PHYSICS TZ1 (IBNA / IBLA)

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 25	26 - 37	38 - 48	49 - 58	59 - 69	70 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-14	15-26	27-38	39-48	49-59	60-69	70-100

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 moderation proceeded well this year. The majority of schools followed the correct formalities, including appropriately completed 4/PSOW forms, group 4-project evidence, teacher instructions, and the 4/IA cover sheet. The majority of schools also had relevant investigations for the given IA criteria, and most of the teacher's IA marks were consistent and at the appropriate level. Schools had rich and diverse practical programmes with sufficient hours and there was evidence of an increased use of ICT.

There were a few areas where difficulties occurred.

- Inappropriate investigations for assessment often included the **group 4 project** that involves collaborative work and was occasionally assessed as if it were done by individuals. In general, the first five IA criteria should not be applied to the group 4 project.

- Other examples of inappropriate investigations involve planning exercises where the teacher gave a clearly defined research question. It must be emphasized that **planning (a)** requires an open-ended teacher prompt. Teachers may provide the dependent variable but there must be a number of possible independent variables. The best planning tasks concern the relationship or function between variables, not specific values of physical quantities or the confirmation of known laws.
- Another problem with **planning (a)** work is the increased use of the Internet for research ideas. Teachers should discourage this, as this often leads to a form of plagiarism.
- The **planning (b)** criterion was occasionally inappropriately assessed when students used standard class sets of equipment. For instance, determining the specific heat capacity of an unknown metal.
- Examples of inappropriate assessment under **data collection** as well as **data processing and presenting** included experiments where the teacher told the student what data to record and how to record it, as well as what graph to draw. This was done inadvertently by giving the student an equation or, occasionally, worksheets were given. “Fill in the blank” instruction sheets are inappropriate for assessment.

Candidate performance against each criterion

Planning investigations were occasionally over-marked by teachers because too much information was provided and the student’s marks had to be reduced. 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 but where 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.

A. Where moderators reduce marks.

Planning (a):

- The research question, hypothesis and/or independent and controlled variables are given by the teacher. The relevant aspect should be awarded ‘n’. A general aim is acceptable if the students have significantly modified the teacher prompt or question (e.g. made it more precise).

- The moderator will reduce the second aspect to ‘p’ when the hypothesis has not been explained or the explanation clearly contradicts theory that an average IB physics student can reasonably be expected to know.

Planning (b):

- A method sheet is given which the student follows without any modification *or* **all** students are using an identical method. Appropriate marking is n, n, n = 0.
- It is clear that the students have been told what apparatus and materials they require. The maximum that can be awarded is n, c, c = 2.

Data Collection:

- Students are given a photocopied table with headings and units. The maximum mark is p, n = 0. If the student has not recorded uncertainties in any quantitative data then the maximum that can be awarded for the first aspect is ‘p’.
- The student has been *repeatedly inconsistent* in the use of significant digits when recording data then ‘p’ is the maximum that can be awarded for the second aspect.
- In physics data are always quantitative e.g. drawing the field lines around a magnet does not constitute DC.

Data Processing & Presentation:

- 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 allow is c, n = 1.
- If there is no evidence of errors being propagated (HL only) or of the total random error being estimated (SL) the maximum moderated mark is c, p = 2. A best-fit line graph is sufficient to meet the requirements for error and uncertainty propagation.

Conclusion & Evaluation:

- If the teacher provides structured questions to prompt students through the discussion, conclusion and evaluation then the maximum award is *partial* for each aspect for which the student has been given guidance. The moderator judges purely on the students input.
- Limited evaluation e.g. the student has only indicated as a criticism that they ran out of time. This is often given c,c,c=3 but is only worth up to a maximum of c, n, p = 1.

B. When moderators do not reduce marks.

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

Planning(a):

- The dependent variable has been given by the teacher or the student has made no mention of a dependent variable

- If the moderator disagrees with the explained hypothesis but feels 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 the teacher as to the poor suitability of the task.
- The independent and controlled variables have been clearly identified in the procedure but are not given as a separate list.
- There is a list of variables and it is clearly apparent from the procedure which are independent and which are controlled.

Planning (b):

- Similar but not identical procedures are given for a narrow task. The moderator will make a comment on the poor suitability of the task on 4/IAF form.
- Moderators do not only mark the equipment list but give credit for equipment clearly identified in a stepwise procedure.
- Moderators do not insist on +/- precision of apparatus to be given in the apparatus list. The concept of recording uncertainties is dealt with in DC.
- Routine items such as safety glasses or lab coats are not listed. Some teachers consider it vital to list them each time but others consider them integral part of all lab work and assume their use. Moderators support the teacher's stance here.

Data Collection:

- The student has been inconsistent with significant digits for just one data point or missed units out of one column heading in a comprehensive data collection exercise possibly with several tables of data. 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 perfection' rule. This is an important principle since often good students responding in full to an extended task unfairly get penalized more often than students addressing a simplistic exercise.
- The student has not included any qualitative observation(s) and the moderator cannot think of any that would have been obviously relevant.
- There is no table title when it is obvious what the data in the table refers to. 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 is 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 digit 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), 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.

