1755*	113	46	1557	3	50.52	0.26
7	67	1704*	328*	1373	2	58.49	0.27
8	1333	1429*	541	161	10	41.13	0.46
9	379	2793*	215	86	1	80.40	0.30
10	163	130	2895*	282	4	83.33	0.29
11	767	1394*	687	620	6	40.13	0.57
12	2211*	482	150	626	5	63.64	0.50
13	869	132	2246*	224	3	64.65	0.50
14	197	655	793	1822*	7	52.45	0.43
15	25	85	1864	1499*	1	43.15	0.46
16	286	353	165	2666*	4	76.74	0.33
17	701	2090*	430	251	2	60.16	0.51
18	318	799	1919*	431	7	55.24	0.56
19	230	65	3017*	160	2	86.85	0.23
20	861	815	1537*	257	4	44.24	0.37
21	59	347	286	2778*	4	79.97	0.32
22	55	445	203	2768*	3	79.68	0.51
23	2452*	295	662	61	4	70.58	0.21
24	1150	206	1806*	306	6	51.99	0.47
25	2068*	671*	429	291	15	78.84	0.31
26	361	58	255	2796*	4	80.48	0.33
27	2601*	370	320	165	18	74.87	0.43
28	150	1842*	1275	201	6	53.02	0.24
29	552	557	548	1799*	18	51.78	0.47

30	249	239	2050*	928	8	59.01	0.43
31	923	1552*	570	421	8	44.67	0.38
32	1203*	433	1048	766	24	34.63	0.50
33	430	1529	1090*	406	19	31.38	0.27
34	568	2567*	201	128	10	73.89	0.44
35	184	393	610	2271*	16	65.37	0.48
36	1375*	909	599	568	23	39.58	0.39
37	398	355	1217	1470*	34	42.31	0.35
38	229	845	1974*	409	17	56.82	0.39
39	2053*	692	231	479	19	59.10	0.43
40	695	76	1037	1647*	19	47.41	0.36

Number of candidates: 3474

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	321	1436*	1058	393	12	44.60	0.22
2	2356*	358	187	312	7	73.17	0.46
3	283	1735*	837	363	2	53.88	0.50
4	2410*	57	339	411	3	74.84	0.17
5	321	27	57	2812*	3	87.33	0.16
6	2017*	456	320	419	8	62.64	0.29
7	1083*	176	63	1890	8	33.63	0.21
8	128	1458*	236*	1392	6	52.61	0.24
9	1327	921*	650	314	8	28.60	0.26
10	167	1910	983*	140	20	30.53	0.06
11	2211*	380	360	247	22	68.66	0.51
12	214	1088	286	1624*	8	50.43	0.50
13	191	308	2521*	199	1	78.29	0.32
14	1800*	761	361	279	19	55.90	0.49
15	141	325	2155*	595	4	66.93	0.47
16	442	563	266	1938*	11	60.19	0.44
17	726	1287*	685	512	10	39.97	0.48
18	658	890	1183*	480	9	36.74	0.48
19	102	528	407	2175*	8	67.55	0.46
20	81	566	406	2164*	3	67.20	0.34
21	1709*	123	1054	331	3	53.07	0.37
22	520	535*	1656	474	35	16.61	0.15
23	1691*	808	419	274	28	52.52	0.54
24	433	467	330	1951*	39	60.59.	0.57
25	217	1690*	1038	263	12	52.48	0.14
26	648	620	754	1118*	50	34.72	0.41
27	1097	200	1624*	283	16	50.43	0.16
28	508	2234*	245	186	47	69.38	0.49
29	530	708	1421*	523	38	44.13	0.32
30	810	1842*	339	187	42	57.20	0.40

Number of candidates: 3220

Comments on the analysis

Difficulty. For HL the difficulty index varies from about 9% (relatively 'difficult' questions) to 87% (relatively 'easy' questions). The corresponding values for SL are 7% and 87% respectively. 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, with one exception, (HL Q25) 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 a high difficulty index i.e. most candidates are getting the correct answer.

'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. Even so, this does not provide an explanation for 'blanks' early in the Papers. 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.

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. Therefore comment will be given only on selected questions, i.e. those that illustrate a particular issue or where a problem can be identified.

SL and HL common questions

SL Q7 HL Q6

On reflection the Examining Team felt it would have been better to have omitted the words "in the motor". However, the question had reasonable discrimination with a popular choice being D which is clearly wrong.

