PHYSICS

Overall grade boundaries

Higher Level

Grade:	1	2	3	4	5	6	7
Mark range:	0-15	16-27	28-39	40-50	51-60	61-72	73-100

Standard Level

Grade:	1	2	3	4	5	6	7
Mark range:	0-15	16-26	27-35	36-48	49-59	60-71	72-100

This report is based on an analysis of the examination papers and of student performance, as well as input from assistant examiners marking the papers and comment from schools and teachers. We would like to thank all those who took the time to provide comments on the papers. All such feedback was considered during grade award deliberations. While it is not possible to respond individually to those who gave input, we would like to acknowledge the role that such contributions play in the grade award process and in helping to improve the examinations.

Overall performance on the physics examinations was satisfactory and the distribution of grades was comparable to previous years.

It is natural in a report such as this to give more attention to areas where candidates had difficulties than to those where they did well, and the report should be read with this in mind.

Standard Level Paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-9	10-11	12-15	16-18	19-22	23-30

IB multiple choice physics papers are designed to have conceptual rather than calculation questions. This approach, emphasizing the qualitative rather than the quantitative, is based on the view that the MCQ format is suited to testing conceptual understanding, while calculations can be better assessed in the problems in Papers 2 and 3. Calculators are thus neither needed nor allowed in Paper 1. The papers were designed to have a range of difficulty of questions and reasonable topic coverage. A proportion of questions are common to the SL and HL papers, and the additional questions in HL tend to be of a somewhat higher level of difficulty.

The November 2002 papers were very well received and the comments were overwhelmingly positive. 64 % of the teachers who commented on Paper 1 felt that it was of broadly similar standard to last year's, 27% thought it a little harder and 9% felt it was a bit easier. 93% felt that the level of difficulty was appropriate whilst 7% thought that the paper was a bit too difficult. All felt that the coverage of the syllabus was satisfactory (53%) or good (47%) and that the clarity and wording of the paper were satisfactory (47%) or good (53%). The presentation of the paper was thought to be satisfactory (27%) or good (73%). The Form G2, available from the *Vade Mecum*, is used to comment on examination papers and teachers are encouraged to submit these forms as they are valuable feedback to the examining team and play an important role in setting grade boundaries. We thank schools and teachers who may have commented on particular questions on the G2 forms. All these individual comments are discussed at the grade award meeting.

Statistical analysis

The overall performance of candidates and how they performed on the various questions can be usefully illustrated by the statistical analysis of responses. These results are given in the table below, SL Paper 1 Item Analysis. The numbers in the columns *A-D* and *Blank* are the numbers of candidates choosing the labelled option or leaving the answer blank. The question key (correct option) is indicated by an asterisk (*). The *Difficulty Index* (perhaps better called facility index) is the percentage of candidates who got the question right. A high index thus indicates an easy question, and the table has been presented in the order of difficulty from easiest to hardest question. The *Discrimination Index* is a measure of how well the question discriminated between better and weaker candidates. A higher value of discrimination index indicates that a greater proportion of the better candidates got the question right compared to the weaker candidates.

SL Paper 1 Item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
13	62	9	64	320*	1	70.17	.30
3	30	80	319*	26	1	69.95	.26
11	114	3	21	318*		69.73	.40
18	304*	38	96	18		66.66	.37
2	57	302*	32	62	3	66.22	.36
15	14	48	102	292*		64.03	.58
20	63	292*	34	65	2	64.03	.44
7	134	39	273*	9	1	59.86	.24
23	41	40	101	270*	4	59.21	.47
16	268*	24	76	87	1	58.77	.61
9	40	47	106	262*	1	57.45	.33
21	69	32	89	262*	4	57.45	.53
30	47	83	258*	51	17	56.57	.57
19	88	72	241*	51	4	52.85	.51
26	52	116	236*	45	7	51.75	.53
8	17	201	4	234*		51.31	.61
17	95	97	234*	18	12	51.31	.54
5	227*	12	197	18	2	49.78	.57
1	98	105	34	217*	2	47.58	.53
28	109	210*	106	22	9	46.05	.63
12	177*	165	81	29	4	38.81	.52
29	53	73	157*	161	12	34.42	.23
14	8	42	257	147*	2	32.23	.54
4	145*	27	39	244	1	31.79	.51
10	26	143*	187	98	2	31.35	.56
24	33	182	105	128*	8	28.07	.31
25	77	171	118*	81	9	25.87	.30
27	70	131	137	106*	12	23.24	.25
22	122	96*	209	26	3	21.05	.25
6	229	60	75*	92		16.44	.18