- 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 variable.
- 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.

Conclusion & Evaluation:

- The student has identified the most sensible sources of systematic error. The moderator will support a teacher's award even if the moderator can identify one more.
- Moderators are 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 4/IAF as to the unsuitability of the task giving full justifications will be provided in feedback but the moderator will not necessarily downgrade the student. A consequence is 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.

C. Moderation and ICT

The IB encourages the use of data logging even 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.).

Recommendations for the teaching of future candidates

- Students and teachers need to study the IA criteria carefully when doing practical work that will be assessed. Remember that assessed work is only a sub-set of the entire IA work that students should experience.
- Group 4 projects are not appropriate for IA by the first five criteria.
- ICT is encouraged in both assessed and non-assessed practical work.
- Research on the Internet for Planning (a) should not be encouraged. Students should do their own thinking on the given teacher prompt.

- A few schools sent in group 4 project evidence on CDs. In two cases, the CD would not open. Teachers need to make sure that CD evidence is easily readable.
- The international system (SI) of units should be used when possible. One school measured force in dynes and another school measured distance in inches. Students are not penalized for this.
- Graph paper or computer-generated graphs are expected. There is still evidence of hand drawn axes and roughly plotted data points from a few schools.
- Teachers are encouraged to read and study this report.

Further comments

The majority of teachers have a clear understanding of the IA requirements and provide their students with a rich and diverse practical program. Although some schools were moderated down and others up, there was good evidence of a consistent application of the IA criteria. Teachers are reminded that May and November 2008 will be the last examination sessions under the current IA regulations. Teachers need to familiarize themselves with the new IA criteria and requirements for the first examination session of May 2009.

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.

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

Paper one

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 9	10 - 13	14 - 18	19 - 22	23 - 25	26 - 29	30 - 38

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 11	12 - 15	16 - 17	18 - 20	21 - 22	23 - 29

General comments

Only a small percentage of the total number of teachers or the number of Centres taking the examination returned G2's. 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 importance of the G2's to the senior examining team is illustrated by the fact that due to a comment by a teacher, it was recognised that one item in HL (Q10-see below) was wrong. The mistake in the question had gone unnoticed through all the checking procedures. Fortunately, had this teacher not spotted the error, the statistics would have alerted the team to the fact that something was wrong with the item.

The G2 replies indicated that the May 2007 papers were generally well received. The majority of the teachers who commented on the Papers felt that they contained questions of an appropriate level. With few exceptions, teachers thought that the Papers gave satisfactory or good coverage of the syllabus. When commenting on coverage, it should be borne in mind that this must be judged in conjunction with Paper 2. Most teachers 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.

HL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	156	602	1070*	64	2	56.49	0.34
2	45	344	47	1449*	9	76.50	0.26
3	213	1542*	43	93	3	81.41	0.35
4	15	167	982*	729	1	51.85	0.49
5	155	408	1135	193	3	0	0.00
6	1766*	49	68	8	3	93.24	0.11
7	416	931*	191	353	3	49.16	0.28
8	895	206*	490	295	8	10.88	0.16
9	465*	792	413	217	7	24.55	0.47
10	727	191	75	895	6	0	0.00
11	198	1537*	123	30	6	81.15	0.33
12	701	353	64	765*	11	40.39	0.51
13	381	160	1219*	131	3	64.36	0.27
14	1085*	192	467	132	18	57.29	0.40
15	70	151	1517*	155	1	80.10	0.25
16	280	84	315	1208*	7	63.78	0.45
17	1428*	93	272	98	3	75.40	0.42
18	208	418	950*	315	3	50.16	0.49
19	501	598	543*	244	8	28.67	0.27
20	53	1488*	108	240	5	78.56	0.19
21	109	907	62	812*	4	42.87	0.48
22	1432*	192	126	138	6	75.61	0.36
23	1560*	207	31	94	2	82.37	0.32
24	143	945*	675	124	7	49.89	0.43
25	1389*	151	309	40	5	73.34	0.33
26	770*	727	252	139	6	40.65	0.44
27	64	70	779*	961	20	41.13	0.54
28	178	1282	118	309*	7	16.31	0.07
29	169	543	270	909*	3	47.99	0.37
30	507*	1085	212	73	17	26.77	0.36
31	223	345*	580	714	32	18.22	0.20
32	704	385	640*	147	18	33.79	0.40
33	289	168	505	897*	35	47.36	0.42
34	291	170	242	1179*	12	62.25	0.53
35	1021	643*	141	76	13	33.95	0.37
36	285	696	713*	176	24	37.65	0.31
37	1019*	367	326	144	38	53.80	0.55
38	508	203	365*	785	33	19.27	0.11
39	418	971*	375	110	20	51.27	0.37
40	380	450	273	770*	21	40.65	0.25

