PHYSICS

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 16	17 - 28	29 - 39	40 - 49	50 - 60	61 - 71	72 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 16	17 - 29	30 - 41	42 - 51	52 - 61	62 - 71	72 - 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 IA samples reveal an excellent range and rich diversity of student experimental work, including many traditional physics labs as well as a number of open-ended investigations. 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. There is evidence of a growing use of ICT, especially for graphing data. This is encouraged as well as other ICT applications.

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. Asking students to conform Ohm's law is a good experiment but not appropriate for evaluating planning (a).
- 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.
- Students taking the IB physics exam in November 2009 should follow the new IA criteria.

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. New teacher support material (including ten student investigations with moderator marks and comments, and many ideas for the new design criterion) is currently posted on the OCC.

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 - 10	11 - 14	15 - 18	19 - 22	23 - 27	28 - 31	32 - 40

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 11	12 - 15	16 - 18	19 - 20	21 - 23	24 - 30

General comments

Fewer than 20% of centres taking this examination returned a G2 form for this component and of these only 7% of all centres made written comments about the paper.

The replies indicated that the majority of teachers believed that the papers were at a similar standard to the previous year; the opinion of the rest was equally divided between ‘a little easier’ and ‘a little more difficult’. The level of difficulty was found to be appropriate by all but one centre. Syllabus coverage was considered good by half of respondents, satisfactory by the remainder (this factor must be judged in conjunction with Paper 2). The wording was judged clear, and the presentation good by two-thirds, the remainder thought it satisfactory.

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	84	102	321 *	106	3	52.11	0.49
2	53	26	479 *	55	3	77.76	0.49
3	163	379 *	44	19	11	61.53	0.50
4	15	530 *	48	22	1	86.04	0.27
5	35	140	402 *	38	1	65.26	0.21
6	385 *	39	69	118	5	62.50	0.47
7	64	4	6	542 *		87.99	0.13
8	76	317	204 *	16	3	33.12	0.48
9	103 *	87	49	376	1	16.72	0.19
10	49	291 *	209	65	2	47.24	0.66
11	73	128	128	286 *	1	46.43	0.57
12	381 *	10	222	1	2	61.82	0.33
13	33	66	465 *	50	2	75.49	0.40
14	13	11	507 *	85		82.31	0.33
15	10	19	286 *	299	2	46.43	0.65
16	142	23	11	438 *	2	71.10	0.38
17	88	297 *	124	105	2	48.21	0.31
18	588 *	4	0	24		95.45	0.10
19	122	347 *	111	33	3	56.33	0.55
20	19	35	7	554 *	1	89.94	0.20
21	202	57	37	318 *	2	51.62	0.45
22	27	121	407 *	59	2	66.07	0.49
23	296 *	44	257	17	2	48.05	0.45
24	428 *	129	34	23	2	69.48	0.52
25	203 *	161 *	119	129	4	59.09	-0.01
26	41	298 *	73	190	14	48.38	0.46
27	179	101	142	189 *	5	30.68	0.47
28	363 *	22	40	189	2	58.93	0.40
29	465 *	56	41	51	3	75.49	0.48
30	266 *	209	65	72	4	43.18	0.46
31	31	96	86	395 *	8	64.12	0.61
32	405 *	35	99	75	2	65.75	0.48
33	57	87	259 *	208	5	42.05	0.71
34	45	400 *	103	65	3	64.94	0.51
35	77	62	117	356 *	4	57.79	0.54
36	459 *	44	69	38	6	74.51	0.41
37	130	99	86	295 *	6	47.89	0.73
38	115	388 *	95	12	6	62.99	0.66
39	46	303	247 *	13	7	40.10	0.35
40	354 *	130	64	61	7	57.47	0.64

