PHYSICS

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 16	17 - 28	29 - 39	40 - 50	51 - 59	60 - 70	71 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 15	16 - 26	27 - 37	38 - 48	49 - 57	58 - 68	69 - 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

Both the range and suitability of the work submitted was extremely appropriate. Teachers have a solid understanding of what is expected by the IA criteria. It is clear that the majority of schools are offering diverse and comprehensive practical programs, with investigations covering the core, additional higher and optional syllabus content as well as non-syllabus content. Only a few schools still make use of fill-in-the-blank worksheets or simplistic investigations. The group 4 projects were in line with IB philosophy. There was evidence that many students are working hard and enjoying their physics studies. ICT skills are evident and only few schools have students constructing graphs by hand.

When practical work was not in line with the IA criteria it was usually under the planning (a) criterion. Planning investigations need to be open-ended, where students define their own research question. The best planning labs are ones that look for a function or relationship between two variables, and not investigations used to determine a known constant or verify a known law.

Other inappropriate labs included data collection for a radioactive simulation and a Snell's law simulation. An inappropriate (or at least difficult) conclusion and evaluation occurs when teachers ask students to improve upon standard textbook investigations with proven equipment and procedures.

In the majority of cases schools completed the appropriate number of hours, had the required student signature on the 4/PSOW form, and completed the rest of the required paperwork appropriately. Overall, the administrative side of IA moderation went smoothly this year.

Candidate performance against each criterion

Student performance against the five criteria was somewhat consistent and in line with previous years. Under planning (a) students are proficient at stating research questions. Providing a hypothesis or prediction has always been difficult for students, and moderators only expect some intelligent thought (not necessarily sound scientific theory). Selecting variables was done well too, but occasionally students list silly constants, like gravity. Students also need to carefully define the variables. When they want to measure, for example, the depth of a crater formed by a ball falling upon a box of sand, just saying the "hole depth" is not sufficient. How is it to be measured and what exactly is the depth? Under planning (b) students showed a limited but fair range of approaches to the teacher prompts. This is expected. An appreciation for the range and scope of data was usually given. Under data collection students consistently demonstrated good scientific form, and the appreciation of uncertainty was clearly given. Under data processing and presentation many students demonstrated competent use of graphing software. The use of ICT is encouraged and, in the new curriculum, it is expected. Minimum and maximum gradients were correctly used to determine the uncertainty in the gradient of a graph. Finally, as in previous years, writing a good conclusion and evaluation tended to be a more difficult task for students. Evaluating procedure was rarely addressed, while limitations and weakness were more easily identified. Suggesting improvements was usually poorly done.

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

A. Where moderators reduce marks.

Planning (a):

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

Planning (b):

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

Data Collection:

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

Data Processing & Presentation:

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

Conclusion & Evaluation:

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

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 the students.

Planning (a):

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

Planning (b):

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

Remember moderators look at the whole report. Moderators do not insist on +/- precision of apparatus to be given in the apparatus list. This has never been specified to teachers and the concept of recording uncertainties is dealt with in DC. Moderators do not downgrade a teacher's mark if something as routine as safety glasses or lab coats are not listed. Some teachers consider it vital to list them each time and some teachers consider them such an integral part of all lab work that they go without saying. Moderators support teacher's stance here.

Data Collection:

In a comprehensive data collection exercise possibly with several tables of data the student has been inconsistent with significant digits for just one data point or missed units out of one column heading. If the moderator feels the student has demonstrated that they were paying attention to these points and made one careless slip then the moderator can still support maximum marks under the 'complete not meaning 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 is not marked down if they have not included any qualitative observation(s) and the moderator cannot think of any that would have been obviously relevant. The moderator does not mark down if there is no table title when it is obvious what the data in the table refers to. Often students do all the hard work for DC and then lose a mark from the class teacher because they did not title the table. Except for extended investigations it is normally self-evident what the table refers to and the section heading Raw Data is sufficient. Once again 'c' does not mean perfect.