SL Q8 and HL Q7

Many candidates got this wrong as they did not notice that the graph was a plot of length against load and so gave the key as B. Although the areas Y and Z are equal only Z actually represents the stored energy. However, the Examining Team decided that because of the possible misinterpretation of the word "represent" in the stem, both keys B and C would be accepted. Another very popular distracter was D, which is clearly wrong.

HL Questions

HL Q13

Several teachers commented that the wording for the question was vague and also misleading since it did not specify which equilibrium was required, translational or rotational. It should be noted that "equilibrium" on its own implies both. The statistics for the question were good with over 2000 candidates selecting the correct key.

HL Q14

The Examining Team acknowledged that this question could have been phrased more clearly. However, the statistics are good and there is nothing to suggest that candidates were disadvantaged.

HL Q25

The statistics suggested that there was there was a problem with this question; the only question with a negative discrimination index. It would seem that most candidates understood the person to be approaching the source head on whereas the diagram clearly shows that this is not so. Because of this misunderstanding the majority of candidates gave the distracter A as their answer. Since it was felt that the intent of the question could have been clearer, the Examining Team decided that both keys A and B would be accepted.

HL Q30

The adjective “magnetic” should have probably been used to describe the force and thereby avoid any possible ambiguity. However, the statistics suggested that the question discriminated well and with over 2000 candidates giving the correct key.

HL Q33

The Examining Team recognises that real transformers are complicated affairs and that self and mutual inductance effects have to be considered. However, an ideal transformer with the secondary open circuit (or with large load) will give the key C. It always has to been born in mind that in MC questions, candidates are asked to select the best answer. This question had good discrimination with many (weaker candidates) choosing the key D, which is clearly wrong.

HL Q37

There were several comments from teachers that the correct response only holds true for non-relativistic speeds. It was felt by the examining team that the inclusion of a comment such as “for low speeds” in the stem would only serve to confuse those candidates who had not taken the Relativity option. It should also be noted that the correct key is the best answer.

SL Questions

SL Q4

Unfortunately there was a proofing error in this question; the fourth error bar from the origin in the graph in A should have just been touching the line. However, the statistics showed candidates had not been disadvantaged with over 2000 getting the correct answer. The other responses were distributed fairly evenly amongst the remaining distracters suggesting that these candidates were guessing.

SL Q10

This question had a low discrimination index. The Examining team agreed that it was a difficult question and this was taken into account when setting the grade boundaries.

SL Q14

The phrasing for this question could have been better in the respect of making it clear that the time *t* referred to the time after the impulse had been removed. The statistics would suggest that this was the interpretation that most candidates accepted and there was little to suggest that candidates had been disadvantaged.

SL Q22

This question had a low discrimination index. The Examining Team agreed that it was a difficult question and this was taken into account when setting the grade boundaries.

Recommendations and guidance for the teaching of future candidates

Candidates should make an attempt at every item. If they are not sure which is the correct response for a particular item then they should leave it and pass on to the next. However, they should leave time to revisit these items and if they still 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, if there is time candidates should check that all other options are not feasible.

Paper two

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 20	21 - 31	32 - 40	41 - 49	50 - 58	59 - 95

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 4	5 - 9	10 - 17	18 - 22	23 - 26	27 - 31	32 - 50

General comments

At both levels there were some excellent scripts. However many candidates found it hard to perform very well although there were a good number of marks accessible to the less skilled or weaker student. A lack of precision and completeness characterized answers to qualitative or descriptive questions. Similar observations apply to the expression of laws as well as to the explanation or interpretation of events in relation to the laws of physics.

Candidates generally showed good knowledge in classical mechanics, thermal physics and waves. Their knowledge of fields (electric, magnetic and gravitational) was more limited. Their knowledge of modern physics was also limited and “sketchy”. At HL, the production and characteristic of X-rays were, surprisingly, very weak. Possibly some parts of the syllabus are poorly or too rapidly covered. This would include gravitation, motion of particles in magnetic field, electromagnetic induction and standing waves.

The question regarding the carriage passing through the water tank was rarely fully answered because candidates found it difficult to adopt their knowledge and analytical skills to new situations even though the question is structured in a helpful manner. In the data analysis question many candidates did not know how to trace free hand a best line nor could they calculate the slope of the curve at one point. Possibly they did not know the signification of the slope of a curve.