Number of candidates: 616

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	130	96	296 *	95	4	47.67	0.34
2	122	225	266 *	7	1	42.83	0.57
3	165	280 *	119	50	7	45.09	0.51
4	28	492 *	77	22	2	79.23	0.32
5	239 *	12	35	334	1	38.49	0.54
6	26	38	168	388 *	1	62.48	0.31
7	67	109	395 *	47	3	63.61	0.19
8	481 *	100	14	25	1	77.46	0.37
9	57	408 *	41	115		65.70	0.44
10	134 *	343	48	93	3	21.58	0.26
11	51	370 *	174	23	3	59.58	0.48
12	85	8	10	515 *	3	82.93	0.19
13	121	348	143 *	7	2	23.03	0.34
14	29	12	500 *	68	1	80.52	0.32
15	34	14	156 *	414	3	25.12	0.34
16	187	45	13	372 *	4	59.90	0.30
17	218	164 *	103	132	4	26.41	0.13
18	39	84	29	467 *	2	75.20	0.35
19	301 *	98	156	65	1	48.47	0.46
20	54	178	283 *	104	2	45.57	0.52
21	309 *	177	92	40	3	49.76	0.56
22	37	77	124	381 *	2	61.35	0.44
23	23	95	400 *	94	9	64.41	0.39
24	27	298 *	62	231	3	47.99	0.48
25	122	148	210 *	132	9	33.82	0.37
26	297 *	59	82	175	8	47.83	0.49
27	344 *	89	75	106	7	55.39	0.45
28	321 *	95	94	104	7	51.69	0.39
29	100	311 *	109	91	10	50.08	0.55
30	24	473 *	82	35	7	76.17	0.40

Number of candidates: 621

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 At SL the difficulty index varies from 20% (relatively difficult questions) to 80% (relatively easy), the same index for the HL paper has a range of 16% to 95%. These gave good spreads of marks for the papers and meant that all candidates had the chance to demonstrate at least some of their physics.

Discrimination. Only one question in the suite has a negative discrimination index (HL, q. 25). Of the remainder, only one HL question has a value significantly below 0.2 (the value should ideally be greater than this).

*'Blank' response. S*ome questions (6 at SL, 5 at HL) have significant numbers of blank responses. An educated guess is always useful if two responses seem equally correct to a candidate. There was evidence that the number of blanks rose slightly towards the end of the HL paper, but not at SL.

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 Q2 and

Candidates were insecure in manipulating the powers of ten or possibly in recognising the approximate mass of a glass of water.

SL Q13 and HL Q8

Too many (presumably) failed to read the question carefully or failed to square the speed in their evaluation of kinetic energy.

SLQ15 and HL Q15

Large numbers of candidates carried through the gas-theory calculation in °C not K.

SL questions

Q2

Significant figures proved troublesome here. Many sought a compromise between the 3 sf and 1 sf data rather than recognising that the 1 sf datum completely overwhelms the final answer.

Q5

Candidates did not think clearly here. They were confronted with a distance-time graph and failed to connect the gradient of this graph with the speed that they were required to give.

Q10

A substantial number were confused about the relationship between inertial and gravitational mass and its constancy even in changing gravitational fields.

SL17

Candidates were asked for the response that was **not** an assumption of the kinetic theory. They failed to read the question carefully and usually gave the first correct assumption available.

Q25

Circuit calculations proved tricky as usual. Candidates need practice in handling such problems with accuracy at speed.

HL questions

Q9

Many confused gravitational potential and gravitational force with a large number assuming that a net zero force also means a potential of zero.

Q13

There was an unfortunate misprint in the Spanish version of the paper that had led to the omission of the second half of the question sentence. The statistics were examined closely by the examiners and compared to the overall profiles of the candidates on the rest of the paper and it was concluded that none were likely to have been disadvantaged. It was relatively straightforward to deduce what the question required (the range of the second particle) given that all the answers were multiples of the range for the first.

Q10

This was a straightforward application of Kepler's Third Law but the manipulation of powers was clearly too much for some candidates.

Q11

Candidates were not clear about the nature of equilibrium. The fact that the spacecraft was under acceleration should have alerted them to the nature of the translational non-equilibrium (even when one engine had failed) and the consequent imbalance in thrust would lead to rotational non-equilibrium too.

Q25

The original negative discrimination index alerted the examiners to a possible problem in this question. It was felt that some candidates may have misunderstood the nature of the comparison that was required by the question. They should have compared potential and charge between the spheres, not before and after the connection. As a result, both answers A and B were allowed so as not to disadvantage candidates.

