PHYSICS TZ1 (IBNA / IBLA)

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 15	16 - 26	27 - 39	40 - 49	50 - 59	60 - 69	70 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 26	27 - 38	39 - 48	49 - 57	58 - 67	68 - 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 a 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 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 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 - 20	21 - 23	24 - 26	27 - 29	30 - 39

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 11	12 - 15	16 - 17	18 - 19	20 - 21	22 - 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.

A small percentage of Centres returned G2 forms. At SL there were 52 responses from 367 Centres. The May 2008 papers were well received by the 52 respondents. The P1 papers were overwhelmingly found to be of a similar standard to last year with an appropriate standard, good syllabus coverage, good clarity of wording and good presentation of the paper overall. Coverage needs to be judged in conjunction with Paper 2.

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.

HL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	298	187	281	1264*	3	62.17	0.58
2	125	925*	546	434	3	45.50	0.27
3	170	191	50	1621*	1	79.73	0.20
4	174	595	825	422	17	0	0.00
5	1268*	175	373	214	3	62.37	0.45
6	1572*	227	92	141	1	77.32	0.15
7	350	106	361	1214*	2	59.71	0.42
8	354	103	1256*	313	7	61.78	0.30
9	332	1420*	124	152	5	69.85	0.24
10	100	251	1188*	490	4	58.44	0.34
11	102	118	1598*	214	1	78.60	0.40
12	535	1086*	287	106	19	53.42	0.37
13	385	745	247	656*		32.27	0.46
14	448	195	282	1107*	1	54.45	0.41
15	120	106	1497*	307	3	73.64	0.53
16	413	1121*	424	73	2	55.14	0.49
17	280	542	790*	416*	5	59.32	0.21
18	962*	874	81	110	6	47.32	0.57
19	1517*	64	306	143	3	74.62	0.21
20	693	1058*	60	222		52.04	0.14
21	140	152	322	1410*	4	69.36	0.45
22	117	638	742*	533	3	36.50	0.12
23	756	153	460	662*	2	32.56	0.52
24	236	337	582	868*	10	42.70	0.45
25	978*	386	315	348	6	48.11	0.25
26	135	91	981*	822	4	48.25	0.40
27	428	135	1067*	394*	9	71.86	0.22
28	323	1153*	234	322	1	56.71	0.44
29	277	305	1134*	300	17	55.78	0.47
30	299	757	143	824*	10	40.53	0.17
31	1484*	198	161	184	6	73	0.21
32	463	340	1127*	100	3	55.44	0.44
33	495	366	65	1100*	7	54.11	0.46
34	487	128	1169*	231	18	57.50	0.28
35	993*	453	113	455	19	48.84	0.44
36	876	370*	603	138	46	18.20	-0.04
37	215	434	1203*	167	14	59.17	0.41
38	802	359	279	564*	29	27.74	0.24
39	480*	907	481	132	33	23.61	0.31
40	1189*	283	265	282	14	58.48	0.32

Number of candidates: 2033

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	1051	675	824	2536*	9	50.13	0.58
2	439	258	4053*	302	7	80.11	0.21
3	560	552	221	3719*	7	73.51	0.32
4	2765*	1447	587	257	3	54.66	0.49
5	2471*	639	1428	513	8	48.84	0.50
6	3896*	580	244	333	6	77.01	0.21
7	143	2631*	1188	1093	4	52.01	0.41
8	335	930*	3550	238	6	18.38	0.19
9	1232	316	942	2560*	9	50.60	0.43
10	343	3217	151	1348*		26.65	0.30
11	898	349	2746*	1054	12	54.28	0.28
12	960	3165*	354	570	10	62.56	0.30
13	315	972	2367*	1387	18	46.79	0.37
14	2985*	952	410	707	5	59	0.51
15	855	1379	1812*	1006*	7	55.70	0.14
16	624	2785*	277	1369	4	55.05	0.31
17	3353*	249	1031	419	7	66.28	0.25
18	122	806	3832*	296	3	75.75	0.28
19	438	1604	1858*	1147	12	36.73	0.14
20	801	3693*	176	380	9	73	0.36
21	361	513	2553	1598*	34	31.59	0.24
22	788	2278*	1109	875	9	45.03	0.41
23	516	446	2080*	2001	16	41.11	0.33
24	1245	576	2288*	934*	16	63.69	0.34
25	2310	1952*	610	167	20	38.58	0.36
26	824	843	2548*	811	33	50.37	0.46
27	452	2536*	561	1468	42	50.13	0.44
28	2015*	1433	456	1093	62	39.83	0.38
29	1023	1265	836	1912*	23	37.79	0.48
30	104	381	1139	3393*	42	67.07	0.35

Number of candidates: 5059

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.