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

The examining team also identified the following areas with which many candidates had difficulty:

In mechanics:

- The nature and role of the centripetal force during the motion of a car around a corner (no need for accelerated frame of reference et all). The centripetal force should always be physically identified.
- Application of dynamics and energy relations to the motion of bodies in gravitational field (satellite)

In fields:

- Nature and characteristics of fields lines
- Behaviour of charged particles in motion in a magnetic field, including circular motion

In electromagnetic induction:

- Faraday's Law
- Detailed operation of a transformer, calculations of rms values of V and I at the primary and secondary

In atomic physics:

- Production of X-rays and interaction of X-rays with matter

In nuclear physics:

- Measurement of lengthy half-life
- Details of the phenomenon of radioactivity
- Binding energy in fission

In waves:

- Principle of superposition of waves and its application to interference of waves
- Formation of standing waves

In thermodynamics:

- Adiabatic process on a p-V diagram

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

Generally candidates demonstrated average to good knowledge in the following areas:

- Latent heat and specific heat
- Wave phenomena (basic facts)
- Numerical applications involving formulae
- Simple, straightforward questions e.g. on momentum and kinetic energy
- Uniformly accelerated motion
- Definitions and derived units

An increasing number of candidates avoided losing marks to incorrect use of significant digits or wrong units. Rarely do we see large number of significant figures carried in calculations

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

There were many common questions between SL and HL. The comments below are arranged in the order that the questions appeared in HL. Questions belonging only to SL are also included.

Section A

A1 [(a)-(d) HL and SL]- Data analysis question

The level of analytical skills varied significantly among candidates. However many were able to gain a good number of marks. The ability to draw a proper free hand curve through the points determined their success in interpolating or extrapolating numerical values or tracing a reasonable tangent to the curve. (a and b) It was expected that candidates would go through the different steps carefully and produce reasonably exact numerical values. The negative slope was not always recognized. In (c) candidates could give some explanation for a non-linear relationship in the graph, but many answers were very incomplete or did not mention the variable gradient or slope. Instead, many attempted to use Ohm's law and the effect of thermal energy on the electric resistance. In (d) many candidates did not use Kelvin degrees or only computed two values from the data but the majority gained at least two marks. In (a) (ii) HL some percentage uncertainties were given with 2 significant figures when the question was about estimating.

A2 [HL] Radioactivity

(a) The fact that the half-life was so long was not recognized by many candidates who suggested unrealistic methods. Very few suggested measuring the activity and the number of atoms of the isotope. The signification of the relation $A = \lambda N$ was not recognized. In (b) only a small number of candidates recognized that the fraction was equal to $(0.5)^{1.6}$.

A2 [SL] Units

Many candidates chose Newton as the "derived" unit but got the right answer for the units of speed. Derived units of k were generally well done, ECF being applied.

A3 [HL] Ideal gas and entropy

(a) The better candidates drew the curve higher and steeper than the given curve.

(b) Many labelled G correctly or scored an ECF mark. Many shaded the area between the two curves or scored a further ECF mark.

(c) Many candidates were able to identify the correct entropy changes. Some gave decent explanations for why the entropy of the gas decreases.

A3 [SL] Springs

(a) Generally well done even though some candidates were unable to determine the actual elongation of each spring. The common mistake in (b) was not to realise that the two forces act in opposite directions when finding the net force.

A4 [HL] Ideal transformer

(a) Faraday's Law (a classic question) was rarely completely given.

(b) In most cases the core was not mentioned in description of the normal operation of the transformer (i). The purpose of the laminated core was not well understood, many suggesting it was to insulate electrically the core from the coils (ii). In (iii) a majority of candidates calculated the number of turns correctly with many losing one mark to significant digits. Often candidates calculated the current for the secondary coil instead of the primary coil. In general the knowledge of electromagnetic induction was weak, vague and incomplete.

A4 [SL] Electroscope

(a) Many candidates determined that the leaf would fall in (a) or rise in (b) but could not show a correct distribution of the negative charges on the cap (a) or over the leaf and cap (b). Consequently candidates found it difficult to suggest why an electroscope can or cannot give a measure of the charge for different reasons:

- No reference made to diagrams specifically identified in stem of question
- Considering the type of charge rather than the amount of charge
- Poor understanding of static electricity

(b) In (b), it is not specifically stated that the rod is also removed but considering that this procedure is classic and that no rod appears on diagram 4 this omission is not at the origin of the difficulties encountered by a majority of candidates in (c). This is confirmed by the fact that many candidates represented diagram 4 with one type of charge. Only very few realised that when the leaf is flattened (diagram 3), the cap still carries a charge.