Q27

This question taxed many with similar numbers opting for each of the responses. It again shows the difficulty candidates have with electrical circuit theory and the need for practice in this type of question.

Q30

Almost all recognised the effect and its result but about half reversed the effect and therefore the charge positions.

Q33

Many were attracted by an incomplete formula ($N_0e^{-\lambda}$) where they had mentally substituted t = 1 incorrectly and then ignored the correct answer.

Q39

The true nature of binding energy eluded many with a large number expressing the inequality the wrong way around.

Recommendations and guidance for the teaching of future candidates

Candidates should be encouraged to read questions very carefully given the nature of a multiple-choice item where the wording is reduced to that which is significant and important.

Candidates are advised to practice simple electrical calculations and to be more secure in their manipulation of powers especially when calculators are not to hand.

Paper two

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 11	12 - 23	24 - 34	35 - 44	45 - 54	55 - 64	65 - 95

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 20	21 - 24	25 - 29	30 - 33	34 - 50

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. It was very good to see that the great majority of candidates did extremely well on the data analysis question (A1). However most candidates at both levels had great difficulty (surprisingly) with the vector diagram in A2.

Various parts of the syllabus appeared to have been very poorly covered. These included motion of charged particles in magnetic fields, stationary waves and electric circuits (at Standard Level) and electric circuits, wave-particle duality and electromagnetic induction (at Higher Level). Questions on thermal physics were, generally 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:

Giving precise definitions of such quantities as electric resistance, electric field and statements of the law of conservation of momentum.

Inability to use a vector diagram to explain the need for a centripetal force in circular motion.

Determining the direction of the magnetic force on a moving charged particle.

Using graphs to solve electric circuit problems.

Electromagnetic induction: incorrect statements of Lenz's law and how it relates to energy conservation.

Working with gravitation.

Thermodynamics: inability to identify an adiabatic process by reference to the lack of energy transfer in the system and difficulty working with the efficiency of a heat engine.

Difficulties with basic explanation of the formation of stationary waves.

Difficulties with the proof of the Doppler formula.

X-rays: difficulties with explanations of the minimum wavelength and the characteristic lines.

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

Generally, candidates seemed well prepared in the following areas:

The data analysis question.

Kinematics calculations.

Calorimetry calculations.

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

This was very well done by the great majority of the candidates.

Many candidates realized that the given equation was that of a straight line and hence inappropriate for the data provided.

In (b) (i) the units of D/v were given as $\mathrm{m/m\,s^{-1}}$ (and were given credit). It must be stressed however that when the units of a specific quantity are asked for they should be given in their simplest form (in this case, seconds).

There were carefully drawn lines of best fit and correct calculations of the intercept and the slope (gradient). It was pleasing to see large triangles used in the calculation of the slope.

[HL only]

(f) There were many correct answers here but many students reached their result by calculating maximum and minimum values in *D* and *v* in order to find the uncertainty in D/v. Whereas correct the standard method of adding the fractional errors in *D* and *v* is faster.

[SL only]

(f) Many candidates failed to make a meaningful comment here other than “the answers are the same” or “the answers are not the same”.

A2 [HL and SL] – Circular motion

Very few candidates were able to score full marks for this question.

This was very disappointing. Most candidates seemed unable to subtract the velocity at A from the velocity at B in order to obtain the change in the velocity vector. Most simply added the vectors. Even in the rare case that the correct vector was found by subtraction many candidates were not able to relate the direction of the change in velocity to the acceleration, and hence, to the force on the particle. To be fair, the change in the velocity vector (for a finite interval of time) does not in general pass through the centre of the circle but it clearly does so for the points A and B chosen in this question.

A3 [HL and SL] - Electric circuits

It is very clear that many students have a very weak understanding of electric circuits and are poorly prepared for questions on this topic. This is in fact one of the parts of the course where the questions are usually straightforward. Further it is one where inexpensive, accurate and relatively easy experiments can be conducted to support the textbook material. At many schools more emphasis needs to be placed on this topic by combining the theoretical and practical sides of things."