Data Processing & Presentation:

The expectation for the treatment of errors and uncertainties in physics 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 figure in a measurement, and can also make statements about the manufacturer's claim of accuracy. They can estimate uncertainties in compound measurements (± half the range), and they can make educated guesses about uncertainties in the method of measurement. If uncertainties are small enough to be ignored, the candidate should note this fact.

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

For both DC and DPP, if the student has clearly attempted to consider or propagate uncertainties (according to whether HL or SL) then moderators support the teacher's award even if they may feel that the student could have made a more sophisticated effort. Moderators do not punish a teacher or student if the protocol is not the one that you teach i.e. top pan balance uncertainties -given as +/- 0.01g when you may feel that if we consider the tare weighing then it should be doubled. Moderation is not the time or place to establish the favored IB protocol.

Conclusion & Evaluation:

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

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. See the *Physics Course Guide* “The use of ICT” pages 30 through 33 for more details. 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

The most important recommendation for teachers is to implement the new syllabus for the first exam in May 2009 (and the first November exam in 2009). The syllabus has been modified and the treatment of errors and uncertainties has been made common to both standard and higher level students. This means that IA expectations for the treatment of errors will apply to both SL and HL students. The new IA format is a simplification of the old system, replacing five criteria with three, and eliminating the role of hypothesis. This means that students can now perform truly open ended investigations. The group 4 project has been revised and will be used for assessing personal skills only. Manipulative skills will be assessed in a cumulative way. Teachers are recommended to visit the OCC and study the ten student IA samples that are marked by the new IA criteria. Finally, the use of ICT is required in the new curriculum.

Further comments

Moderators increased some teacher’s marks, reduced others, and kept most marks as given by the teacher. The biggest reason for moderators lowering marks was that the teacher had assigned inappropriate tasks to the student thus making it impossible for students to achieve complete levels on the IA criteria. Confirming Boyle’s law is not a good design lab; giving students a data table tells them what to record and how to record it. Under the new criterion of Data Collection and Processing, students are expected to construct graphs. When investigations simply derive a specific value then assessment under DCP will be inappropriate.

Overall, the vast majority of schools are offering rich and diverse practical programs. Teachers are following the administrative rules and regulations, and teachers clearly and competently appreciate the spirit of the IA criteria.

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 sometimes without requiring 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. It is however essential that candidates are able to perform simple calculations and orders of magnitude estimates without a calculator.

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 - 15	16 - 21	22 - 25	26 - 28	29 - 32	33 - 40

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 10	11 - 14	15 - 17	18 - 20	21 - 23	24 - 30

General comments

A very small percentage of Centres taking the examination returned G2's. Nevertheless, those that did indicated that both Hl and SL papers were well received. Almost all centres felt that the papers were of a similar standard to those of the previous year and that the level of difficulty was appropriate. The syllabus coverage, the clarity of wording, and the presentation of the paper were also found to be of a good standard.

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	129	95	166	339 *	5	46.19	0.31
2	520 *	177	20	16	1	70.84	0.29
3	31	90	139	468 *	6	63.76	0.61
4	3	64	469 *	198		63.90	0.55
5	29	119	484 *	102		65.94	0.56
6	585 *	9	125	15		79.70	0.28
7	140	19	412 *	160	3	56.13	0.50
8	518 *	35	168	11	2	70.57	0.44
9	17	507 *	16	194		69.07	0.36
10	620 *	18	79	13	4	84.47	0.29
11	59	540 *	81	48	6	73.57	0.44
12	56	642 *	10	26		87.47	0.29
13	59	52	68	554 *	1	75.48	0.36
14	456 *	134	104	38	2	62.13	0.53
15	336 *	304	33	54	7	45.78	0.60
16	98	193	331 *	112		45.10	0.42
17	75	210	437 *	11	1	59.54	0.22
18	152	513 *	15	51	3	69.89	0.36
19	97	510 *	58	68	1	69.48	0.41
20	76	123	50	482 *	3	65.67	0.56
21	93	81	465 *	89	6	63.35	0.51
22	206	38	51	433 *	6	58.99	0.48
23	588 *	30	71	44	1	80.11	0.31
24	342	33	23	335 *	1	45.64	0.60
25	65	18	17	626 *	8	85.29	0.35
26	156	81	162	331 *	4	45.10	0.31
27	555 *	14	159	4	2	75.61	0.33
28	414 *	183	58	69	10	56.40	0.62
29	391 *	48	272	22	1	53.27	0.27
30	36	75	184	431 *	8	58.72	0.56
31	22	326 *	319	65	2	44.41	0.21
32	310 *	82	292 *	46	4	82.02	0.30
33	27	85	38	580 *	4	79.02	0.41
34	122	41	433 *	126	12	58.99	0.37
35	45	606 *	41	38	4	82.56	0.37
36	160	43	29	496 *	6	67.57	0.61
37	51	199	112	366 *	6	49.86	0.44
38	101	450 *	123	49	11	61.31	0.52
39	310 *	21	150	246	7	42.23	0.49
40	49	509 *	95	71	10	69.35	0.56