Section B

B1 [Part 1 HL and (a-b) SL] Units and momentum

Units [HL]

(a) Very few candidates were able to satisfactorily define fundamental units.

(b) A common mistake was expressing units of R in terms of "momentum" and not: "rate of change of momentum". There were many correct answers.

Definitions [(c) HL, (a) SL]

Generally well done.

“Carriage in pleasure park” [(d) HL, (b) SL]

Most candidates correctly calculated answers for (i) and (iii) but did not always indicate that the change of momentum of the carriage was transferred to the water. In (iii) some found it difficult to calculate the acceleration even though different approaches were possible. Total loss of kinetic energy of carriage was done well (some SD-1 here) in (c)(i) but a number of candidates assumed that the gain in kinetic energy of the water was the same, hence missing the key point of the question (iii). The actual loss of kinetic energy (noticed by a number of candidates) was not explained or poorly explained in (d). Instead laws of conservation were given without any relation to the event. Very poor results here, sound and heat being often part of the final conclusion.

B1 [Part 2 HL] X-rays

Rarely a candidate got full marks for the X-ray diagram (a). X-ray and photoelectric effect often confused in (b) and (c). The explanation of breaking radiation poorly explained or understood (c). This part was a fairly direct question for which basic knowledge should yield at least 6 or 7 marks.

B1 [Part 2 SL] B2 [Part 2 HL] Force fields

(a) A majority correctly identified field strength changes (i) but few were able to explain completely why field lines never cross (ii). Many suggested that field lines repel each other. In [HL (iii)] many good field patterns drawn, at times lack of care (some lines crossing each other).

(b) “Path of particles in bubble chamber”: Many missed the idea of circular motion of particles but many correctly identified opposite charges. Some ambiguity when answering “different charges”. Few candidates completely explained the spiral shape of the path. Many suggested that the two particles repel each other.

B2 [Part 1 HL and SL] latent heat and specific heat

(a) (i) most identified the energy/mass concept but many missed “at constant temperature”.

(ii) many wrote about “breaking of bonds” but did not mention an increase in potential energy (a difficult concept to grasp). Temperature and E_k well related. Concepts of vaporization and evaporation confused at times.

(b) (i) Often the variable resistor is missing or not identified as such.

(ii): Current correctly calculated.

(iii): Rarely did a candidate get the full 4 marks. The loss of thermal energy to the environment was not realised so no effort was made along these lines. Typically one or two values of s.h.c. were correctly calculated as well as an average value. Some candidates could not cope with $\Delta m/\Delta t$ or did not know $Q = Pt$. They could not apply the familiar equation $Q = mc\Delta T$ to the data given, where mass lost per unit of time appears. Most gained 1 or 2 marks.

(c) Good success in (i) and (ii). Some cases of lack of attention in (iii) where the question was not read attentively (“each year”).

B2 [Part 2 SL] B4 [Part 2 (a)-(b) HL] Linear motion (oil drops)

A significant number of candidates had a great deal of difficulty in interpreting the question. Few correctly drew 3 dots on the left-hand side of the diagram, including the position at t = 0 as a dot. Most candidates made reasonable efforts. Many got marks in (a)(i) and (b)(i). Mixed results when acceleration was calculated in (b)(ii). Here, at times, equations of uniformly accelerated motion were used blindly without thorough thinking of how to apply them to the specific situation. Examiners applied ECF throughout the question to recognize the candidates' knowledge.

B3 [Part 1 HL and SL] Wave phenomena

Part 1 was generally well answered with the better candidates offering complete answers. (a): mixed results about the interpretation of the graph x(t) (i) or reading the period correctly on the time axis (the unit "ms" confused many) (ii). (b): the conditions for standing waves were often incomplete, some candidates describing a standing wave rather than the conditions required to produce it (i). Many associated the heaps to a node of a standing wave (ii). The fact that $\lambda = 2 \times 9.3$ cm was not always recognized (iii). In (c) many candidates drew on their prior theoretical knowledge rather than using the experimental evidence given in the stem of the question (separation of heaps increases $\Rightarrow \lambda$ increases, hence…)

B3 [Part 1 (d-e) HL]

(d) Constructive interference often explained in the context of a specific situation rather than in general terms. The key word "displacement" not often used. Very good interpretation of wavefronts diagram.

(e) Many candidates calculated the wavelength correctly though they lost one mark because of an error in the calculation of the slit width.