[HL only]

The first parts to this question were well done by most. The problems appeared in (c) where very few candidates realized that they had to draw a horizontal line on the graph and, by trial and error, see which current gives a *sum* of voltages across T and R equal to 4.0 V.

[SL only]

(a) Students had great trouble with the definition of resistance. Many defined it in terms of “the difficulty of electrons to move” and in other similar ways. Even among those who realized that a ratio of potential difference to current was involved (the formula in the booklet) very few paid attention to the fact that they had to refer to the potential difference *across* the device and the current *through* it. Many students were able to do the rest of the question well.

A4 [HL only] - Wave particle duality

This question was either very poorly done or very well done by the candidates.

Most candidates were aware that there was some kind of interference pattern on the screen. Responses were divided between the correct answers of a ring pattern and the incorrect answers that were copies of the standard two slit pattern. Many students did the second part correctly by realizing that the increased momentum resulted in a smaller electron wavelength and hence a changed interference pattern.

Section B

B1 [Part 1 HL and SL (a)] – Linear motion

This question was a very popular choice at both levels and was, generally, done well.

Part (b) asked for the distance travelled by the skier down the slope. Since the path was not a straight line and the acceleration was not constant the usual formulae of kinematics did not apply and students had to use the area under the curve. Unfortunately very few candidates chose this route. In (b) (iii) candidates had to identify two causes of the retarding force on the skier. Friction was a common answer without, however, identifying where the friction force was coming from (for example friction between the skis and the snow).

[HL only part (c)] This was very well done by most candidates.

[SL only part (c)] This was very well done by most candidates.

[HL and SL part (d)] Most realized that the skier would land further to the right and many correctly identified a softer landing but very few could give a coherent argument as to why.

B1 Part 2 [HL and SL] – Nuclear reactions

(a) There were rather vague answers to this part. Frequently students talked of atoms or molecules decomposing with few identifying nuclei emitting various particles. The random nature of the decay was well tackled by many. In (b) a surprisingly large number of candidates could not correctly identify the atomic and mass number of the proton (and hence the oxygen isotope). Many candidates correctly calculated the mass difference in the reaction and those who used the conversion into MeV had better results than those who chose to first convert the u's into kg. However, few noticed that the mass on the left of the reaction was less than the mass on the right and hence energy had to be provided.

B2 [Part 1 HL and SL] Momentum

Most candidates managed to score many marks in this part of the question.

Part (a) was completed by almost all candidates. Many used the term "closed system" without defining it. In (b) (ii) the question explicitly asked for reference to Newton's laws. In such situations it is not sufficient to simply state the laws – one must state the laws in the concrete context of the particular question. Thus in this case, the examiners expected statements such as "the rate of change of the momentum of the ejected water gives the force on the water" and "the force exerted on the water downwards by the rocket is equal and opposite to the force exerted by the water on the rocket upwards" etc.

In (b) (iii) the HL and SL questions were slightly different. At HL they had to explain why the rocket does not lift off immediately after the nozzle is opened and at SL they had to calculate the delay time. At HL most realized that the weight of the rocket initially was greater than the upward force and so the rocket could not move before the weight was reduced. However few could express this clearly. At SL there were few correct answers as few candidates realized that at lift off the normal reaction force from the ground becomes zero and at that moment the weight of the rocket must be less than the upward force of 2 N.

B2 [HL and SL (a) – (c)] Temperature and thermal energy

In (a) the great majority of candidates replied by reference to a "centigrade" thermometer and scored one of the two marks available, failing to realize the general issue behind a temperature dependent property of the thermometer. In (ii) most concentrated on general uncertainties produced in a measurement missing the point of the question.

In (c) the definition of the specific heat capacity was, mostly, correctly given. The calculation in (ii) was also well done by most students. Those that missed the energy absorbed by the ice after it had turned into water were given partial credit.

[HL only (d) – (e)]

There were mixed responses to (d) (i). Many identified the process as adiabatic but few could point to the rapid compression of the gas as the reason that there was not enough time available for any thermal energy to be transferred in or out of the system. In (ii) the question clearly asked for an explanation based on the molecular model of an ideal gas. This meant that answers based on the gas law $pV = nRT$ could not be given any credit.