Number of candidates: 1894

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	552	1513	2202*	228	10	48.88	0.41
2	110	867	128	3382	18	75.07	0.28
3	173	3624*	236	458	14	80.44	0.22
4	1777	1534*	594	585	15	34.05	0.41
5	69	644	1775*	2001	16	39.40	0.46
6	651	1004	2286	560	4	0	0.00
7	4040*	183	241	38	3	89.68	0.16
8	1027	1739*	690	1035	14	38.60	0.32
9	2555	414*	1019	504	13	9.19	0.12
10	580	186	72	3661*	6	81.27	0.34
11	150	228	4068*	49	10	90.30	0.13
12	1216	902	1462*	887	38	32.45	0.38
13	2413*	440	974	671	7	53.56	0.51
14	264	1006	2863*	327	45	63.55	0.39
15	3028*	311	892	270	4	67.21	0.43
16	603	1362	1702*	822	16	37.78	0.45
17	1695*	317	829	1644	20	37.62	0.42
18	202	638	506	3147*	12	69.86	0.46
19	392	2450	206	1438*	19	31.92	0.43
20	3098*	650	416	312	29	68.77	0.40
21	375	1488	359	2222*	61	49.32	0.39
22	2932*	167	1131	262	13	65.08	0.41
23	1482*	1918	587	494	24	32.90	0.40
24	531	2889	353	707*	25	15.69	0.10
25	757	366	1632*	1656	94	36.23	0.21
26	591	2853*	682	287	92	63.33	0.40
27	892*	2357	809	338	109	19.80	0.15
28	673	3275*	383	135	39	72.70	0.36
29	2220	1466*	422	333	64	32.54	0.31
30	428	553	223	3249*	52	72.12	0.38

Number of candidates: 4505

The numbers in the columns A-D and Blank are the numbers of candidates choosing the labelled option or leaving the answer blank. The 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 option 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. For both HL and SL, the difficulty index varies from about 10% (relatively 'difficult' questions) to about 93% in HL and 90% in SL (relatively 'easy' questions). The majority of items were in the range 30% to 70%. Thus, the Papers provided ample opportunity for all candidates to gain some credit and, at the same time, give an adequate spread of marks.

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

'Blank' response. In both Papers, there were a large number of blank responses and not just towards the end. 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 only be given on selected questions, i.e. those that illustrate a particular issue or where a problem can be identified.

SL and HL common questions

SL Q6 and HL Q5

Because of two poorly produced graphs (B and C), this question was deleted. The graph in C shows infinite acceleration at the t = 0 and so is clearly wrong. The option B would be correct if the graph did not show serious "kinks".

SL Q8 and HL Q7

A few teachers commented that the weight of the peg should be considered. In this respect, it would have been better if the stem had specified a light peg. However, there was no evidence to suggest that candidates had been disadvantaged by this omission. Clearly B can be the only correct option but this did not stop a lot of the weaker candidates choosing D, where all the forces are shown to be equal in magnitude.

SL Q9 and HL Q8

For some reason, what the examiners thought was a clearly an incorrect option (A), was often chosen, even by the better candidates.

SL Q19 and HL Q21

A common error made by the weaker candidates was to use the period instead of the frequency (option B).

SL Q23 and HL Q26

A number of teachers thought that candidates might be disadvantaged by the use of the UK word "earthed" as opposed to the US word "grounded". There was no evidence to suggest that this was so, weaker candidates chose option B and clearly did not read the stem carefully.

SL Q24 and HL Q28

The majority of candidates do not know a correct statement for Ohm's law. This law does not state that for a conductor, the current is proportional to the potential difference across it. This only applies if the temperature of the conductor is constant. This was the reason for inserting the word "always" into option A. However, this did not stop 84% of candidates at SL and 67% at HL, choosing this option.

SL Q27 and HL Q30

Many candidates did not appreciate that, at the position specified, the particle is moving parallel to the direction of the magnetic field and therefore the force acting on it is zero.

SL Q29 and HL Q35

The weaker candidates did not read the stem carefully enough and chose option A.

SL questions

Q17

Nearly 50% of candidates chose the incorrect option (D) which specifies the complete opposite of what is happening in this phase change.

HL questions

Q9

This question discriminated well with the better candidates. The rate of change of momentum is equal to the force.

Q10

This question should have referred to the total input energy to the machine. This would then give option D as the key. The question was deleted.

Q32

The question discriminated well with many of the weaker candidates choosing option A and not recognising that there is a constant flux change.

Q36

Many weaker candidates did not read the stem carefully and chose option B which is the frequency-dependence graph.

Q38

Candidates should be reminded that they need to be able to explain both the origins of the continuous and of the characteristic regions of an X-ray spectrum. Options A and D were the most popular choices.

Recommendations and guidance for the teaching of future candidates

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

The stem should be read carefully. It appears that some candidates do not read the whole stem but rather, having ascertained the general meaning, they move on to the options. Multiple choice items are kept as short as is possible. Consequently, all wording is significant and important.