B3 [Part 2 HL and SL] Nuclear decay

As observed in the other parts of the paper where modern physics is involved the level of success is quite mixed even though the questions are often purely knowledge based.

(a) Few candidates got full credit describing natural radioactive decay. Lack of precision (unstable nuclei, not atoms, decay), completeness or a tendency to repeat rather than bring up different aspects. Rarely reference is given to a more stable "daughter" as the product of decay, the original nucleus "disappearing".

(b) Fission generally well recognized (i). Mixed results placing the three elements on the graph (ii). Less than half of the candidates correctly calculated the binding energy per nucleon with the majority adding 187 MeV rather than subtracting it (iii), a serious error indicating very poor understanding of the event. Only a few stated correctly and completely why neutrons do not have binding energies (iv).

B4 [Part 1 HL] Gravitation

(a) This question was highly popular perhaps because it is all based on mechanics and, possibly, without modern physics. A number of candidates may have underestimated the high level of expectation for answers to qualitative or descriptive questions. Most candidates explained well why the satellite was not in equilibrium (i). Many suggested that the satellite (ii) was beyond the gravitational attraction of the Earth… showing very poor knowledge. Only a small number demonstrated complete understanding here.

(b) Most stated the correct expression for E_p (i) and a good number correctly derive the expression for E_k (ii).

(c) Not many wrote down the correct expression for total energy. The application of this equation to a satellite was often incomplete and confusing. A majority gained a maximum of 2 marks. Some did not refer to (b) even though it is clearly indicated in the question to do so.

(d) Very poorly answered. Four marks were dedicated to this question suggesting that four important and different points must be brought up. Among the weaknesses shown:

- Concepts of orbital mechanics ignored
- "Superficial" ideas: "PE decreases hence KE increases…"
- Rarely the loss of total energy is attributed to atmospheric (increasing) drag $\Rightarrow$ decrease in height $\Rightarrow$ increase in speed $\Rightarrow$ increase in drag, et all
- Considering the relation $E_k = ½\ mv^2$, "small" satellite $\Rightarrow$ "small" mass $\Rightarrow$ greater speed.

A large number of candidates gained only 1 mark out of 4.

B4 [Part 2 (c) HL] "Car turning with passenger inside"

(i) Often brief mention of centripetal force without identifying it as a friction force between tyre **and** road and without giving its direction "toward centre of circle" (vague expression "toward centre of turn" used often).

(ii) A large majority obtained 1 mark out of 3 for mentioning the role of inertia. Vague, incomplete and confusing knowledge shown. Many suggested that passengers experienced an outward force as a reaction to the centripetal force. Some suggested that a centrifugal force was balancing the centripetal force… non-inertial frame of reference type of answers. Some answers did demonstrate clear and efficient critical thinking.

Recommendations and guidance for the teaching of future candidates

The efforts of teachers in covering a demanding syllabus are fully recognized. Hopefully, the following recommendations will be of some help.

- Candidates should realise the importance of reading the question and instructions **very** carefully.
- Practice with past IB papers and mark-schemes so that candidates get familiar with all the facets of an IB paper. Indeed, it is an efficient way to verify the level of candidates' knowledge and skills as well as getting candidates familiar with the IB type questions and the expectations of the mark-scheme. Interlocking sub-questions guide candidates towards a specific goal.
- Candidates should become familiar with action verbs. When the action verb is "explain", the number of marks and the number of lines available for the answer indicate that more than factual recall is required to gain full marks. Each and all of the steps of reasoning have to be part of the answer.

- Candidates should have the opportunity of applying their knowledge and skills to new and unfamiliar situations. Analytical skills to be emphasized.
- Candidates should focus on precision and completeness when providing definitions and stating laws. They should be able to identify symbols in an equation by interconnecting them.
- Candidates should practice drawing free hand best-fit curves, reading scales, calculating slopes. The concepts of linearity and proportionality to be clarified. Candidates should realise that by just looking at a graph, it is not possible to qualify a curve as parabolic or exponential.
- Candidates should be given the opportunity of organizing their ideas, presenting their answer in a comprehensible and precise manner, using correct terminology. A “more or less” approach generates little success.
- It is worth giving special attention to Modern Physics. Greater mastery here would broaden the number of questions available to candidates.

Paper three

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 12	13 - 20	21 - 25	26 - 31	32 - 36	37 - 60

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 3	4 - 7	8 - 11	12 - 15	16 - 20	21 - 24	25 - 40

General comments

The majority of candidates appeared to find the Paper accessible with some examples of good or very 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 10% of Centres submitted G2 forms, therefore when the statistics read e.g. 2%, it means one school only.