Very many candidates gave the (incorrect) argument “the molecules collide with the walls more frequently and hence the temperature goes up”.

Part (e) was well answered by many but unfortunately just as many got lost in the efficiency formula and could not correctly solve for the work done. Part (ii) was well done with very many candidates correctly identifying where the entropy decreased and where it increased.

[SL only (d)]

There were fairly good responses to (i) about the differences between boiling and evaporation but in (ii) few could point to the increased separation of molecules as the reason for an increase of potential, rather than kinetic, energy.

B3 [Part 1 HL (a) and SL Part 2 (a)] Electric and magnetic force fields

This was the least popular question for HL. The combination of electromagnetic induction and gravitation scared off many students.

(a) Most could calculate the speed and the force of the proton correctly but the direction of the force in the magnetic field was not always correct. The path outside the field should have been straight and tangential to the circular path in the field region. It must be stressed that many who drew a straight path outside the field failed to score the mark precisely because the tangency part was missed. This must alert students that precision and detail are required when answering examination questions.

[HL only (b) – (d)] Part (b) was well done. Part (c) was poorly done. Statements of Lenz’s law were generally vague. The connection between Lenz’s law and the law of conservation of energy made it a difficult question. Few could answer this part in general and many attempted to answer it in the context of a specific situation (for which the markscheme allowed full marks) but even then the answers were not always satisfactory. In (d) (i) most could calculate the induced e.m.f correctly but parts (ii) and (iii) were poorly done. Part (ii) was difficult but in part (iii) candidates should have seen that with a vertical magnetic field no flux was cut by the window.

[SL only (b)]

This was well done by the candidates even though the definition of electric field strength often lacked precision.

B3 [Part 2 HL only] Gravitation

This part was generally well done but perhaps not as well as might be expected. The manipulation of many and large numbers on the calculator is clearly a problem for many students. Students must practice problems involving “number crunching’ much more. The interesting “physics” question in this part was (c). Here students were expected to see that since the total energy decreased a force opposite to the direction of motion must have acted on the satellite. This version of the “satellite paradox” must be better taught in class.

B4 [Part 1 HL, B3 Part 1 SL] Waves

This question was generally well done.

[SL only (a)] This was poorly done. Students lacked the necessary definitions of ray and wave speed.

[HL (a) and SL (b)]

The calculation of the frequency was marred by many students missing the fact that the time was in ms requiring a conversion to seconds. A surprising number of students calculated *different* frequencies for wave A and B.

[HL only (b)]

Many candidates saw that the bright fringes would be less bright and the dark ones brighter but failed to pinpoint the reason for this on the displacement of the waves no longer completely canceling out at points of destructive interference or adding up to the previous amount at points of constructive interference. Once again students must be alerted to the need for detail in their answers.

[HL and SL (c)]

This question on stationary waves was generally well answered but very many students could not explain the formation of the stationary wave in the particular context of the question. Many missed the interference of the reflected wave with the downward travelling wave. In (iii) the common error was the calculation of the wavelength. Even though this question has appeared many times before (including Paper 1) students did not realize that the distance of 56 cm was equivalent to half a wavelength.

[HL only (d)]

The definition of the Doppler effect was well done by many but just as many missed the crucial reference to "the change of the frequency observed". The derivation of the Doppler formula was an all or nothing question. It was good to see many candidates providing the correct proof. This was a significant improvement over similar past examination questions. Many correct reasons could be given for part (iii) and all were accepted as such for full marks.

B4 [Part 2 HL only] X-rays

This was either perfectly done or very poorly done. In (a) many candidates confused the phenomenon under consideration with the photoelectric effect. In (b) those candidates who first solved for $Z-1$ and then found *Z* were much more successful than those who first expanded $(Z-1)^2$ and then tried to solve for *Z*.

Recommendations and guidance for the teaching of future candidates

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. Finally, every part of the syllabus must be studied, including the ones that are perceived as difficult!