Comments on the analysis

Difficulty. The difficulty index varies for both HL and SL from about 18% (relatively ‘difficult’ questions) to about 80% (relatively ‘easy’ questions). The majority of items were in the range 30% to 80%. All candidates could therefore gain some credit from the papers which overall provided an adequate spread of marks.

Discrimination. All questions, with one exception (HL Q. 36) had a positive value for the discrimination index. Ideally, the index should be greater than about 0.2; this was the case for all but 6 questions from the entire suite of 70. 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.

'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. However, some early questions also have significant numbers of blanks (e.g. HL Q.4). 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.

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 Q15 and HL Q 17

It was felt at the Award meeting that there was sufficient ambiguity in the wording of the question to accept two responses, C and D, for this item. This was because an examination of the G2 forms indicated some concern that students had been disadvantaged by misunderstanding whether a change in temperature in one direction was the same as the change in the opposite direction.

HL Questions

Q 4

There was an unfortunate typographic error in the correct response and one of the distracters. As a result this item was deleted from the test.

Q 9

A G2 form suggested that this item represented the same piece of physics as a question in HL P2. This was not the case as the Paper 2 question focussed on the correct transformation of one expression into another rather than recall.

Q 13

Candidates have problems in understanding the definition of gravitational potential.

Q 20

This question had proved difficult. The essential problem was that candidates had failed to read the axes on the graph carefully enough. It is of importance to pay attention to all the information in an objective test, where the information presented to the candidate is pared down to the absolute essentials.

Q 22

The poor responses here indicated that candidates failed to understand that whenever light enters another medium there is always reflection.

Q 25

Candidates had not appreciated that *observable* interference requires a constant phase difference at one point.

Q 27

It was felt at Award that there was ambiguity in this question and that some candidates were confused by the meaning of ‘resistance changing’. Two responses were accepted as correct to avoid penalty to those who knew the essential physics. There is however a continuing significant number who erroneously believe that the resistance of an object is related to the gradient of its *I*-*V* characteristic.

Q 36

Many were guessing here. The physics of the photoelectric effect, in particular the influence of the intensity of the incident light on photon flux and emitted current is not well understood by candidates.

Q 39

Although there was a misprint in the unit for the responses, this was common to all of them and was not judged to prejudice the outcome of the item. Candidates should be aware of the relationship between the value of the half life and the decay constant.

SL questions

Q 2

Even though the kilowatt-hour equivalence in joules is printed in the Data Book, about 20% of candidates still answered this question incorrectly.

Q 8

Although candidates appreciated the comparison of gravitational forces acting on the system, there was clear evidence from the statistics that they did not understand that the tension forces in the string are equal in the free-body diagram.

Q 21

The physics was not well understood here. The popular distractor indicated that many had used the wrong value for the standing wave wavelength.

Q 25

There was a widespread misunderstanding that a resistance of zero means an open circuit rather than (the correct) short circuit.

Recommendations and guidance for the teaching of future candidates

As indicated earlier, Centres should encourage candidates to make an attempt at every item, having first eliminated distracters so far as is possible. There are no mark deductions for incorrect responses.

As reported in previous years, candidates fail to read the stem and they do not pay close attention to graphs and diagrams. There is detail in the diagrammatic material that is invariably needed in order to answer the questions correctly.

Paper two

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 20	21 - 32	33 - 42	43 - 53	54 - 63	64 - 95

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 5	6 - 11	12 - 16	17 - 21	22 - 27	28 - 32	33 - 50

The G2 comments that were received were very helpful when reviewing the perceived difficulties of this year's Paper. The small number of forms received for both Papers means that one should be cautious about drawing any firm conclusions. However at both levels the majority of teachers thought the paper to be of a similar standard to those in previous years. About 20% of Centres thought that the papers were more difficult than last year's. The mean mark for SL was slightly lower this year but the mean mark for HL was slightly higher. The vast majority felt that the syllabus coverage, clarity of wording and presentation of both papers were either satisfactory or good.