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

Paper two

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 9	10 - 19	20 - 29	30 - 40	41 - 52	53 - 63	64 - 95

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 5	6 - 10	11 - 16	17 - 21	22 - 27	28 - 32	33 - 50

The G2 comments that were received were 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. More than 80% of the respondents thought that the papers were at an appropriate level of difficulty. The vast majority felt that the syllabus coverage, clarity of wording and presentation of both papers was either satisfactory or good.

General comments

There were some excellent scripts. However, many candidates, at both levels, found it hard to perform well on these papers even though there were many marks accessible to the weaker candidates. As identified last year, candidates often lose marks as a result of definitions that either lack precision or are expressed in non-scientific language. A significant number of candidates lost some relatively easy marks as a result of unacceptable lines-of-best-fit in the data analysis question (A1). **It should be emphasised to candidates that a best-fit line is not necessarily a straight line.**

Candidates often lacked algebraic manipulation skills and also the ability to give coherent, scientific explanations for particular phenomena. Various parts of the syllabus appeared to have been very poorly covered. These included motion of charged particles in magnetic fields and stationary waves (at both Levels) and electromagnetic induction (at Higher Level). Surprisingly, many candidates had problems with momentum conservation and the concept of an elastic collision. The question on the motion of the ball in the presence of air resistance gave candidates serious problems. Questions on thermal physics were well done.

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:

- Calculating the slope (gradient) of a curve by drawing an appropriate tangent
- Determining the direction of the magnetic force on a moving charged particle and the sign of the charge.
- Understanding the meaning of an elastic collision
- Calculation of the distance of closest approach of an $\alpha -$ particle to a nucleus
- Working with situations in which mechanical energy is not conserved
- Explaining the formation of stationary waves
- Explaining the inversion of a wave pulse incident on a fixed position
- Defining half-life
- Electromagnetic induction
- Describing energy transformations in a current carrying wire
- Working with gravitation

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

Generally, candidates seemed well prepared in the following areas:

- Solving basic mechanics problems such as the inclined plane
- Solving thermal physics problems
- Thermodynamics
- Mathematical substitution into a given equation

- Basic properties of travelling waves
- Working with the correct number of significant figures and correct units

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

(a) This was well done by most.

(b) Many candidates drew a straight line as a line of "best fit". (See above).

(c) There were many references to "parabolas", "hyperbolas" and "exponential decay like curves" without any justification for these choices. These were not penalized however.

(d) Students still do not draw a tangent line in order to determine the gradient of a curve. In many cases where a tangent was drawn, the length of the hypotenuse of the triangle used to calculate the gradient was too short.

(e) It was pleasing to see many students arguing correctly to answer this part.

(f) [**HL only**] Surprisingly, there were few correct answers to this part. Many said that *k* is the gradient of the graph, without specifying to which graph they were referring.

A2 [HL and SL] Collision of train carriages

(a) Most candidates were able to score full marks for this question.

(b) This was very disappointing. Many candidates stated, without any calculations, that the collision must have been elastic since momentum was conserved. Others thought the collision must have been elastic since the trains did not stick to each other. It is clear that many candidates did not have a clear idea of what is meant by an elastic collision.

(c) This part was well answered by most candidates.

A3 [HL and SL] Motion in a magnetic field

This was a straightforward question discussed in every textbook, yet candidates had considerable trouble in obtaining marks. The question revealed major weaknesses in the students' understanding of the concept of work done by a force.

(a) Most candidates were able to score the mark for the direction of the force.

(b) (i) Very few candidates could explain why the charge is negative. Students must be reminded to read the questions carefully. The question asked for an explanation of the sign of the charge. A bald statement that the charge is negative received no credit.

(ii) Many candidates thought that since there was a force and the particle was moving, then work had to be done. Others thought that no work was done and gave as a reason the fact that the net displacement of the particle was zero, which is clearly an incorrect argument.

(c) Very few candidates had any idea about the correct path of the second particle.

A4 [HL only] Distance of closest approach

This question was very poorly done by the candidates.

(a) Most candidates were able to state that the potential energy at P is 3.8 MeV but were unable to convert this into joules.

(b) Very few candidates could complete the calculation to find the distance of closest approach. ECF from (a) did not help.

(c) Most were able to answer this part correctly.

(d) The responses here were mixed, with many students able to correctly deduce the density of nuclei. Some failed to understand what was required when they substituted a numerical value for the mass number.

Section B

B1 [Part 1 HL and SL] Motion in the presence of air resistance

This question was a very popular choice at both levels but had extremely poor results, especially in parts (e) – (g).

(a) Answers here were vague but a generous mark scheme allowed students to obtain the mark.

(b) It was surprising to see so many incorrect responses to this straightforward exercise.

(c) There were hardly any responses where a tangent was drawn in order to determine the acceleration. In (ii) many used their answer from (i) to write $F_{\text{air}} = ma$ without realizing that $ma = F_{\text{air}} + mg$ and hence $F_{\text{air}} = ma - mg$.