Comments on the analysis

Difficulty Range. It will be noted that the Difficulty Index has a very wide range. The index varies from about 16 (a hard question with only 16% of candidates getting it right) to about 70 (an easy question with 70% of candidates getting it right).

Discrimination. The Discrimination Index is satisfactorily high overall. The index reaches values up to 0.63 and drops to less than 0.20 for only one question. This is a satisfactory outcome, indicating that on the whole the paper discriminated reasonably well.

Comments on selected questions

For the most part the questions were judged to be good, in that they were conceptual, well formulated and suited to the MCQ format. 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. Thus comment will only be given on selected questions, i.e. those that illustrate a particular issue or where a problem was identified. Note that questions on which students performed well are not in general discussed, but can be identified from the analysis above. Detailed discussion are reserved for questions that students found difficult or where misconceptions are identified by popularity of distracters. Thus most of the comments below identify conceptual difficulties that students have with certain physical situations, and hence should serve as feedback for teaching. Each of the comments below resulted from discussions in the Grade Award Meeting.

It is also worth pointing out here that the use of boldface is supposed to make it easier for the student to understand the question even though in isolated cases this may have been overdone.

QUESTION 5

There was a spelling mistake in this question but that did not appear to have influenced the candidates in a negative way. 50% of them got this question right but 43% incorrectly chose C. When the speed doubles the kinetic energy increases by a factor of 4 and thus so does the work that must be performed to bring the car to rest. Since the braking force is constant the distance required is also 4 times as large. Students must be exposed to more examples of this kind of problem.

QUESTION 6 (HL question 3)

With only 16% getting this right, question 6 proved the most difficult question on the examination paper and the one with the lowest discrimination index. 50 % of the candidates chose A. The only forces on the body are the tension acting in a direction along the string and the weight in the vertically downward direction. No other force is acting and so the answer is C. In choosing A, many candidates thought a third horizontal centripetal force was acting as well. It must be stressed that this is not an additional force acting on the body but simply the resultant (net) force of the two individual forces (tension and weight).

QUESTION 7

This question was answered correctly by 60% of the candidates. This was not a hard question but it did not discriminate well. About 29% chose A, showing a misunderstanding of Newton's third law. The law does not refer to *any* two forces that happen to be equal and opposite. Rather it refers to a situation where a certain body, say A, exerts a force on a second body, say B, and so body B exerts on *A* an equal and opposite force.

QUESTION 10

This was similar to question 6. Only 31% of the students got this question right and it discriminated rather well. The comment here is the same as that for question 6: students must be exposed to problems involving multiplicative changes in a variable and asked to find the change in a dependent variable. Here, speed and distance are related through $v^2 = 2ad$ and so the speed attained after travelling double the distance is $v\sqrt{2}$. Many students chose the answer that involved doubling the speed as well. This cannot be right though since speed and distance are not proportional to each other.

QUESTION 11

Most students found this question easy with 70% answering it correctly. The word *smooth* was understood by most students to be equivalent to frictionless.

QUESTION 13 (HL question 14)

This question might be technically more correct if it had specified whether the beakers were insulated or not and perhaps if the phrase *warm water* had been replaced by a statement such as *the temperature of the water was greater than 10 degrees Celsius*. However, these technical details did not in any way prevent the students from finding this the easiest question on the examination paper with 70% of them answering it correctly.