General comments

Many candidates found it hard to perform well on these Papers even though it was felt that there were plenty of marks accessible to those who may struggle with the more conceptual aspects of the course.

Lack of precision was an issue throughout the Papers. As identified last year, candidates often lost marks as a result of definitions that were incomplete or were expressed in non-scientific language or were just not known. Also many candidates did not perform well in answering questions starting with the action verbs “explain”, “outline” and/or “deduce”. A significant number of candidates lost some relatively easy marks as a result of unacceptable lines of best fit in the data analysis questions (A1). It should be emphasised to students that “line of best fit” does not necessarily mean a straight line. There are many other types of line. This is an issue that arises each year. Teachers who insist that “line” is assumed to mean a “straight line” should note that candidates cannot be asked to draw a “curved line” as this would be, perforce, an oxymoron.

Many candidates do not seem to take note of the number of lines available for the answer and/or the marks available for a part question and either give answers that are far too detailed and that often contain many irrelevancies or give answers that lack relevant details.

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

The examining team identified the following areas: -

- Drawing of best-fit lines
- Kinetic theory and compression of an ideal gas
- Conservation of momentum
- Difference between longitudinal and transverse waves in terms of direction of energy transfer
- Newton's second law in terms of rate of change of momentum
- Meaning of the term "nuclide"
- Nuclear binding energy
- Definition of electric field strength
- Concept of drift velocity
- Definition of e.m.f.
- Circuit calculations
- Solving projectile problems using energy conservation (HL)
- Statement of Newton's gravitational law(HL)
- The principle of superposition(HL)
- Magnetic fields (HL)
- Definition of electrostatic energy (HL)
- Photoelectric effect (HL)
- Efficiency calculations for heat engines (HL)

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

As last year, it was pleasing to see the following skills demonstrated: -

- Mathematical substitution into a given equation
- Symbol manipulation to prove a given relation or formula
- Computational skills
- Transposition of power equation into logarithmic form
- Specific heat and latent heat problems
- Proof of Kepler's third law

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.

Section A

A1 [HL and SL] - Data analysis question

It should be remembered that the data analysis question often deals with situations that might be unfamiliar to students.

(a) The role of the error bars was often missed leading to incomplete answers.

(b) Quite a few candidates drew a straight line (see above).

(c) This was often well-answered although the unit was often missed or incorrect and not all recognised that the value is negative. Weaker candidates attempted to obtain the answer from a single data point.

(d) [HL only] This was often well-answered.

SL (d); HL (e)

(j) This was often answered well.

(ii) Credit was given for "minimum refractive index" but several candidates also appreciated the limiting value as λ tends to infinity.

A2 [HL only] Projectile motion

(a) Many candidates did not appreciate that the stone has kinetic energy at the maximum height. Several tried to solve applying the equation of uniform motion to only the vertical motion of the projectile.

(b) This was often answered well. However, several candidates started the graph at zero and/or drew curved lines.

A3 [HL] B2 Part 2 [SL] Nuclear reactions

(a) (i)Very few candidates could adequately describe what is meant by a nuclide.

(ii) The term isotope was well known.

(b) [HL] This was often answered correctly but some candidates did not know a correct notation for a negative beta particle.

[SL] Most candidates recognised this as beta decay.

(ii) [SL and HL]. Unit conversion caused problems and many candidates thought that the rest mass was equal to the energy released in the decay.

(c) Many candidates gave their answers in terms of nuclear binding energy per nucleon and/or gave non-scientific answers such as "more energy needed to bind the nucleus".

(d) [SL only]

(i) and (ii) Often well-answered.

A4 [HL] Induced e.m.f.

(a) Although the symbolic definition was often correct, many candidates could not give the correct definition in words. A typical answer was “the amount of magnetic field that cuts an area at an angle”. This is another example of the lack of precision mentioned at the beginning of this report, apart from the fact of course, it is wrong!

(b) Not all candidates made the connection with rate of change of flux and e.m.f.

B1

B1 Part 1 [SL and HL] Momentum and energy

(a) This was often well-answered but sometimes symbols were not always clearly defined.