Paper three

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 19	20 - 25	26 - 31	32 - 37	38 - 60

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 4	5 - 9	10 - 13	14 - 17	18 - 22	23 - 26	27 - 40

General comments

Some candidates found it hard to perform well on these papers even on the parts of questions that required basic recall. 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 know that definition of gravitational field strength, luminosity, apparent magnitude and refractive index.

Some candidates did very well and had clearly studied the chosen options in depth and would seem to have had practice in answering previous examination questions.

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:

- gravitational fields and potential
- rotational equilibrium
- thermodynamics
- simultaneity
- principle of equivalence
- optical dispersion

- single slit diffraction
- wedge films.

The understanding of concepts created great difficulties for a significant number of candidates. This was particularly true as regards Option G.

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

There is a feeling that in general, those candidates who attempt option E would seem to be less well-prepared than those candidates who attempt other options.

Generally, as in previous years, candidates are better at answering recall questions and straight forward calculations.

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

Option A [SL] Projectile motion

This was a popular option but not always answered well.

A1 Projectile motion

a) This was often answered well but a straight line was drawn by several candidates.

b) A common mistake was to draw a triangle.

c) Often correct.

A2. Gravitational field strength and gravitational potential

Definitions tended to be imprecise in that the ratio of force to mass was not indicated and a reference to a test mass or a point mass was not included. Many candidates quoted the gravitational law as the definition.

a) This was generally done well.

b) There was a lot of guess work here and the question was often unanswered.

c) Better candidates made the correct link to part (b).

d) Those candidates who left (c) unanswered also left this unanswered whereas those who answered (c) correctly tended to get this correct as well.

A3 Rotational equilibrium.

a) The condition was generally known but there was often confusion with forces rather than torque.

b) Many candidates did not draw the vectors through point P.

c) The concept of taking moments was alien to many candidates. Better candidates recognised that the for tipping, point P would be above X.

Option B

This was not a popular option but candidates who attempted it often did quite well.

B1 Photoelectric effect.

a) This was generally well known

b) Although the determination of the threshold frequency and the explanation of how it related to the graph was well done, many candidates failed to explain their calculation of the Planck constant and so could not gain full credit.

B2 The de Broglie hypothesis

a) Candidates sometimes just quoted the formula but did not define the terms.

b) As in previous papers, candidates often did not make use of the relation between energy and momentum and so made the calculation that bit longer.

Option C

This was not a popular option and was rarely answered well.

C1 The first law of thermodynamics and state changes in an ideal gas.

a) This defeated most candidates. The majority seemed to be incapable of relating their answers to the first law.

b) Most candidates who actually attempted the calculation only got as far as calculating the work and then came to a halt.

C2 Power generation in nuclear power station.

a) This was well known.

b) For some reason, this was quite often left blank.

c) This was generally well done.

d) Not very many candidates appreciated that fission is favoured by slow moving neutrons.

e) This was generally not well answered with confusing and/or unlabelled diagrams.

Option D (SL and HL)

This was not a popular option but there were some very good attempts with quite a few of those candidates who chose the option scoring high marks.

D1 Scaling

a) Good candidates had little difficulty with this.

b) There seemed to be a feeling amongst some candidates that scaling only applies to cubes and spheres.

c) Many candidates failed to make a link with part (b).

D2 Hearing

a) Although generally answered correctly, some candidates were careless with significant digits.

b) The physics of the situation was often lost with more emphasis being put on the anatomy with no reference to lever action or pressure as force x area.

D3 X-rays and imaging.

a) This was generally well known.

b) This was usually correct.

c) Many candidates recognised the relationship between the tissue thickness and the half-value thickness of muscle. Others used the equation to find the solution.

d) This was generally well known.

D4 (HL) Metabolic rate

a) Some candidates confused the two rates.

b) This was usually done correctly.

D5 (HL) Iodine-131

a) This was generally well-known.

b) Few candidates appreciated the importance of the effective biological half-life or the importance of iodine-131 being a beta emitter.

Option E

This was not a popular option and the feeling was that it was often attempted by the weaker candidates.