QUESTION 17 (HL question 20)

Students probably thought that much calculating was involved in this question. In fact this was not the case. The sines of the angles were given and the answers were sufficiently different so a bit of arithmetic would give the right answer very quickly even without a calculator.

QUESTION 19 (HL question 21)

Most books at this level (as well as past IB exams) make use of *displacement* nodes and antinodes rather than pressure nodes and antinodes. Many students answered this correctly (53%) so the possible confusion between what kind of nodes and antinodes the question referred to did not appear to play a role. Only 11% chose answer D.

QUESTION 22

Many students were misled by this question with only 21% selecting the correct answer. However, the question does begin with the very clear sentence that the wire obeys Ohm's law, which in effect gives the answer that the resistance is constant.

QUESTION 23

This question was answered correctly by 59% of the candidates. The symbol of the heating element possibly confused some students. Students must be reminded to familiarise themselves with the data booklet (the heating element symbol is shown there) before the examination. To have both the motor and the heating element on means that D could be the only answer.

QUESTION 24

This was a problematic question. Only 28% answered this question correctly and it was not a good discriminator. The question did not specify whether the resistance of the filament was constant or not and this made the question very difficult. The majority of the students chose B as the right answer, which of course does not make sense irrespective of what happens to the resistance. Thus, not specifying the behaviour of the resistance did not appear to have influenced the candidates in a negative way. Even with the resistance increasing due to increased filament temperature, the answer best represented by the four choices is D because at *low* voltage Ohm's law is expected to be valid and hence $P = \frac{V^2}{R}$ gives D as the answer.

QUESTION 27 (HL question 33)

The fact that the word *into* was written in boldface appeared to have misled some candidates. It would have perhaps been fairer to bold the word *stationary* instead, which might have alerted candidates to the fact that a stationary electric charge experiences zero magnetic force. The most popular answers to this question were B and C, which indicate that students were guessing to a considerable degree with this one. As with past similar questions it is clear that students need more practice with the magnetic force.

Areas where students had difficulties and areas where they were well prepared

It is difficult to generalise in a broad-based paper such as Paper1 over areas of difficulty or where students were well prepared. The comments on the individual questions and the percentages of student selections for each question should provide enough information about student difficulties and areas where they were well prepared. Some candidates struggled with the conceptual nature of these multiple-choice questions but it is encouraging to note from the statistics that many candidates did remarkably well.

Recommendations for the teaching of future candidates

The nature of the questions highlights the need to emphasize conceptual understanding of the basics. Qualitative reasoning about physical systems should be taught in addition to formula-based problem-solving. As mentioned earlier in connection with questions 5 and 10 it is clear that students need more practice in figuring out the change in one variable given the change in a related one. With practice most students will be able to this ``in their heads``. In Mechanics, a recurrent problem that appears in drawing free body diagrams is the selection of non-existent forces to act on the body. A centripetal force may be the resultant of many individual forces acting on the body in which case it must not be included as one of the forces on the body. In the case of a car taking a circular turn the only force horizontally is the friction between the wheels and the road. This force can be *identified* with the centripetal force and so *the centripetal force* must not be included as one of the forces on the body. More attention must also be placed on Newton's third law and students must learn to avoid the trap of associating this law with any two equal and opposite forces. As always, the magnetic force on a moving charge is a difficult concept for most students. The dependence of this force on charge and speed must be emphasized and students must practice more with finding its direction. Even though it may appear redundant to say this in this report, we must never stop reminding students to read the questions carefully. Often, incorrect answers are given simply because the student has gone through the question too quickly and missed a crucial word that prevented him/her from getting the right answer.

Higher Level Paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-14	15-18	19-22	23-25	26-29	30-40

IB multiple choice physics papers are designed to have conceptual rather than calculation questions. This approach, emphasizing the qualitative rather than the quantitative, is based on the view that the MCQ format is suited to testing conceptual understanding, while calculations can be better assessed in the problems in Papers 2 and 3. Calculators are thus neither needed nor allowed in Paper 1. The papers were designed to have a range of difficulty of questions and reasonable topic coverage. A proportion of questions are common to the SL and HL papers, and the additional questions in HL tend to be of a somewhat higher level of difficulty.