(b) Although there were some very good answers to this question, too often answers were anecdotal and muddled and there was often confusion with the conversation of mechanical energy.

(c) (i) Usually well-answered, although some candidates used a circular argument via the conservation of momentum and the value given in (ii).

(ii) Most candidates recognised to use conservation of momentum but some tried using conservation of mechanical energy which is in contradiction to part (iii)

(iii) Often well answered but weaker candidates tended not to attempt this question.

(d) [HL only] Usually well- answered but a common error was to omit the latent heat of fusion.

B1 Part 2 [HL only] Gravitation

(a) It was rare to see a complete and accurate statement of the law. Candidates generally did not seem to appreciate that the law only applies to point masses (particles). There were also loose statements such as “proportional to the masses”. Statements such as “all bodies exert a force” were often seen.

(b) A significant number of candidates got the correct value but a common error was to use the formula for gravitational potential.

(c) This was answered well by the better candidates although there was a tendency to miss out some of the steps or explanation to what the algebraic symbols referred.

B2

B2 Part 1 [SL B1 Part 2] Waves

(a) There were some very loose and incomplete answers to this question e.g. “the direction of the wave is at right angles to the direction of travel”. Many candidates did not seem to appreciate that for both types of wave the direction of travel of the wave is in the direction of energy transfer and that it is the relative direction of oscillations of the particles (or electric field for light) of the medium that distinguishes them.

(b) (i) and (ii) Usually well done but some candidates lost a unit mark here.

(c) It is important that candidates realise that "deduce" means that they should show their working, so here it is not sufficient to write $\lambda = \frac{v}{f} = 15$ cm s-1.

(d) Often answered correctly but quite a few candidates scored only 2 of the marks by making an error in either the starting point, amplitude or wavelength.

(e) Answers here were often incomplete in the respect of regarding the refraction angle as the angle between normal and wavefront.

(f) and (g) [HL only]

(f) (i) Of those candidates who gained credit here, quite a few tended to miss out some of the detail e.g. the fact that the slits act as point sources.

(ii) Often correct.

(g) (i) Often correct.

(ii) Diagrams were often poor with the distribution not touching the axis and/or with variable widths and amplitudes.

B2 Part 2 [HL only] Magnetic fields

(a) This was rarely answered correctly. Most candidates started with the formula for the field strength of a solenoid even though the question gave the hint that each side of the coil acts as an infinitely long wire.

(b) Diagrams were often poor and very confusing.

B3

B3 Part 1 [HL] B3 [SL] Fields and electric charge

(a) [SL only] Definitions were often incomplete or not known.

(a) [HL] (b) [SL]

(i) Often answered completely.

(ii) Often correct but sometimes the distance was not squared even though the formula had been quoted correctly.

(b) [HL] (c) [SL]

(i) Usually answered well.

(ii) The better candidates recognised to use the concept of centripetal force but there was a lot of muddled answers by candidates who clearly did not understand the situation.

(c) [HL]

(i) Very few candidates knew how to define electrostatic potential correctly. Answers were often wild guesses or incomplete. Some candidates knew that infinity came into the definition but were not sure how.

(ii) The negative sign was often omitted which led to an ECF in (d).

(d) [HL] The conversion of eV confused a lot of candidates.

Fields and electric charge in conductors

(d) [SL] The concept of drift velocity was known or understood by very few candidates.

(e) to (g) [HL and SL]

(e) Very few candidates knew a correct definition of e.m.f. Answers such as “the force that drives a current through a circuit” were seen far to often. A few candidates defined it as the potential difference across the terminals of the cell when the current is zero not realising that this is what the e.m.f. is numerically equal to as a consequence of its definition.

(f) (i) Usually correct.

(ii) Usually correct.

(g) (i) Usually correct.

(ii) Many candidates got tied up in knots and did not realise that their answer to (i) was there to help them with (ii).

B3 Part 2 [HL] Thermodynamics

(a) Many candidates forgot to mention work.

(b) (i) The misprint in the paper did not seem to bother candidates. Some noticed it and commented on this fact, others just ignored it and calculated $p\Delta V$ to be equal to the value given in the question. Not all candidates recognised that the work done is equal to the energy transferred to the surroundings.