(d) The question expected the candidates to realise that, since the magnitude of the slope is decreasing then the air resistance force has to decrease as well. It was pleasing to note that many students were able to appreciate this change and obtained the marks for this question.

(e) This is where the problems began. The great majority of candidates did not realize that mechanical energy is not conserved and, since the acceleration is not constant, the usual formulae for kinematics in the data booklet do not apply. It was very disappointing to see so many incorrect answers to a rather straightforward question.

B1 Part 2 [HL only]

(a) The first part to this question guided students through an example showing the failure of the classical electromagnetic theory to account for the photoelectric effect. Many students were able to obtain the correct answer (often in less than one line) but many others were completely lost as to how to approach the problem.

(b) The responses here, and in the following parts of this question, were very poor indicating that the photoelectric effect is not studied adequately by candidates. For example very few mentioned the word "photon".

(c) Most students were unable to explain how the kinetic energy of the electrons could be measured. A very small minority recalled that the stopping voltage is the minimum voltage for which the current becomes zero. There were few correct responses for the graph showing the variation with frequency of the kinetic energy of the electrons.

(d) This part proved almost impossible for the great majority of candidates.

B1 Part 2 [SL only]

(a) It was very surprising to note that many candidates were unable to state the nature of an $\alpha -$ particle.

(b) This was a difficult question

(c) Most candidates were able to write down the correct reaction equation but the definition of half-life gave rise to very vague answers. It is crucial that students give precise and accurate definitions.

(d) This part was well done by very many candidates, but far too many gave the answer $\frac{1}{7}T_{1/2}$. Many SL candidates were familiar with the formula $N = N_0 e^{-\lambda t}$ and could calculate the decay constant correctly (this is not on the SL syllabus) but incorrectly substituted $\frac{N_0}{N} = \frac{1}{7}$.

B2 [Part 1 (a) – (d) HL and SL, (e) HL only] Waves

(a) Most candidates managed to score full marks in this part of the question.

(b) Part (i) was completed by almost all candidates but (ii) was attempted in very few scripts. The candidates misunderstood this question. With hindsight, the question might have been clearer if it had mentioned in the stem that graph 2 is a drawing of the displacement of the string rather than the wave.

(c) Most candidates knew that the reflected pulse is inverted but the explanation of this fact using Newton's third law proved beyond most candidates. Many invented a new law that effectively said "for every incident pulse there is an equal and opposite reflected pulse".

(d) Answers to how a stationary wave is formed were too vague and missed the basic points. Most described the nature of a stationary wave rather than how it is formed.

(e) **[HL only]** Answers to (i) and (ii) were poor and in (iii), very few candidates were able to perform the calculation to find the height of the satellite. Many were using the beat frequency formula and the Doppler shift formula for this question.

B2 [HL Part 2 only] Electromagnetic induction

Candidates appeared to be extremely ill-prepared for this question. Very few could state Faraday's law correctly in (a) and the rest of the question was very poorly done. Very few could explain why an e.m.f. would be induced in the moving loop in (b) and the direction of the induced current was pure guess-work with incorrect reasoning. In (iii) very few candidates realized that there is an attractive force between the loop and the wire, resulting in the wire having to be pushed in order to make it move at constant speed.

B2 [SL Part 2 only] Specific latent heat

This question was generally well done, perhaps more so than any other question in the paper. Students had difficulty in the last part only where they were not able to explain clearly how the water would freeze again.

B3 [Part 1 (a)-(e) HL and SL, (f) HL only] Electrical conduction

(a-d) These parts were not well answered. Candidates seemed to have some notion of the concepts but their answers lacked detail and precision. The phrase “conduction electron” was unfamiliar to many. The mole calculation gave mixed results. In (c) most candidates were unable to point to the fact that with random velocities there would be no net transfer of electric charge.

(e) Again most candidates gave answers that lacked precision. The energy transformations in (iii) were not described well. Most answers failed to mention that collisions between electrons and atoms would involve the transfer of kinetic energy to the atoms.

(f) [**HL only**] This was very well done by most.

B3 [Part 2 HL only] Thermodynamics

This question was generally well done.

(a) Most candidates knew what is meant by an isothermal change.

(b) Most candidates realized that gas X was at a lower temperature but the explanation of this proved to be difficult for some.

(c) Again this part was well answered, with many fully correct responses.

B3 [Part 2 SL only] Block on an inclined plane

(a) This was done well with many candidates able to draw the forces correctly, as well as calculating the tension in the string.

(b) Parts (i) and (ii) were well done even though many candidates could not explain clearly why the tension would be the same. Part (iii) was what caused most of the problems in this question. Students did not realize that, since the block is in equilibrium, the power calculated in (ii) would be the same as the rate of increase of the block’s potential energy. Consequently, no new calculation was required.

B4 [Part 1HL only] Plutonium as a power source

Parts (a) and (b) (i) were well done by most. In (ii) candidates failed to realize that since the momenta of the two particles are equal and opposite (due to momentum conservation) the particle with the smaller mass would carry most of the energy. It is advisable to remind students of the usefulness of the equation $E_K = \frac{p^2}{2m}$ for kinetic energy.