The November 2002 papers were very well received and the comments were overwhelmingly positive. 93 % of the teachers who commented on Paper 1 felt that it was of broadly similar standard to last year's while 7% thought it much harder. 94% of all respondents felt the difficulty was appropriate while 6% thought the level was too difficult. All respondents rated the paper as satisfactory (35%) or good (65%) as far as syllabus coverage was concerned. All thought the clarity of wording of the paper was satisfactory (41%) or good (59%). All also felt that the presentation of the paper was satisfactory (24%) or good (76%). The Form G2, available from the *Vade Mecum*, is used to comment on examination papers and teachers are encouraged to submit these forms as they are valuable feedback to the examining team and play an important role in setting grade boundaries. We thank schools and teachers who may have commented on particular questions on the G2 forms.

Statistical analysis

The overall performance of candidates and how they performed on the various questions can be usefully illustrated by the statistical analysis of responses. These results are given in the table below, HL Paper 1 Item Analysis. The numbers in the columns *A-D* and *Blank* are the numbers of candidates choosing the labelled option or leaving the answer blank. The question key (correct option) is indicated by an asterisk (*). The *Difficulty Index* (perhaps better called facility index) is the percentage of candidates who got the question right. A high index thus indicates an easy question, and the table has been presented in the order of difficulty from easiest to hardest question. The *Discrimination Index* is a measure of how well the question discriminated between better and weaker candidates. A higher value of discrimination index indicates that a greater proportion of the better candidates got the question right compared to the weaker candidates.

HL Paper 1 Item Analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
15	4	14	39	339*	1	85.39	.30
14	52	6	28	311*		78.33	.12
5	5	76	5	310*	1	78.08	.41
25	32	24	40	300*	1	75.56	.41
19	297*	8	48	44		74.81	.37
10	292*	17	69	19		73.55	.43
21	37	33	291*	36		73.29	.41
20	45	50	286*	14	2	72.04	.36
7	23	24	67	283*		71.28	.40
1	36	279*	19	62	1	70.27	.34
35	38	277*	43	37	2	69.77	.45
22	55	23	276*	43		69.52	.29
6	270*	117	9		1	68.01	.53
29	20	90	266*	19	2	67.00	.44
24	71	263*	35	26	2	66.24	.50
9	5	27	258*	107		64.98	.41
13	47	29	62	257*	2	64.73	.43
26	256*	78	41	19	3	64.48	.50
16	46	237*	12	100	2	59.69	.34
31	83	235*	41	37	1	59.19	.40
18	71	229*	52	45		57.68	.38
2	134	7	*213	41	2	53.65	.43
8	10	207*	107	73		52.14	.45
12	166	195*	30	6		49.11	.37
34	60	28	193*	114	2	48.61	.46
40	193*	92	68	40	4	48.61	.33
17	90	18	108	181*		45.59	.26
28	50	140	177*	30		44.58	.48
4	52	158	175*	11	1	44.08	.15
23	9	113	104	171*		43.07	.52
32	138	41	170*	48		42.82	.34
38	169*	50	149	22	7	42.56	.00
30	42	159*	153	41	2	40.05	.34
33	35	67	151	142*	2	35.76	.59
11	129	86	49	132*	1	33.24	.51
39	87	38	128*	139	5	32.24	.31
3	221	23	120*	33		30.22	.48
37	88	111*	171	23	4	27.95	.36
27	110*	31	29	227		27.70	.24
36	121	178	86*	9	3	21.66	.29

Comments on the analyses

Difficulty Range. It will be noted that the Difficulty Index has a good range. The index varies from about 22 (a hard question with only 22% of candidates getting it right) to about 85 (an easy question with 85% of candidates getting it right).