(ii) Many arithmetic errors here by the candidates who knew how to solve the problem leading to a possible ECF in (iii).

(iii) Not many candidates knew what was going on here and often just quoted the value given in (i)

B4

B4 Part 1 [SL B2 Part 1] Power [and ideal gases - HL]

(a) Too many candidates wrote “the work done in a given time”. This is just another example of the lack of precision in definitions in general.

(b) Not all candidates clearly identified the symbols used.

(c) (i) Not very many candidates identified friction as the force that accelerated the sand and so had problems with (v).

(ii) Few knew to use Newton’s second law as the rate of change of momentum but got the correct numerical value perforce, by multiplying the two rates.

(iii) Usually correct.

(iv) Often correct.

(v) Very few correct answers were seen here even by those candidates who correctly identified friction in (i). A frequent answer was “because they measure different quantities.

(d) [HL] Generally very poor answers relying on anthropomorphism rather than physics e.g. "the molecules are squeezed closer together and so hit each other more often and so increase their energy and hence their temperature".

[SL] Often answered correctly.

B4 Part 2 [HL] Photoelectric effect

(a) Answers were generally very poor with reference to energy appearing only occasionally.

(b) Again, generally not well answered and again with little reference to energy and/or photons.

(c) Very few correct answers were seen to this question. It was not appreciated that for an increase in photon energy and constant intensity there will be fewer photons in the light beam.

(d) Often answered correctly by the better candidates. Weaker candidates tended to leave it unanswered.

Recommendations and guidance for the teaching of future candidates

Whereas candidates in this year's examination appeared to do well in calculations, a common theme has been the lack of precision in written answers, especially in those requiring an explanation. Arguments that logically follow through relevant stages were few. Candidates should be encouraged to define the symbols that they use. A significant number of candidates (particularly at Standard Level) appeared to be under-prepared for this examination. For these candidates, the experience cannot have been rewarding or encouraging. Candidates should also be alerted to the significance of the action verb that starts a question; an "explain" requires a more detailed answer than a "state".

As has been suggested in the past, the examination team recommends working through past papers (and the associated mark schemes) as a good preparation for the examination. Not only will this give candidates a familiarity with the format of the examination but also they should be able to gain a better understanding of the level of detail required, as well as the skills that are being assessed. Some candidates answered all the questions on separate sheets of paper and wrote nothing on the script itself. This included copying graphs that must have been very time consuming for those candidates. Situations such as this would have been avoided if those candidates had practiced with past papers. Candidates must also be encouraged to write clearly and legibly, to avoid the use of a pencil and always to have a ruler with them during the examination.

Paper three

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 5	6 - 11	12 - 18	19 - 24	25 - 29	30 - 35	36 - 60

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 3	4 - 7	8 - 12	13 - 16	17 - 20	21 - 24	25 - 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 there were only 44 G2 forms submitted at Standard Level and 21 at Higher Level.

Standard Level

- 81% found the paper to be of a similar standard to last year, 8% easier and 11% more difficult. Overall, 91% found the paper to be of an appropriate standard and 4% thought it too difficult with 5% too easy
- About 16% found the syllabus coverage satisfactory, 4% thought it was poor and 80% found it good
- About 20% found the clarity of wording satisfactory and 80% found it good
- About 11% found the presentation satisfactory and 89% found it good
- 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, 25% a little easier with 6% describing it as a little more difficult. All the G2 form responses indicated that the level of difficulty was appropriate
- About 24% found the syllabus coverage satisfactory and 76% good
- About 19% found the clarity of wording satisfactory and 81% found it good
- About 14% found the presentation satisfactory and 86% thought it was good
- As in previous years, the most popular options were H (Optics), G (Relativity) and F (Astrophysics)

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:

- Definitions – there were striking deficiencies in the definition of such basic quantities as refractive index, focal point of a lens, apparent magnitude and apparent brightness of a star.
- Explaining concepts in Physics in a way that demonstrates understanding (e.g. discussions of the cosmological background radiation, simultaneity)

- Construction of ray diagrams.
- Serious problems with the nuclear energy levels. Inability to discuss the connection between matter waves, the uncertainty principle and the Schrödinger theory.
- Calculations based on a logarithmic graph of sound intensity.
- The application of the first law of thermodynamics to a heat engine.
- The details of a nuclear reactor, in particular the use of control rods and the role of the moderator.
- Discussions of computed tomography imaging.
- Use of relativistic units in the relativity option.
- Unclear discussions of Brahe's, Kepler's and Newton's contributions to the understanding of planetary motion and confusion as to who preceded whom.
- Coulomb's experiment on the electrostatic force.
- 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 "describe".