Number of candidates: 734

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	171	128	154	330 *	3	41.98	0.32
2	590 *	135	28	32	1	75.06	0.34
3	28	641 *	46	68	3	81.55	0.37
4	107	123	65	491 *		62.47	0.43
5	7	103	349 *	327		44.40	0.67
6	94	77	226	387 *	2	49.24	0.55
7	35	136	478 *	136	1	60.81	0.52
8	591 *	15	168	12		75.19	0.29
9	15	265	44	461 *	1	58.65	0.46
10	185	44	309 *	243	5	39.31	0.41
11	600 *	58	120	5	3	76.34	0.44
12	155	54	526 *	42	9	66.92	0.53
13	35	533 *	167	46	5	67.81	0.50
14	29	196	270	287 *	4	36.51	0.45
15	72	265	434 *	13	2	55.22	0.29
16	610 *	12	88	74	2	77.61	0.38
17	192	489 *	15	86	4	62.21	0.27
18	149	570 *	36	27	4	72.52	0.48
19	131	117	390 *	146	2	49.62	0.50
20	244	63	75	403 *	1	51.27	0.45
21	209	81	424 *	71	1	53.94	0.36
22	559 *	39	93	90	5	71.12	0.31
23	355 *	233	82	107	9	45.17	0.55
24	110	286	225 *	156	9	28.63	0.27
25	424 *	56	271	26	9	53.94	0.34
26	114	96	507 *	58	11	64.50	0.55
27	67	128	222	350 *	19	44.53	0.51
28	103	529 *	98	46	10	67.30	0.52
29	26	167	490 *	89	14	62.34	0.53
30	52	82	577 *	58	17	73.41	0.47

Number of candidates: 786

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 varied from about 40% in HL and 29% in SL (relatively ‘difficult’ questions) to about 87% in HL and 82% in SL (relatively ‘easy’ questions). This is a narrower spread than usual. 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 all questions in both papers. 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. In the SL papers there were significantly more gaps towards the end of the paper. 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 Q5 and HL Q4

D was a popular distractor and candidates made this error through failing to recognise that the area under the graph is ½ x *base* x *height*.

SL Q11 and HL Q8

Many were distracted by the erroneous idea that the incident ball must rebound. This is a case where all the momentum of the incident ball is transferred to the second ball.

SL Q15 and HL Q17

Candidates were distracted by response B showing that they do not understand the true meaning of thermal equilibrium. Under the conditions specified in the question no ice will melt.

SL Q17 and HL Q18

A popular error was to imagine that the pressure of the gas halves (response A) when the partition is removed, perhaps because candidates assumed that there was a vacuum in one half of the container despite a clear indication in the question that this was not the case. Candidates need to read the whole of the question carefully.

SL Q20 and HL Q22

Many were unable to manipulate the inequality signs correctly and gave response A as their answer, showing that they had reversed the signs.

SL Q23 and HL Q28

The statistics show that this item was answered rather better by HL candidates. They were able to manipulate the algebraic symbols with more facility than those at SL. At SL there were large numbers of incorrect B responses.

SL Q27 and HL Q30

A popular distractor was C where candidates introduced an intrusive π into the equation.