Standard Level

- 72% found the paper to be of a similar standard to last year, 12% easier or much easier and 16% more difficult. Overall, 93% found the paper to be of an appropriate standard and 5% thought it too difficult with 2% finding it too easy.
- The great majority found the syllabus coverage good (91%), 7% thought it was satisfactory and 2% found it poor.

- Also the great majority found the clarity of wording good (86%), 12% found it satisfactory with 2% finding it poor.
- 91% found the presentation good with 9% finding it satisfactory and none poor.
- As in previous years, the most popular options were A (Mechanics) and H (Optics).

Higher Level

- About 69% found the paper to be of a similar standard to last year, 8% a little easier with 23% describing it as a little more difficult (19%) or much more difficult (4%). Overall, 91% found the level of difficulty appropriate and 9% thought it was too difficult.
- The great majority (91%) found the syllabus coverage good, 9% thought it was appropriate
- About 86% found the clarity of wording good, 12% found it satisfactory and 2% found it poor
- About 93% found the presentation good, 5% thought it was satisfactory and 2% found it poor
- As in previous years, the most popular options were H (Optics), F (Astrophysics) and G (Relativity), even though there was a considerable increase in options D (Biomedical Physics) and E (The History and Development of Physics).

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

The areas identified by the examination team as being difficult were as follows:

- Explaining concepts in Physics in a way that demonstrates understanding (e.g. explaining proper time, frames of reference, apparent brightness or principal axis of a lens.) Vagueness and lack of precision were found in many attempts to define basic concepts.
- Providing sufficient depth and detail in questions with a mark allocation of more than one mark. This was particularly true in those questions involving the action verbs “explain”, “discuss” and “outline”.
- Interpreting graphs, failing to understand them through the careful reading of the axes’ units.
- Using trigonometric expressions when resolving vectors on inclined planes.
- Understanding the de Broglie hypothesis
- Explaining the origin of the continuous X-ray spectrum and the role of excitation in the formation of the characteristic spectrum.
- Dealing with radioactive decays where t is not an integer number of half-lives.
- Identifying and expressing mathematically the energy transfers in Particle acceleration.
- Describing the basics of ultrasound imaging.
- Knowing of the Bohr model of the atom.
- Relating the electromagnetic spectrum to possible sources for those waves emitted.

- Explaining thin film interference.

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. Many candidates appeared well prepared and able to produce some excellent answers that showed a good understanding of the concepts, particularly in the Mechanics, Astrophysics and Optics options.

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

SL only

Option A – Mechanics

A1Projectile motion

Many candidates were able to read the graph correctly and easily score the first two marks, applying simple skills. However, a considerable number experienced problems interpreting the graph with some students clearly wondering about the units ($J\ kg^{-1}$), and therefore only attempting solutions through kinematics formulae. Those who correctly read the graph as of kinetic energy per unit mass were usually able to score full marks. Some students showed a poor treatment of significant figures, when it came to solve the velocity from the square root.

A2 Orbital motion

Many candidates were familiar with Kepler's third law and easily obtained the mark identifying correctly the symbols used in the expression. Most candidates were then able to score the marks, correctly identifying the force and the orbital speed as requested. A pleasing number of candidates deduced the constant from the basic expression of the net (gravitational) force equal to the mass of the satellite times its centripetal acceleration. The vast majority stated correctly the expression for the gravitational field strength, with some not gaining the mark as they were not careful enough to state it in terms of M_E and R_E. It is important to highlight that, as a general rule, the mere quotation of a formula as given in the data booklet does not score a mark, unless referred with the correct symbols to the context of the question or unless symbols are explained, depending on the wording of the specific question. The final point was less successfully answered, with many candidates failing to use the correct height of $2R_E$ or starting from scratch without applying the concepts structured in the question.

A3 Friction

This question gave clearly much more difficulty to candidates than anticipated. Even though a fair number gained both initial marks, a surprising large number was either incorrectly exchanging the use of the sine or cosine of the angle or stating the component of the acceleration instead of the weight. Those who identified the components and showed familiarity with this typical situation moved on to easily gain full marks. However, a surprising number were unable to get the expression for the net force and thus, ended up either with an incorrect value of the coefficient of friction or just writing it even though the calculation was not really showing it.