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

Simple mathematical calculations and derivations were often done well by the majority of candidates. Many candidates appeared well prepared and able to produce some good answers that showed a good understanding of the concepts, particularly in the Mechanics, Astrophysics and Relativity options

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

SL only

Option A – Mechanics

A1 Projectile motion

Very many candidates were able to score full marks on this question. Many realized that with an air resistance force the maximum height reached would be less but not as many could also get the second marking point that required an asymmetric path with shorter range. It was not always clear if the asymmetric paths drawn were intended to be so!

A2 Orbital motion

Many candidates were able to able to perform the derivation of Kepler's third law even if in some cases the arguments presented were somewhat convoluted and unclear. But generally this was well done. However, very few could score full marks for the first part of the question, many missing the reference to point masses. A surprising number referred to Newton's third law.

A3 Rotational equilibrium

Many scored full marks in this question but for a substantial number of students the concept of torque is sill mysterious.

Option B – Quantum Physics and Nuclear Physics

B1 Models of the hydrogen atom

Option B was perhaps the option where students struggled the most and where the level of the questions appeared to be above the level of preparation of the majority of candidates attempting it. The explanations of the hydrogen spectrum in terms of the Bohr model went no further than the statement that the Bohr model predicted energy levels. Details of transitions, emission of photons of energy equal to the difference in energy of the levels and references to the dependence on frequency of the photon energy were all, too often, absent. Students also had difficulty explaining the crowding of the lines in the ultraviolet.

B2 Nuclear energy levels and radioactive decay

References to nuclear energy levels were absent in the explanation for the emission of gamma ray photons and few students had any idea about why the particles in beta decay had different energies. The last bit of the question on particle physics was almost a universal failure. As mentioned earlier, this option proved too difficult for the majority of candidates who must have felt disappointed with the level of the questions.

Option C - Energy extension

C1 Heat engine

The first two parts of the question were accessible to almost all who tried them. Part (c) required that the candidates realize that for an ideal gas the internal energy is a function of absolute temperature and so for a change in temperature there will be the same change in internal energy. The majority of the candidates failed to see this however. There were better results with the calculation of the work done and the efficiency of the engine.

C2 Nuclear power

This straightforward, mostly descriptive question was answered better than similar questions in past exams but there were points where the candidates seemed to have no idea about what to say. This included the use of control rods. The majority of candidates seemed never to have heard of them. There were also general statements about energy produced without really answering the question that was asked in part (c). Most could describe a chain reaction and could calculate the number of neutrons produced.

SL and HL combined

Option D - Biomedical physics

D1 Scaling

This question was expected to be answered well and it was, with the majority getting the first part correct. A few had difficulty explaining why the result of the first part implied a limit on the size of the insect.

D2 Sound and hearing

There were surprisingly few correct answers to the first part of the question about conductive and nerve hearing losses. The graph of the threshold of hearing of the curve for an elderly person was not at all well done with the majority of candidates drawing a curve below rather than above the curve given. The calculation involving sound intensity was very poorly done. It seemed that the majority of candidates had never performed a similar calculation before the examination.

D3 X-rays

The statement of attenuation mechanisms in X-radiation was well done. However, few were able to give convincing accounts of either computer tomography or how its images differ from those of conventional X-rays.

D4 [HL only] Energy expended in exercise

This question was answered well. The common mistake was to mix up the sine, cosine and tangent of the angle or to forget to multiply by 40 for the total work done by the person. There were reasonable responses as to why more energy was actually produced by the body except that very few concentrated on muscle inefficiency.

D5 [HL only] Exposure

This was well done mostly but very many students tried to fiddle their way through the question (as is often the case when the numerical answer is provided) and there was no indication that the students were aware of the difference in the unit for absorbed dose and that for dose equivalent.

Option E – The history and development of physics

E1 Motion of stars

This was reasonably well done by the majority of those who attempted it. A few confused the rotation of the Earth about the Sun with the rotation about its axis. A few went astray and brought epicycles etc into their answers. Most were able to estimate the time that camera shutter was open.