(c) There were many correct answers to this part.

(d) Answers here, as elsewhere in the paper, lacked precision. It is probably the case that students thought they knew the answers to these questions and left the examination room thinking that they had performed well. In reality, most answers were too general and vague and did not concentrate on the main points of the question.

B4 [Part 2HL only] Motion of a satellite

This was an all or nothing question. A few candidates were able to collect all the marks for this question in what appeared to be an effortless way while many others struggled at every part of the question.

(a) The definition of gravitational potential was mostly given incorrectly.

(b) Most were able to derive an expression for the speed of the satellite and hence the required expression for kinetic energy. There were many who used energy arguments to obtain the expression for kinetic energy without much success, even though the required expression miraculously appeared after lines of algebra! In (ii) there were few who were careful with the minus sign in front of the expression for gravitational potential energy and, as a result, were able to obtain the correct answer. In (iii), only a handful of candidates were able to identify the negative sign in front of the total energy as the evidence that the satellite is in a bound orbit and could not escape.

Recommendations and guidance for the teaching of future candidates

A significant number of candidates (at both levels) appeared to be under-prepared for this examination. For these candidates, the experience cannot have been rewarding or encouraging. A striking feature of this examination was that candidates demonstrated little knowledge of essential parts of the syllabus. As in previous years, the lack of precision in written answers and associated definitions was apparent. For instance, candidates should be given precise and unambiguous definitions of physical quantities and statements of physical laws.

It is important that candidates are made familiar with the action verbs. For example, where the action verb is “explain”, the number of marks and the number of lines available for the answer should alert candidates to the fact that more than factual recall is required to score high marks.

As has been suggested in the past, the examination team recommends working through past papers (and the associated mark schemes) as good preparation. Not only will these give candidates familiarity with the format of the examination but also many should be able to develop an appreciation of the level of detail required and of the skills that are being assessed.

Paper three

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 5	6 - 10	11 - 19	20 - 24	25 - 30	31 - 35	36 - 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

The number of G2 comment forms that were received was very disappointing. The response was less than 20%. This small number means that one should be cautious about drawing any firm conclusions. As in many different situations, it must be assumed that there is a silent majority that is satisfied with the situation. The majority of G2's indicated that the syllabus coverage, clarity of wording and presentation of both papers was either satisfactory or good.

General comments

Many candidates found it hard to perform well on these papers even though there were marks accessible to those who may struggle with the more conceptual aspects of the subject. As identified in previous reports, candidates often lost marks as a result of definitions that lacked precision or were expressed in non-scientific language. For example, it would be expected that candidates would distinguish clearly between the terms energy, power and intensity. In fact, many candidates used all three terms as if they were all equivalent.

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

There were areas of difficulty in each Option. In many instances, these difficulties arose through a lack of knowledge of the underlying physics. Examples include:

- The definition of centre of gravity
- The meaning of internal energy
- The definition of luminosity
- The meaning of dispersion

The understanding of concepts created great difficulties for a significant number of candidates. What was written on scripts would include some key words but these words would be quoted out of context. This was particularly true as regards Option G.

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

Option A [SL] Gravitational field strength

A1

(a) Definitions tended to be imprecise in that the ratio of force to mass was not indicated and the fact that the test mass must be a point mass was not included. Many candidates did realise that there is a connection between field strength and acceleration of free fall but frequently this was poorly expressed.

(b) With few exceptions, an appropriate expression was given. There were some comprehensive explanations as to why the field strength would not change appreciably. It was expected that the height would be compared to the radius and then the effect on the formula would be considered. Many only compared the height to the radius. A common error was to think that there would be no change because the field strength is always measured on the surface of the planet.

(c) In (i), only a minority considered the horizontal distance moved in successive time intervals. The majority made a reference to either the smooth nature of the path of the sphere or to the steadily increasing spacing in the vertical direction. In (ii), there were many correct responses. However, candidates should be advised to use as large a time interval as is reasonable. All too often, a time interval of only 0.40 s or 0.60 s was used.

(d) The candidate's answer in (c) was always accepted as the basis for this calculation. A common error was a failure to square the value for *R*, despite having written down a correct expression for the mass.

A2 Centre of gravity

(a) There were very few adequate descriptions. Most gave the impression that either the weight or 'gravity' actually acts at this point. Candidates should be discouraged from making reference to 'gravity' when what they really mean is 'weight'.

(b) (b) A surprisingly large minority of candidates drew arrows from the region of P in the general direction of C. The arrow should have originated at C. In (ii), a common error was to merely refer to the initial potential energy being transferred to kinetic energy. Very few gave a comprehensive account as to the mechanism by which the energy of the sheet would be transferred. In (iii), there were very few candidates who mentioned that the weight would have a moment about C and that, when the sheet comes to rest, this moment about C would be zero. A common incomplete and unacceptable answer was to say that 'C tries to get as low as possible'.