Discrimination. The Discrimination Index is satisfactorily high overall. The index reaches values up to 0.59 and drops to below 0.20 for only three questions. This is a satisfactory outcome, indicating that on the whole the paper discriminated reasonably well. Those questions with a very low index are in general easy ones, but not exclusively so, indicating that it is not always the case that hard questions discriminate best between good and poor students.

Comments on selected questions

For the most part the questions were judged both by the examining team and by the schools to be good in that they were conceptual, well formulated and suited to the MCQ format. 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 when looking at a specific question. Thus comment will only be given on selected questions, i.e. those that illustrate a particular issue or where a problem was identified. Note that questions on which students performed well or which discriminated well will generally not be discussed, but can be identified from the analysis above. Detailed discussion are reserved for questions that students found difficult or where misconceptions are identified by popularity of distracters. Thus most of the comments below identify conceptual difficulties that students have with certain physical situations, and hence should serve as feedback for teaching. Each of the comments below resulted from discussions in the Grade Award Meeting.

It is also worth pointing out here that the use of boldface is supposed to make it easier for the student to understand the question even though in isolated cases this may have been overdone.

QUESTION 3

This common question with Standard Level was answered correctly by 30% of the candidates (as opposed to only 16% at SL). 56% of the students chose distracter A. The only forces on the body are the tension acting in a direction along the string and the weight in the vertically downward direction. No other force is acting and so the answer is C. In choosing A, many candidates thought a third horizontal centripetal force was acting as well. It must be stressed that this is not an additional force acting on the body but simply the resultant (net) force of the two individual forces (tension and weight).

QUESTION 4

This question was answered correctly by only 44% of the candidates. This was not a hard question but it did not discriminate well. About 40% chose B, showing a misunderstanding of Newton's second law. The hanging block is accelerating and therefore the net force on it is not zero. Thus the tension cannot possibly be 30 N, which should have eliminated answer B immediately.

QUESTION 8

52% of the students got this question right but 27% chose selection C. Students must be exposed to problems involving multiplicative changes in a variable and asked to find the change in a dependent variable. Here, speed and distance are related through $v^2 = 2ad$ and so the speed attained after travelling double the distance is $v\sqrt{2}$. Many students chose the answer that involved doubling the speed as well (C). This cannot be right though since speed and distance are not proportional to each other.

QUESTION 9

This question would have been expressed more clearly if it had been stated that the angle of incline was such that the block was about to slip. However, the statistics indicate that this did not seem to cause a problem to the candidates.

QUESTION 11

About 33% of the students got this question right and about just as many chose selection A. Obviously the presence of a sinusoidal curve misled candidates who should have paid attention to the axes to see that they involved acceleration and displacement.

QUESTION 12

About 49% of the students got this question right but almost 42% chose A as the answer not realising that the expression for gravitational potential energy is $U = -\frac{GMm}{r}$ and therefore never positive. The confusion probably arises because of the ordinary Mechanics formula $U = mgh$ which students (incorrectly) keep on using even in this context.

QUESTION 14

This question might be technically more correct if it had specified whether the beakers were insulated or not and perhaps if the phrase *warm water* had been replaced by a statement such as *the temperature of the water was larger than 10 degrees Celsius*. However, these technical details did not in any way prevent the students from finding this the easiest question on the exam paper with 70% of them answering it correctly.

QUESTION 20

Students probably thought that much calculating was involved in this question. In fact this was not the case. The sines of the angles were given and the answers were sufficiently different so a bit of arithmetic would give the right answer even without a calculator.

QUESTION 21

Most books at this level (as well as past IB exams) make use of *displacement* nodes and antinodes rather than pressure nodes and antinodes. Many students answered this correctly (73%) so the possible confusion between what kind of nodes and antinodes the question referred to did not appear to play a role. Only 9% chose answer D.