SL questions

Q6

Too many failed to define instantaneous velocity correctly, relying on a ratio rather than a rate of change in their understanding.

Q10

Many relied on an elementary and incomplete statement of Newton's second law (*F=ma*) rather than the formal definition in terms of rate of change of momentum.

Q14

Candidates thought that the centripetal force was provided by the weight of the car even though there was a clear statement that the road was horizontal. They may have been answering on the assumption that the road was banked.

Q24

More candidates selected B than C (the correct response) having erroneously multiplied the accelerating pd by the electronic charge in order to find the kinetic energy of the electron in joules. They had failed to read the question carefully.

Q25

As in previous years, too many candidates define resistance in terms of the gradient of a V versus I graph. They need to remember that this is always a ratio issue.

HL questions

Q14

One centre suggested that the phrase 'minimal effect on the frictional force' is difficult for students whose first language is not English. There was no evidence from the statistics that this was the case and the Spanish translation was felt to be appropriately expressed.

Q15

B was a strong distractor showing that candidates were applying the equation for torque blindly without realising that the force of gravitation is along the line joining the centres of the two bodies hence has zero torque about any axis through the centre.

Q24

This was poorly done with more choosing the incorrect A (probably considering amplitude changes to the received signal) rather than B. It is important for candidates to recognise that they should identify the response that is closest to the correct physical situation. Graph B is very close to the observed physical situation but would only be completely correct if the observer is standing in the direct path of the train.

Q31

As in the past, candidates were often confused when confronted by comparatively straightforward dc electrical circuits. Here candidates were unable to analyse the situation when a bulb in a parallel circuit goes open circuit, even though the question clearly indicated that the resistance became of infinite value. Very many students chose option C reflecting the very common misconception that with no current in the burned lamp the other two get more current! This ignores the fact that with the third lamp burned out, the total resistance changes (increases) and so the total current decreases!

Q32

A possible definition of electric field strength involves the gradient of a potential versus distance rather than the actual ratio of potential to distance (even though in this case they were numerically the same). For this reason both answers A and C were accepted as correct.

Q39

About half the candidates did not realise that the determination of the half-life of a long-lasting isotope needs special experimental measures that do not involve waiting for the mass of active material to halve. Both the initial activity and the initial mass of a pure sample of the material are required.

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 response options. All the wording in a question is significant and important. Items have few if any superfluous words.

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

Candidates need to remember that standard definitions (e.g. Newton's second law, field strength definitions, and so on) can and are tested in this component. They need to be as familiar with these parts of the syllabus as all the others for the P1 components.

Paper two

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 11	12 - 22	23 - 32	33 - 42	43 - 53	54 - 63	64 - 95

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 12	13 - 16	17 - 21	22 - 26	27 - 31	32 - 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.

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 poorly understood by candidates. These included electromagnetic induction (at Higher Level) and very surprisingly the basics of waves (at Standard Level). Many candidates had problems with application of the laws of Mechanics to rockets. Questions on thermal physics (calorimetry) and radioactivity 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:

- Deriving the equation of a straight line of best fit.
- Drawing a line of best fit that is a curve.
- Applying the laws of mechanics to a rocket.
- Defining an ideal gas and working with the concept of internal energy for an ideal gas.
- Using graphs to work with traveling waves.
- Explaining the concept of wave speed for stationary waves.
- Determining the direction of the magnetic force on a current.
- Electromagnetic induction.
- The Doppler effect.

- Working with gravitation.
- Definition of e.m.f.

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 kinematic problems and simple applications of Newton’s second law.
- Solving thermal physics problems (calorimetry)
- Thermodynamics
- Mathematical substitution into a given equation
- Basic properties of travelling waves and standing waves
- Radioactivity
- 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(a) – (d)] - Data analysis question

This was generally well done as a whole, with many candidates receiving most of their marks from this question. At the same time it was surprising to see a very large number of candidates unable to score many points form this question.

a) This was well done by most.

b) Many students struggled for an explanation of a linear relationship and many had difficulties with the derivation of the equation of the straight line. Many used incorrect variables rather than the expected *R* and *M*.

c) Very many did this correctly.

d) It was disappointing to see so many candidates attempting to fit a straight line to the new data when this seemed so obviously impossible.

e) [**HL only**] It was pleasing to see many students arguing correctly to answer this part.