Option B – Quantum Physics and Nuclear Physics

B1 de Broglie hypothesis

This question showed clear differences between candidates who scored full marks easily and those who just did not know the basics of the topic.

B2 X-ray spectra

Explanations of the origin of the continuous spectrum were poor and incomplete. The essential reasons for the lack of characteristic spectra under a potential of 20kV were rarely attempting to cover the number of marks allocated. Candidates would benefit from using the marks allocated as a guide to structure the answer. The calculations required were more successful, with a significant number of candidates obtaining full marks.

B3 Nuclear reactions

Surprisingly, a significant number of candidates had difficulties to gain both marks by stating correctly the proton and neutron number for a β^+ decay. Those who answered correctly also obtained marks in the remaining parts of the question. Many candidates had difficulties dealing with a situation where t is not an integer number of T.

Option C - Energy extension

C1 Thermodynamic processes and a diesel engine

Many candidates were confident in their description of an adiabatic change. However, identifying the change for thermal energy to be transferred to the air was less successful and answers practically covered all the existing possible answers. A good number of candidates showed familiarity with the Carnot cycle.

C2 Solar power

This question was usually well answered. However, a significant number of candidates experienced problems clearly confusing or exchanging units of power with units of energy.

C3 Nuclear energy

This question showed confusion or plain lack of understanding about the role of neutrons in fission reactions, and confusion with methods of energy transfer instead of a focus on the actual energy transfers.

SL and HL combined

Option D - Biomedical physics

D1 Scaling

This question was usually well answered with many candidates scoring full marks.

D2 Sound and hearing

This question had candidates scoring a significant number of marks, even though lack of precision constituted a problem in identifying I in the equation provided. The simple term “factor” seemed to have puzzled the less mathematical candidates. The graph was usually well produced though some candidates were not careful enough to show the three elements that were expected, an increased intensity at all frequencies, a reduced frequency range and larger differences in intensity for higher frequencies.

D3 Medical imaging

Very few candidates were able to state approximately a correct range of ultrasound frequencies, with the most common mistake being the range of audible frequencies. More successful was the analysis of the remaining questions about ultrasound imaging. Those candidates who realised that there was an integral number of half thicknesses in the X-ray imaging question usually scored full marks. The wording of the ratio was confusing but the mark-scheme allowed for those who literally interpreted the ratio as written and used the actual decrease of intensity to calculate it.

D4 [HL only] Energy used by the body

Candidates would benefit from identifying the action verb used to indicate the depth of treatment required, as many showed the calculation without stating any conclusion for the energy available to the body in one slice of bread. The action verb "deduce" asks, as the subject guide clarifies, to reach a conclusion from the information given. In the same line of argument, most candidates scored by explaining the need for the body to use much more energy, even though few used the number of marks allocated to structure the question.

D5 [HL only] Radioisotopes in medicine

Whilst the straightforward definition of biological half-life was usually well stated, the remaining calculations combining both half-lives and applying the concept of λ_{eff} and the corresponding equation to get the ratio of activities indicated that candidates were not familiar with the way to handle them.

Option E – The history and development of physics

E1 Models of the solar system

The essential difference between Ptolemaic and Copernican models was universally well answered but many then failed to describe correctly the stars being fixed to the surface of a sphere with centre at the Earth. A few excellent answers were read about Newton's contribution related to Kepler's work, with most candidates at least obtaining partial credit.

E2 Theories of projectile motion

Even when candidates were familiar with Aristotle's ideas about motion, only general references to violent and natural motions were read. Candidates would benefit from attempting to use their knowledge to address the specific context of the question.

E3 Theories of heat

Generally well done with almost all candidates scoring most marks.

E4 Measurement of the charge to mass ratio

Many had reasonable knowledge of the cathode-ray tube used by J J Thomson and were successful in the question. Lack of precise language was a problem to identify the potential difference applied to the plates to deflect the beam.

E5 [HL only] Bohr Theory

Surprisingly, few candidates were able to state properly Bohr's second postulate. Even though many scored partial marks in the remaining part of the question, candidates usually opted for giving examples instead of outlining (outline: give a brief account or summary) the answer. Candidates were more successful with the simple calculation required to determine the value of n. Very few suggested correctly why the value of R_H would be greater.

Option F – Astrophysics

F1 Stellar clusters and galaxies

A surprisingly large number of candidates failed to score full marks, just by focusing on the basic aspects of a stellar cluster and a galaxy. Many showed no idea about galaxies, attempting to include Solar Systems as their main characteristic. A reasonable number of candidates were aware of the approximate ratio of distance between stars in a galaxy / distance between galaxies and fell within the range accepted of 10^{-5} to 10^{-7}.