QUESTION 27

Many students (57%) chose answer D with only 28% selecting the right answer (A). The filament breaks which means that no current goes through it. Apparently students took this to mean that the potential difference across it is also zero, which of course is not correct. This is a common mistake, which we must try to rectify with more examples in the classroom.

QUESTION 33

The fact that the word *into* was written in boldface appeared to have misled the candidates. It would have perhaps been fairer to bold the word *stationary* instead, which might have alerted candidates to the fact that a stationary electric charge experiences zero magnetic force. The most popular answer to this question was C (38%) which makes one wonder how exactly this answer was arrived at. As with past similar questions it is clear that students need more practice with the magnetic force.

QUESTION 36

This question was answered correctly by only 22% of the candidates. Most chose A or B for one or two particles produced. The correct answer involves three particles. The electron anti-neutrino is often forgotten but a lot of important Physics is associated with it and its existence must be stressed in the classroom.

QUESTION 39

This proved a tricky question. 43% got it right which is good, but 38% chose answer C. They obviously had in mind the graph that is found in most books, namely the graph of binding energy *per nucleon* plotted against mass number. This graph indeed increases and then decreases leading to C. The question involved total binding energy though and the word *total* was in fact put in boldface. Since binding energy per nucleon is essentially constant, the total binding energy increases with atomic number.

Areas where students had difficulties and areas where they were well prepared

It is difficult to generalise in a broad-based paper such as Paper1 over areas of difficulty or where students were well prepared. The comments on the individual questions and the percentages of student selections for each question should provide enough information about student difficulties and areas where they were well prepared. Some candidates struggled with the conceptual nature of these multiple-choice questions but it is encouraging to note from the statistics that many candidates did remarkably well.

Recommendations for the teaching of future candidates

The nature of the questions highlights the need to emphasize conceptual understanding of the basics. Qualitative reasoning about physical systems should be taught in addition to formula-based problem-solving. As mentioned earlier in connection with question 8, it is clear that students need more practice in figuring out the change in one variable given the change in a related one. In Mechanics, a recurrent problem that appears in drawing free body diagrams is the selection of non-existent forces to act on the body. A centripetal force may be the resultant of many individual forces acting on the body in which case it must not be included as one of the forces on the body. In the case of a single force in circular motion, for example a satellite in a circular orbit around the earth, the only force is the gravitational force. This force can be *identified* with the centripetal force and so *the centripetal force* must not be included as one of the forces on the body. As always, the magnetic force on a moving charge is a difficult concept for most students. The dependence of this force on charge and speed must be emphasized and students must practice more with finding its direction. Even though it may appear redundant to say this in this report, we must never stop reminding students to read the questions carefully. Often, incorrect answers are given simply because the student has gone through the question too quickly and missed a crucial word that prevented him/her from getting the right answer.

Standard Level Paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-12	13-17	18-23	24-29	30-35	36-50

General comments

The feedback from teachers was generally very positive. 87% thought that the paper was of the appropriate level of difficulty and the same percentage thought that the paper had a satisfactory or good syllabus coverage. All replies rated the clarity of wording and the presentation of the paper to be satisfactory or good. A clear majority rated the paper to be good in all aspects.

In general candidates appeared to allocate their time appropriately and there was no evidence that candidates were disadvantaged by lack of time. However, some candidates, as in previous years, did not pay heed to the space available for answering a particular sub-question or to the marks available and give needlessly lengthy answers.

Fewer candidates than in previous sessions made significant-digit errors and unit-omission errors.

The majority of candidates showed the steps in calculations, if at times somewhat messily, and so were able to take advantage of "error carried forward" marks. However it is worth mentioning that a significant number did not do so, or did so in a manner so obscure and "coded" that they could not be followed by the examiners or interpreted in a way which would favour the candidate in the marking.

Section A was compulsory while candidates had a choice of questions in Section B. The vast majority of candidates correctly followed the rubric and answered the required number of questions. However, a few answered more than one question in Section B and did not indicate on the front of the question paper which question they wanted marked. Under such circumstances the examiner marks the first question answered and ignores the other whatever its merits.