A2 HL, A3 SL Rocket

Students were unable to obtain many points from this question. The application of the laws of mechanics to this situation proved difficult for most but the most able candidates. The question was not entirely “easy” as the speed of the gases was given relative to the rocket.

To correctly apply momentum conservation, velocities had to be referred to an inertial frame of reference. Failing to do so gives, in this case, the same numerical results, and this was not penalized in the markscheme.

A3 HL, A2 SL An ideal gas

a) Most candidates were vague referring to "gas laws" without specifically mentioning $pV = nRT$ or any of the kinetic theory assumptions.

b) Most candidates referred to potential energy forgetting that the question applied to an ideal gas. Despite the fact that many could recall the connection between temperature and the average random kinetic energy of the molecules, few could actually connect the two to realize that internal energy had to be proportional to absolute temperature.

c) [**HL only**] This part was well answered by most candidates. [**SL only**] With hindsight, the word "isothermally" should have been replaced by "at constant temperature" but students had no problem obtaining the new pressure. Very few were successful with the curve joining the two states, most choosing a straight line.

Section B

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

This question was the most popular choice especially at standard level.

a) This was well done with a few exceptions from those candidates who took 0.20 s as the period of the wave despite being told that this was not the case!

b) The differences between traveling and standing waves were also well described by candidates.

c) However, most had difficulties in providing correct explanations especially in the case of standing waves. Few could relate the speed of the standing wave to the speed of one of its component traveling waves.

d) The explanation of how a sound wave is created by a vibrating string proved surprisingly, difficult for most. On the other hand many could calculate the wavelength of the wave in air, which was a good improvement over similar questions in the past.

B1 Part 2 [HL only] Electromagnetic induction

a) Electromagnetic induction continues to be a problem area for many students. Very few could adequately state Faraday's law of induction.

b) There were very vague answers as to why the loop is slowing down. Most referred to a force opposing the motion but very few could actually demonstrate this using Lenz's law and a rule giving the direction of the magnetic force in any convincing way. The derivation of $V = BLv$ went somewhat better but in evaluating the induced e.m.f. at $t = 0.18\text{ s}$ very few realized that by then the loop was entirely within the region of magnetic field and so the magnetic flux was constant.

c) There were a few good responses here but not all saw that the easiest way of doing this problem was by concentrating on the kinetic energy of the loop.

d) It was disappointing to see very few good responses here. Most had the speed of the loop going back up to its original value before entering the magnetic field region.

B1 Part 2 [SL only] Mechanics

a) This was answered well by the majority of candidates.

b) Again, those who attempted this question did this part correctly.

c) There were mixed results here. Part (i) was done rather well but many students calculated the average acceleration rather than the instantaneous in (ii).

d) This should have been a straightforward straight line graph but the majority of candidates answered in terms of a curve.

B2 [Part 1 HL only] Nuclear Physics

a) Generally this was a well done question with many candidates answering either in terms of the energy required to separate the nucleons or the energy released when the nucleus is assembled.

b) Also a well done question.

c) Again the majority of students did this well with a few who did not realize that they needed to convert from binding energy per nucleon to total binding energy receiving partial credit.

d) Students started to find difficulties at this stage. Many used incorrect methods such as work done by the (non-constant) electric force is $Fd = (kq^2 / d^2) = kq^2 / d$ and setting this equal to $2E_K$.

e) Answers to (i), (ii) and (iii) were reasonably good. In (iv) many failed to stress the importance of the short range of the nuclear force.

B2 [Part 2 HL only] The Doppler effect

There were reasonable answers to (a) and (b) but the demonstration that the wavelength remains unchanged proved difficult even to those who got part (b) right. In part (d) many used a single Doppler effect and got partial credit.

B3 [Part 1 HL], B2 [Part 1 SL] Girl on trampoline

As with the rocket question, students faced Mechanics in a slightly unusual context. Most did well with the exception of part (b) where answers were generally poor.