Option B [SL]

B1 Photoelectric emission

(a) The calculation in (i) was, in general, completed successfully although there were some power-of-ten errors. In (ii), there was a tendency to make a statement based on the calculation in (i), rather than deduce an answer. That is, give some explanation for the conclusion they reached.

(b) With very few exceptions, this was answered poorly. Candidates did not appear to appreciate that the maximum kinetic energy is associated with an electron released from the ‘surface’. Electrons released from below the ‘surface’ require energy to bring them to the surface and thus have less kinetic energy.

B2 Radioactive decay

(a) There were some acceptable responses here although a common error was to confuse atomic energy levels with energy levels in the nucleus.

(b) Explanations in (i) were usually not convincing. However, this part of the question did enable candidates to proceed to obtain the correct answer in (ii).

B3 Fundamental particles

As is usually the case with such questions, candidates were divided into two groups. There were those who could recall the relevant factual knowledge and they scored high marks. The remainder scored very few marks. Amongst this group, it was common to find that, in (a), mass-energy and momentum were quoted for the conservation laws.

Option C [SL]

C1 First law of thermodynamics

(a) Of those who did have some understanding of *internal energy*, many gave a general statement rather than confining themselves to an ideal gas.

(b) In (i), candidates should use the symbols that are defined in the question. However, alternative recognisable symbols were allowed.

C2 Heat pumps

(a) There were very few correct answers. Many failed to draw an arrow indicating ‘work done’.

(b) There was much confusion here which was to be expected in view of the fact that candidates were unable to give the directions for the energy transfers.

(c) Many candidates replaced the symbol Q in their equations with the letter T with no explanation. Explanations in (iii) were imaginative but not acceptable.

C3 Solar heaters

(a) There were many loose phrases such as ‘to catch the sunlight’. It was expected that candidates would appreciate that such an orientation would optimise the exposure to solar energy.

(b) There were some correct calculations. However, many were confused as to how to incorporate the efficiency into the calculation. A surprisingly large minority was unable to use the specific heat capacity in an appropriate manner.

Option D [D1 – D3, SL and HL]

D1 Sound and hearing

(a) Many candidates gave confused or contradictory answers in that they did not appear to appreciate that a lower threshold intensity level implies more sensitive hearing at that frequency.

(b) For many candidates, this was a straight-forward calculation.

(c) Again, many candidates were able to extract relevant data from the graph but were then unable to interpret it.

D2 Scaling

(a) In general, candidates gave either the correct response or the answer 4.0 with little or no explanation.

(b) The work involved scaling two separate factors. This gave rise to much inappropriate work and answers.

D3 Medical imaging

Candidates' knowledge of CT scanning left much to be desired, with many not even realising that an X-ray image of a 'slice' through the body is taken from many different angles. Many answers were based on the use of a radioactive tracer.

D4 [HL only] Energy expenditure

(a) There were many correct responses. The most common error was to fail to appreciate that radiation losses would be unchanged.

(b) Frequently, the discussion was limited to a mention of increased convection losses.

D5 [HL only] Dosimetry

(a) Generally defined well, with the ratio made clear.

(b) Explanations very rarely included a reference to the density of ionization or deposition of energy.

(c) In (i), many did not realise how to determine the risk. It was disappointing to note that, in (ii), candidates did not appear to have an appreciation of 'balanced risk'. That is, the increased risk associated with the diagnosis far outweighs the inherent risk of no adequate diagnosis.

Option E [E1 – E4, SL and HL]

E1 Models of the Universe

(a) Frequently answered well. The most common omission was an explanation as to the passage of stars across the night sky.

(b) Well answered in most cases.

(c) There were some very well drawn diagrams. Candidates should be encouraged to draw diagrams with the necessary precision. Other drawings were so poor that it was not possible to judge the essential features.

(d) Usually answered correctly.

E2 Caloric theory

Answers to this question were, in general, poor. Most candidates seemed to have a minimum knowledge of the caloric theory and wrote down this knowledge, regardless as to whether the facts were relevant.

E3 Electric charge

Most candidates made an attempt to explain that Coulomb's approach was experimental. However, with few exceptions, the theoretical approach of Priestley and Franklin was not appreciated.

E4 Electrons and neutrons

(a) Most answers included a reference to charge. Few considered how beams of the particles would be produced.

(b) Candidates were expected to discuss the penetration of the radiation in the lead, reaching the conclusion that the radiation could not be charged. This was achieved by many candidates. However, most neglected to mention that photons would be unable to remove protons from the wax and hence the radiation must be uncharged particles (have mass).

E5 [HL only] Atomic spectra

(a) It was common to find that no mention was made of a line spectrum being a distinct series of wavelengths.

(b) Part (i) was not understood by most candidates. In (ii), the wavelength was calculated but in very few answers was any explanation given for the substitution $m = 3$.

E6 [HL only] Heisenberg uncertainty principle

(a) For candidates who had any understanding of the Heisenberg uncertainty principle, the calculation was straight-forward.

(b) Only about 50% of answers were correct. The remainder usually gave the direction as being along the beam.