E1 (SL and HL) Galileo and Newton.

a) This was well-known.

b) This was usually well-answered.

c) Answers were often weak with little appreciation the four moons behave like a miniature heliocentric system.

d) (i) This was well known. (ii) This was usually poorly answered with candidates rarely making the link between the second law and weight,

E2 (SL and HL) Magnetism and Electricity

a) Both parts of this question were usually well done.

E3 (SL and HL)

a) Both parts were usually answered poorly and in particular part (b) where little knowledge of the importance of this experiment was exhibited.

E4 (HL) The hydrogen atom.

a) It was very rare to see a good answer to this question and often, all parts were left unanswered.

Option F

A very popular option at both levels.

F1(SL and HL) The Sun

a) Usually well done.

b) Answers were often incomplete with rarely a mention that the absorption spectrum is compared with an emission spectrum to identify the lines.

F2 (SL and HL)

a) This was usually known.

b) In spite of the question stating that only data from the table should be used, many candidates worked out the luminosities independently.

F3(SL and HL) The Sun and Sirius

a) Few candidates failed to note the action verb and did not explain what is meant by the apparent magnitude scale.

b) This was often answered correctly.

F4 (SL and HL) The development of the universe.

a) This was well known

b) Diagrams often lacked precision and it was difficult to see if the line drawn touched the given curve at $t = T$.

c) Very few candidates made reference to the only known data point.

F5 (HL) Nuclear synthesis

a) This was well-known.

b) The changes were generally compared correctly but some candidates mis-read the question and described the evolution of the two star types.

F5 (HL) Hubble's law

a) This was well-known.

b) As in past papers, the units defeated many candidates.

Option G

A popular option at Higher Level.

G1 Simultaneity

a) This was generally poorly answered with many candidates seeming to misunderstand the situation. Answers often lacked any reference to relativity or to Lucinda. Many candidates thought that Simon was moving towards the birds.

G2 Time dilation.

a) This was often answered correctly.

b) Although many candidates recognised the astronaut as measuring the proper time, few correctly indentified the events to which the time referred.

c) Few candidates mentioned the asymmetry of the situation.

G3 Mass and energy

a) This was often answered well.

b) Few could actually state the energy of the electron correctly in MeV and hence got into a mess with part (ii). The incorrect value given in part (ii) would not appear to have disadvantaged candidates who were able to do this part. Full credit was awarded for a correct value of gamma.

G4 (HL) Momentum

a) Candidates who knew their way around the units had no difficulty with this; the others floundered or did not even start.

G5 (HL) General relativity

a) This was usually correct.

b) Too many candidates gave imprecise statements of the equivalence principal such as "gravity and acceleration are the same" to gain credit.

c) Apart from the frequent omission of "gravitational" in (ii), this was generally answered correctly.

Option H

A popular option at both levels.

H1 Refraction

a) Generally well-known.

b) Generally answered correctly.

c) Very few candidates referred their answer to part (b) and therefore did not gain full credit.

H2 Plane Mirror

a) Many candidates omitted to mention the plane of reflection.

b) (b) and (c) Usually well-answered except that quite a few candidates did not appreciate that if the person stands further from the mirror there will be no effect on (c)(i) and (ii).

H3 Compound microscope

a) There were many poor ray diagrams and often correct diagrams did not label the focal length.

b) This was often correctly answered.

c) Some candidates added the two magnifications in (c).

H4 (HL) Diffraction.

a) Interference of light from each element of the slit was rarely mentioned.

b) Often answered correctly.

c) Few correct diagrams were seen.

H5 Wedge film.

a) Usually well-known

b) This simple calculation defeated many candidates.

Recommendations and guidance for the teaching of future candidates

Candidates frequently draw such poor diagrams and graphs that they are of little meaning. Straight lines should be drawn with a ruler.

Candidates should also be alerted to the significance of the action verb that starts a question and also to the number of marks allocated to the question; an “explain” requires a more detailed answer than a “state” as does a 4 mark allocation compared to a 1 mark allocation. Conversely, a “state” does not require the detail that is expected of an “explain”.

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. Some candidates answered in pencil and this should be discouraged as often the answers are then difficult to interpret; candidates must also be encouraged to write clearly and legibly.