B2 [Part 2 SL only] Radioactivity

Every part of this question was generally well done and was very straightforward. It was assumed common knowledge that dinosaurs died many millions of years ago. No other detail about dinosaurs was required for this question!

B3 [Part 2 HL only] Wave properties of the electron

a) It must again be stressed that when a formula is given in place of a definition, the symbols appearing in the formula must be defined.

b) Although most could calculate the wavelength of the tennis ball, few argued that it was small compared to the gap width and therefore no wavelike properties were observable.

c) This was very well done by most.

d) Also a well done part.

e) In part (i) few could identify the path difference and in (ii) even fewer could explain why the condition given implied constructive interference of the electron wave.

f) The calculation here was well done but many missed the crucial link that the calculated wavelength agreed with that in (d), thus providing support for the de Broglie idea.

g) This was poorly done with all kinds of irrelevant answers being provided.

B4 [Part 1 HL only] Gravitation

Students struggled with the derivations in (a). Most were unclear about the value of the radius in the formula for gravitational force and the formula for the centripetal force. Part (b) was generally done well. Answers to part (c) lacked clarity, with many students failing to explain why a reduction in energy implies a reduction in orbital radius and <u>hence</u> period.

B3 [Part 1 SL only] Calorimetry

A very well done question by those who attempted it. Most could give one but not two sources of error in the experiment described.

B4 [Part 2 HL, B3 [Part 2 SL] Electricity

a) As always the definition of e.m.f. is proving problematic.

b) Generally well done with some problems in neglecting internal resistance. Part (iv) however was hardly done correctly.

c) There were rather muddled answers to this part. Few could state clearly that with an ideal voltmeter, no current would flow between X and Y. With a finite resistance real voltmeter, that would change.

d) [**SL only**] This part involving the magnetic part of the syllabus was rather poorly done. Few could explain the direction of the magnetic force on the rod (another perennial problem encountered in examinations). In part (iii) the idea of the question was missed by most. Few realized that they had to consider whether the magnetic field of the permanent magnet and that created by the current were parallel or anti-parallel. (Error carried forward was applied here for those who got the magnetic field direction in (i) wrong.)

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. 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. Similarly, the action verb “deduce” implies that the candidate must start from basic principles and reach a certain result.

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, candidates must practice with many varied questions and questions that deal with familiar topics in unfamiliar contexts (the trampoline question in this examination, for example).

Paper three

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 13	14 - 18	19 - 23	24 - 29	30 - 34	35 - 60

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 3	4 - 7	8 - 12	13 - 16	17 - 20	21 - 24	25 - 40

General comments

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.

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 turning effect of a force
- An understanding of the quantization of energy in atoms
- Bohr theory
- Determinism
- An understanding of the causes of loss of speech discrimination
- The definition of apparent brightness
- Spectroscopic parallax
- The application of the relativistic relation between energy and momentum

- The ability to draw accurate ray diagrams
- The effect of diffraction on double slit interference.

The understanding of concepts created great difficulties for a significant number of candidates. Answers would contain 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]

A1 Gravitational field strength and escape speed

a) Definitions were often incomplete in respect of not mentioning that it is the force per unit mass on a point mass or small mass.

b) If the action verb is "deduce" candidates should not just write down equations but should also explain their reasoning. There were far too many instances here where candidates lost marks through lack of clarity by trying to "cook" a method.

c) Many candidates used gravitational PE instead of the expression given in (b).

d) (i) Again, candidates failed to make clear their reasoning. A statement regarding the relationship between KE and PE was required for full credit.

(ii) Usually answered correctly.

A2 Friction and rotational equilibrium

a) Most candidates recognised 15 N as the maximum frictional force but few gave a correct explanation in terms of the value of the two forces acting.

b) Full credit was only awarded if a correct explanation was also given and many candidates achieved this.

c) The problem was not generally well answered. Many candidates were able to calculate the resultant force but thought that this was the frictional force

d) (i) The rotational nature of the problem was rarely noticed.

(ii) The correct value was often given.