E2 Motion of planets

This was generally well done but many candidates were confused as to who did what and in what order. The fact that Newton actually derived Kepler's laws from his laws of gravitation and mechanics was not properly appreciated by some.

E3 Caloric theory of heat

This was generally well done and many candidates could provide evidence against the caloric theory, at times with vague references to "cannons". There were a few interesting "anachronistic" pieces of evidence against the caloric theory such as "microwave ovens".

E4 The inverse law of electrostatics

The overwhelming majority of candidates had no idea of what this experiment was all about and very few could score more than half the points allotted to the question. The second part was answered correctly by just a handful of candidates.

E5 [HL only] Models of the hydrogen atom

The limitations of the Bohr model were well known and clear, as was the calculation of the photon wavelength that was answered well by most. However the description of how the Bohr model accounts for the spectrum were incomplete and lacking in detail. The connection between the Schrödinger theory and the uncertainty principle eluded most but it was good to see a fair number do a good job on this difficult question.

Option F – Astrophysics

F1 Comets and stars

Most candidates did well here. In the estimate of the number of stars in a typical galaxy a few missed a point due to significant digits – at most two were accepted but answers with usually 3 digits were provided.

F2 Cepheid stars

The definitions of apparent magnitude and apparent brightness were, surprisingly, poorly done. It was odd to see so many candidates defining apparent magnitude in terms of the size of the star. In the definition of apparent brightness there were often vague references to "luminosity taking distance into account". Most could explain why Delta appeared brighter and equally many could correctly explain why Delta was also closer. These parts well done. Most were also aware that the variation in luminosity of a Cepheid was due to expansions and contractions of the surface but again the detail eluded most, namely the connection of the changes in luminosity to the changes in the surface area of the star. The next question dealt with determining the distance to a galaxy and whereas answers were good most missed the important point that first a Cepheid had to be identified as being part of a galaxy. Many fiddled their way through the calculation of the distance and there was evidence that many candidates could not read the logarithmic graph for luminosity and period.

F3 Cosmology

This standard question was, surprisingly, not well done. Few could define what CMBR was and even fewer could give any coherent argument relating the existence of this radiation to the big bang and the expanding universe. This is strange in view of the fact that this question has appeared many times in past exams.

F4 [HL only] Stellar evolution

It was good to see that many students were aware that the sun would leave the main sequence after using up a fraction of its hydrogen. Most, but not all, saw that as the sun moved away from the main sequence the luminosity would increase but few could relate this increase to the increase in the surface area. Most had some understanding of the Chandrasekhar limit but some were unable to express it sufficiently clearly to be given credit. It was important to state that region F was the white dwarf region and that the sun would end up there as it obviously fulfilled the Chandrasekhar limit. The path of a high mass star on the HR diagram is complex but only the most basic was required here, not least to start the path to the left of the sun, something not everyone did.

F5 [HL only] Hubble's law

Hubble's law was stated generally well and the relation between the Hubble constant and the age of the universe was well known to most. However, in deriving the result, few could provide any explanatory comments.

Option G - Relativity

G1 The speed of light

The majority of candidates realized that a calculation was required for the second part of this question. A few just wrote down the correct answer (c) for the speed of light. The question did ask for a calculation, however, and it was a [3] mark question. Few could rewrite the data booklet formula so as to get the formula for *u*.

G2 Relativistic kinematics

Most parts of this question were well done indicating that students had practiced the standard relativistic calculations. The less successful candidates were those who did not use relativistic units and seemed unaware of 1 light year/c = 1 year. Converting light years to meters and then finding the time in seconds created a lot of unnecessary work and resulted in loss of time. The last part of the question dealt with simultaneity. It was clear that this question has now been studied well enough for candidates to know the answer but the explanations were still not there. The mark-scheme was generous to award points for correct answers even in the absence of correct reasoning. Without this, few candidates would have scored any of the 4 marks allotted to this part. It was, however, nice to see a few candidates giving the correct arguments to both parts of this question.