Option F [F1 – F3, SL and HL]

F1 Luminosity

(a) A significant minority did not appreciate the difference between luminosity and brightness.

(b) The general impression was that many candidates lost marks through carelessness. Candidates should always ensure that the appropriate features on diagrams are clear. A smooth curve, above the one drawn, with a sharper peak shifted to shorter wavelengths was required.

(c) With few exceptions, the diagram was labelled correctly.

(d) It was pleasing to note that most candidates realized that area is a factor. However, explanation was not always clear.

F2 Stellar magnitude

(a) As is usually the case, most definitions were either correct or indicated a complete lack of understanding.

(b) The calculations presented very little difficulty for those candidates who had an understanding of the topic. There were, however, many incorrect answers where not even the initial approach showed any promise.

F3 The expanding Universe

(a) Generally well answered.

(b) Comprehensive definitions of critical density were few in number. Most candidates realized that the density would affect the fate of the Universe. However, many merely referred to ‘flat’, ‘open’ and ‘closed’ without any further explanation. A popular misconception was that the density of the Universe would change so that it would change from ‘open’ to ‘closed’ or *vice versa*.

F4 [HL only] Stellar evolution

(a) As is usual in such questions, important aspects were frequently omitted. In this case, very few mentioned that the core collapses to form a neutron star.

(b) A common misconception was that the radiation is emitted in pulses. Very few related the spinning of the neutron star to the pulsing of the radiation detected on Earth.

F5 [HL only] Galactic motion

Completed successfully by many candidates. As is usually the case, the most common error was in powers-of-ten.

Option G [G1 – G3, SL and HL]

G1 Measurement of time

(a) Generally, the diagram was satisfactory although a minority lost marks through careless and sloppy drawing. Candidates should use a straight edge when drawing straight lines.

(b) (b)Well-prepared candidates had no problems with this derivation. Surprisingly, there were candidates who were attempting this Option and who had no real understanding as to how to approach this problem.

(c) It was common to find that, in (i), the factor of 2 had been omitted. Similar observations were made in (ii) as in part (b).

G2 Observation of clocks

Very few candidates scored full marks. Many failed to state that the speed of light is the same for both observers. Others realised that, for Frank, the clocks would not read the same time. However, they failed to explain which would change time first.

G3 Length contraction and muons

(a) There were some good answers where the candidates calculated a speed for the muon and then argued correctly that this speed would be impossible, leading to the concept of length contraction. Others were aware of the muon experiment and introduced data that was not provided in the question.

(b) As is usual in such calculations, a number of answers indicated that the candidates had little or no understanding of the situation.

G4 [HL only] Energy and momentum

(a) Frequently, the deduction was absent. Candidates merely wrote down the answer that was given in the question.

(b) Again, there were some good answers but in other scripts, the candidates appeared to have no understanding of the situation.

G5 [HL only] Spacetime

Candidates were expected to distinguish between the degree of warping of spacetime in the two situations. In weaker scripts, no reference was made to the shortest distance being a curve. Some candidates insist in the belief that a black hole 'sucks in everything'.

Option H [SL and HL]

H1 Refraction and dispersion

(a) Generally, reference was made to 'splitting' of something. There was some confusion between dispersion and refraction.

(b) It was surprising to note the very large proportion of scripts where rays did not obey the laws of refraction.

(c) The consequence of the poor level of understanding, as demonstrated in (b), was that explanations were frequently incorrect or contradictory.

(d) Some candidates did realize that the two prisms would behave as a parallel-sided block. Others had rays emerging from the upper and lower surfaces.

H2 Lenses

(a) There were some good diagrams but there were many that were almost illegible. Candidates should always use a straight edge when drawing rays.

(b) In general, the description was correct, even when an inappropriate diagram had been drawn.

(c) This question gave the opportunity for students to show their understanding of the structure of a microscope without having to draw a ray diagram. There were some who clearly had no appreciation of the relative positions of focal points, the object and the images.

(d) With few exceptions, the explanation was given in terms of increased magnification. The possibility of reducing aberrations was not considered.

H3 [HL only] Diffraction grating

(a) It was common to find that the grating formula was not used. Others had difficulty with obtaining the line spacing from the lines per unit length.

(b) Very few could quote two observable differences.

H4 [HL only] Thin films

(a) Surprisingly, only a minority realised that the fringes are formed as a result of interference.

(b) Very few candidates could make a satisfactory approach to this question. Rarely was there any mention of two waves interfering destructively so that one colour would be absent from the 'white' light and that this absent colour would change as the angle of viewing changed.

Recommendations and guidance for the teaching of future candidates

The number of candidates who appear to be poorly prepared for the examination does not show any decline. Candidates should be encouraged to learn the bookwork so that they can develop an understanding of the underlying concepts.

Candidates frequently draw such poor diagrams and graphs that they are of little meaning. Straight lines should be drawn with a ruler. Single lines should be just that – and not as series of overlapping short dashes.

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 many should be able to gain a good 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 examination paper 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.