Option B [SL]

B1 Quantization of energy in atoms

a) Few candidates were able to give a thoughtful answer here in respect of quantization.

b) Diagrams were often poor. The evacuated region was rarely labelled and there was often confusion with the photoelectric effect.

c) The characteristic spectrum was often correctly identified but explanations were often poor.

d) With very few exceptions, this was answered poorly. Candidates did not appear to appreciate that the calculated photon energy corresponded to a difference between two energy levels.

B2 Beta + decay

a) There were some wild guesses here and often little attempt to identify the mass number and atomic number.

b) Again, many wild guesses.

c) Units were often omitted in the answer.

d) Both (i) and (ii) were often answered well.

Option C [SL]

C1 Thermodynamics of an ideal gas-

a) Explanations were often absent or completely incorrect in both (i) and (ii).

b) Again, the explanation was often absent.

c) Many candidates correctly identified the area as the energy transferred in one cycle.

d) Answers were often correct.

C2 The generation of electrical power.

a) The identification and explanation of renewable and non-renewable sources were often correct.

b) Few scripts showed any appropriate discussion of the main energy transformations and rarely was any reference made to energy dissipation.

c) This was usually answered correctly.

d) This was usually answered correctly.

Option D [D1 – D3, SL and HL]

D1 Scaling

a) Many candidates answered (i) correctly though many did not realize or could not state the assumption used in part (ii).

b) Many candidates correctly recognised the inverse length dependence but then failed to make the connection with rate of fall of temperature

D2 Hearing

a) Quite a few candidates correctly identified Frank as having a greater threshold of hearing and others, judging by their explanations, often just guessed

b) Few candidates were able to do the calculation correctly failing to appreciate the logarithmic nature of the decibel scale

c) This was often answered correctly.

d) Answers were often confused with few candidates appreciating that it is the loss of sensitivity of certain frequencies present in speech that results in the brain not being able to distinguish different sounds.

D3 X-ray imaging

a) This was often answered well but the idea of multiple readings was often missed.

b) Many candidates thought that the barium was either radioactive or it emitted X-rays!

D4 [HL] Conversion and energy expenditure

a) In general, candidates gave the correct response but some missed the idea of rate.

b) Generally answered well.

c) Explanations of evaporation in (i) often made no reference to sweating and in (ii) the similar role played by expiration was not often appreciated.

D5 [HL] Physical and biological half-lives

This was often correctly answered.

Option E [E1 – E3 SL and HL]

E1 The motion of stars and planets.

a) Well answered in most cases. There were some very well drawn diagrams. Other drawings were so poor that it was not possible to judge the essential features.

b) Not often answered with any precision and sometimes only reference made to one of the models.

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. The only thing that most candidates knew with certainty was that Rumford was associated with boring cannons.

E3 Electric charge

a) Most candidates made an attempt to explain the Du Fay model approach in (i) but in (ii) rarely was any reference made to electrons and the separation of charge.

E4 [HL] Bohr and Rydberg

a) (a) and (b) There were few successful attempts at either part.

E5 [HL] Determinism

Again as in E4 answers were weak and often non-existent, only a very few candidates were able to answer with any confidence.

Option F [F1 – F2, SL and HL]

F1 Stellar distances

(a) (i) Energy was often stated as opposed to power and a reference to Earth was often missing.

(ii) Many candidates confused apparent brightness with luminosity.

(iii) The 10 pc was often appreciated.

(b) Often correctly answered.

(c) Many candidates recognised that Ross 128 is within 10 pc of Earth

(d) The method of spectroscopic parallax was not well known by many candidates. Many thought that once the temperature was known then the luminosity could be found from the Stefan-Boltzman law. Rarely was the H-R diagram or spectral class of a star mentioned.

e) The calculation was often correct but quite a few candidates thought that the answer in metre was the answer in parsec. It is clear that candidates must practice much more with questions involving ratios and distinguish those from problems in which numbers are substituted in a single formula requiring the use of SI units.

F2 Doppler shift

a) Usually answered well.

b) Answers were often confused with a link to the early universe rarely made.

c) Usually answered well.

[HL]

a) The calculation was often correctly done but significant digit errors were common.