G3 Relativistic mechanics

The calculation of the accelerating voltage did not appear mysterious to many candidates and those who used relativistic units did well. However, many did the first part correctly but got bogged down in incredible calculations with strange numbers when they started multiplying or dividing by powers of c. The sketches of the variation of speed with voltage were often so negligent as to lose marks. The essential physics is that at low speeds the Newtonian and the relativistic curves have to agree and, in the relativistic case, the speed must approach the speed of light asymptotically. Candidates really must pay more attention to delivering sketches that show essential features clearly.

G4 [HL only] Relativistic decay

This was extremely disappointing with only a handful of candidates scoring full marks. Most were lost in relativistic formulae involving energy and momentum. Very few could argue clearly from conservation of energy and momentum. It is clear that this part of the syllabus needs to be paid much more attention to in the classroom with many and varied examples of relativistic mechanics calculations. As in the previous question, those who attempted to use S.I. units found the going much tougher than those using relativistic units.

G5 [HL only] Black holes

Candidates could describe well what was meant by the Schwarzschild radius of a black hole and many understood that with mass falling into the hole the radius would increase (however many missed the second marking point by failing to refer to the fact that the radius is directly proportional to the mass). There were good curves drawn for the path of a radio signal around the black hole (and a few amusing ones as well) but the explanation of the path eluded most. In particular, although candidates often recognized that the black hole curves the path, few could relate this to the shortest path in the curved space around the hole.

Option H Optics

H1 Refraction

The striking feature of answers to this question was the almost universal inability to define refractive index correctly. The most typical answer was “the degree to which light bends”. On the other hand most could do the calculation of the minimum refractive index of the glass prism correctly. The last part of the question was hardly answered correctly by anyone. A common answer was that “refraction does not have anything to do with wavelength”.

H2 Converging lens

The question began with a definition of focal point, to which hardly any satisfactory answers were given. Many referred to “half the distance to the centre of curvature” (perhaps a sign that mirrors are also taught, confusing candidates) and others referred to “the point where all rays converge”. The calculation of the displacement was well done by most but at the same time most missed the direction in the answer for displacement. A few who had attempted a ray diagram were not as successful and some produced diagrams with mirrors.

H3 The astronomical telescope

Good answers to this question were rare. The ray diagram was extremely poorly done. Candidates were putting the image in every conceivable position without any apparent relation to rays. The very low level of ray diagrams is consistent with similar performances in past exams and shows that something is not going well with this topic. Is time running out at this stage and the topic is not covered in class?

H4 [HL only] Diffraction

This straightforward question was not answered well. Surprisingly few could estimate the wavelength from the graph and the sketches of the diffraction pattern were disappointing. The graph was not put on millimeter paper and that made reading the angle of the first diffraction minimum somewhat difficult. Even so, the angle could be read sufficiently accurately to give a wavelength within the range that was acceptable by the mark-scheme. Diffraction continues to be, as in past exams, a difficult topic that students do not appear to have studied in any obvious depth.

H5 [HL only] Thin film interference

This was not a well answered question. Most explained the coherence of the two reflected rays in terms of the rays having the same frequency or that they were parallel. For the thickness of the film many gave various answers in terms of multiples of the wavelength but clear, convincing arguments in terms of path difference, phase shifts and reference to the conditions for interference were few. Most candidates realized that the film would be coloured (there were many references to the rainbow) but few could explain why convincingly.

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. They should have access to past examination papers and mark-schemes.
- Having said that it must also be stressed that not all examination questions will be like previous ones! Students must practice as many varied questions as possible and not just what has appeared on exams previously.
- Students must be encouraged to learn the correct definitions of various physical quantities and must be able to reproduce them accurately.
- 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 recognize the difference between, for example, the stating and the explaining of an answer. Knowing the meaning of the action verbs implies the level of the detail expected in the answer.
- When using a diagram to help answer a question, candidates should be encouraged to pay attention to the precision of the diagram. This is particularly true of ray diagrams, as many candidates failed to use even a sharp pencil and / or a ruler.
- Students must get practice with sketch graphs. The point of such a graph is to provide the salient physical points of a problem. For example, Newtonian and relativistic graphs must be identical for speeds low compared to the speed of light.
- Enough time should be devoted to cover in depth the Options chosen and students must be strongly discouraged from studying an option on their own or attempting an option that they have not studied.

International Baccalaureate® Baccalauréat International Bachillerato Internacional