F2 Surface area of a star

Even though many candidates were in trouble to precisely define basic concepts as apparent brightness and apparent magnitude, there were pleasing answers in the outline of how the surface temperature of a star is determined. Most were aware of methods to measure the distance of a star but few related it to the context of the question, not showing it in the specific case of star Wolf-359 by using the information provided. All remaining calculations were consistently well handled.

F3 Olbers' paradox

Usually well answered by those candidates who had obviously discussed the paradox in class.

F4 [HL only] Main Sequence stars

Many candidates were familiar and showed correctly the evolutionary path of star Q, and also scored by pointing out the difference with P, expected to become a neutron star or a black hole as opposed to a white dwarf. However, very few were able to do anything more significant than stating the Chandrasekhar limit as to suggest how P could have the same fate than Q.

F5 [HL only] Galaxies and red shift

A question that was usually well answered leading to a reasonable number of candidates obtaining full marks.

Option G - Relativity

G1 Reference frames and length contraction

A significant and surprising number of candidates were not able to explain what a frame of reference is, with almost none referring to a system of coordinates. Many candidates knew and stated correctly the postulates of special relativity but failed to recognize and apply them in the typical context of simultaneity of measurements needed to validate the relativistic transformation equation for length contraction. Most candidates scored partial marks outlining Michelson-Morley experiment even though not necessarily in the context of the question.

G2 Particle acceleration

The graph was usually scoring at least the mark corresponding to the curve asymptotically tending to 1.0, with less success with the graph curving as from around 0.3. Some candidates were puzzled by the use of $MeVc^{-2}$, even though the most skilful candidates were able to obtain partial or full marks.

G3 [HL only] Relativistic momentum

A range of answers was displayed from full marks in those centres that seemed to have met the calculation before to those who had clearly never faced it. A significant number thought the 500 MeV to be the total energy. Some candidates changed units to finally answer with the momentum in Ns.

G4 [HL only] Space time

Candidates here ranged very clearly from those who were familiar with the topic and managed to get full or high marks to those who had not faced the topic and based their answers to the satellite orbiting around the Earth in Newtonian mechanics, despite the framework of the topic, Relativity.

Option H - Optics

H1 Electromagnetic spectrum

Even though some candidates were able to score several marks, with a very few scoring full marks, an unexpectedly large number of candidates were influenced by the example provided, gamma radiation, and moved on to complete the table with α and β particles. In general students showed a better recollection of the spectrum than an understanding of what can actually constitute a possible source.

H2 Refraction

This question showed many candidates obtaining full marks. The most common mistake was omitting the reflected ray despite the plural in the question and then the drawing of the ray towards the normal ignoring or misreading the information provided through the relationship of the refractive indices.

H3 Image formation

The ray diagrams were consistently drawn correctly and almost all candidates scored here full marks. The definitions, however, showed a lack of precision that repeatedly prevented candidates from gaining marks, particularly in the case of the principal axis. Candidates usually did not provide meaningful details as to differentiate the principal axis from any other one just crossing the lens. The identification of the image as virtual and the calculation regarding the distance were usually scoring fully, but the advantage of using the lens at the near point was also not usually stated precisely as expected.

H4 [HL only] Single-slit diffraction

Complete answers to this question were rare indeed. Even though the candidates showed familiarity with the term secondary wavelets, many opted for the typical explanation of interference due to double slits, showing a lack of detailed reading of the question. The calculation also showed a similar number of candidates either attempting it correctly or going through the double slit case. A large number of those who correctly answered about diffraction were unsuccessful at reading the correct screen distance but were able to get marks through error carried forward.

H5 [HL only] Thin film interference

The question discriminated well between those who successfully outlined the reasons from those who very vaguely talked about dispersion or provided no meaningful details or diagrams without proper labels.

Recommendations and guidance for the teaching of future candidates

Recommendations from the examination team included the following ideas:

- Strategies regarding the initial reading of a problem should be emphasized and practiced. Many answers go on to address the topic as it has probably been learnt without a careful understanding of the context and therefore the subtle points of a specific text of the question.
- Candidates should be given more opportunities during the course to practice examination style problems. They should also be familiar with markschemes as to try to guide their answers linked to the number of marks allocated.
- 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.
- Enough time should be devoted to cover in depth the Options chosen.