[HL]

a) (ii) The unit was quite often omitted and powers of ten errors were common.

(ii) Usually answered well.

F3 [HL] Stellar evolution

Both (a) and (b) were often answered well.

Option G [G1 – G2, SL and HL]

G1 Special relativity

a) Often answered correctly.

b) Explanations for both (i) and (ii) were often weak and confused. It was rarely recognised that for Bob lamp X moves toward the signal.

c) Candidates often did not answer the question correctly by omitting to refer to the paths followed by the waves and/or referring to the switch.

d) From the answers to both (i) and (ii) it is clear that many candidates are not clear as to the correct definition of proper time. A proper time interval refers to the time between events taking place at the same point in space. It is essential to recognize that the simple formula that relates two time intervals with the gamma factor only applies when one of the intervals is a proper time interval.

e) Both parts were often answered well.

G2. Relativistic velocity and mass

It would be fair to say that candidates either knew how to tackle both parts or did not. However, there were some incomplete answers to part (b) where some candidates failed to find the gamma function for particle Q in the laboratory frame of reference.

G3 [HL only] Energy and momentum

a) Deductions of the pion momentum were poor. Most candidates were unable to see a clear route to the solution from the data provided even though the calculation was straightforward. It is clear that candidates need much more practice with problems in relativistic mechanics.

b) Subsequent calculations of the pion speed were rather better with many candidates working towards a correct solution using a route involving a calculation of γ.

G4 [HL only] Spacetime and black holes

a) Many were able to describe spacetime appropriately as a four-dimensional quantity with a somewhat smaller number of candidates able to relate the path of an object to the geodesic or the shortest spacetime displacement.

b) The description was often well done with most candidates identifying the black hole as an object that causes extreme curvature. Statements that light cannot escape from the surface were rarer and less convincing.

Option H [SL and HL]

H1 Dispersion

a) Most candidates recognised that the white light was dispersed into its component colours but there was sometimes uncertainty as to which colour was refracted most. The direction in which refraction occurs when the light enters and leaves the prism was often misunderstood so that some rays took paths that were completely unrealistic.

b) Most recognised that the light on the screen was mainly white, but very few were able to describe the colour fringing accurately.

H2 Reflection and refraction

a) Refractive index was often well defined but some answers were too vague or failed to emphasise the ratio involved.

b) The diagram was often well constructed, but too many candidates failed to read the question and did not label the rays correctly. In some cases the refracted ray was deviated in the wrong direction. In the calculation, far too many used an angle of 80° (quoted in the question in another context) rather than 90° in the determination of the critical angle. Otherwise, candidates had good control over their qualitative description of the refracted ray.

H3 Astronomical telescope

a) Completion of the ray diagram of the astronomical telescope was poor in many cases. Candidates seem to understand neither the mechanics of the drawing or the underlying theory and it was rare to see a well-drawn convincing diagram. There was a widespread misunderstanding of the required position of the eye – some candidates even placing it between the lenses. Candidates were equally at a loss when writing about the instrument; few were able to state the location of the final image.

b) Candidates gave vague comments about the magnification of the telescope and failed to make quality statements about either the angular changes in image size and subtended ray angle or the magnification equation.

H4 [HL only] Double and multiple slit diffraction

a) Only a handful of scripts showed an understanding that fringes are missed when the diffracting slit minimum suppresses the interference maximum. The calculation of the slit width was consequently poor with correct solutions rare.

b) Candidates should recognise that a mark allocation of 3 signifies three marking points in the answer. There was some recognition that the fringes are brighter (more energy) but that was often as far as it went. Consideration of fringe sharpness was rarely seen.

H5 [HL only] Thin film interference

a) Many candidates gave a satisfactory sketch showing the paths of the interfering rays.

b) The position of the π phase change was marked correctly by about 50% of candidates. The subsequent explanation was however poor and often arbitrary in nature.

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 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”. Also with “deduce” they should realise that some explanation of their approach to the solution is required.

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.

It’s wise not to leave the teaching of the Options until the end of the course nor is it recommended that students be left to study an option without supervision.