Areas of the program and examination which proved difficult for candidates

A very large number of candidates had difficulty with concepts in electricity, and in particular voltage drop, power rating and transformers. A significant number (really, a big majority) had difficulty with the thermodynamic temperature scale. Conversion of mechanical energy to work was notably weak for many candidates.

The levels of knowledge, understanding and skills demonstrated

Most candidates coped well with standard definitions, with substituting numerical values into standard formula and with graph plotting. The level of knowledge and understanding varied, just as one would expect across the entry with some candidates showing an excellent grasp of the concepts tested in this examination. At the other end of the scale some candidates exhibited little or no understanding of the concepts addressed by the questions. Most candidates consistently showed competency in kinematics, radioactive decay, conservation of momentum, behaviour of circular waves and fundamental precepts of the Kinetic Model for Gases. The levels of knowledge and understanding are treated in more detail in the following section.

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

Section A

QUESTION A1 *Projectile Motion on a planet (data analysis question)*

Some candidates failed to understand the concept of launch velocity and tried to perform a vectorial calculation on the initial displacement vector. In (b), many answers were incomplete, the candidates not indicating why the equally-spaced horizontal positions indicated a lack of atmosphere. Many made such statements as "because the curve has a smooth shape" or "because it is a parabola" which would require verification. The majority of candidates recognised the two key factors of a planet's mass and radius in determining a given planet's gravitational field strength. A few spoke of atmosphere, distance from the sun and other things, indicating perhaps that they were unfamiliar with this syllabus area. In fact, the specific mention of $\frac{Gm}{r^2}$ is not made in the SSC and this was taken into account in the setting of grade boundaries for this component. Nevertheless, the great majority of candidates at least scored one out of the two marks available here. The most common errors in (d), the drawing of the displacement vector and its components, was a failure to understand what a displacement vector (as opposed to a velocity vector) looked like. In addition, components were drawn in the wrong place or just as lines, without arrows. The plot of the half-speed trajectory was very well done by nearly everybody.

QUESTION A2 *Portable Radio Power Supply*

This proved challenging to some candidates. Power rating was a concept few seemed to have grasped, and the explanation of what would happen if a resistor of too low a rating were used produced vague responses such as saying it would "blow up", and "too much current or voltage would pass" and so on.

QUESTION A3 *Radioactive decay.*

This question caused the least difficulties and virtually every candidate scored well on parts (a), (b) and (c).

Section B

QUESTION B1

Part 1 *Millikan-type experiment*

Question B1 was not often chosen. For those candidates who did the question, (a) and (b) caused little difficulty though some candidates forgot the unit of field strength. Many candidates did not start with the underlying assumption of equilibrium, $mg=Eq$. Those that could do this part generally scored full marks. The reasoning required in (d), of the impossibility of fractional charges, escaped most candidates.

Part 2 *Pendulum collision.*

Part (a) presented little difficulty to most candidates although quite a few wrote $v = \sqrt{2gh}$ instead of $v = \sqrt{2gh_1}$ even though both h_1 and h_2 appeared in the diagram. A considerable number offered "Conservation of Momentum" in (b) and some missed the point about the double mass in (c), offering reasons of energy loss due to friction, etc.

Part 3 *Beats.*

Candidates applied their knowledge of superposition well and it was clear that the majority knew what they were talking about, though many could not *explain* the phenomenon solidly and merely quoted the beats formula. There were few references to *time* even though the given graphs were displacement/time functions. Very few candidates appeared to have used a ruler to align points and in (b) the explanations of how beat frequency slows as the frequencies approach one another were poor or non-existent.

QUESTION B2

Part 1 *Thermodynamics of two-stage gas process*

This was by far the most popular question on the paper and in general was satisfactorily done. In (a), many got the correct point but failed to draw the curve or drew a straight line instead. The explanation in molecular terms of gas pressure taxed many students, who often thought that increased "freedom" due to increased volume *per se* meant less pressure. Many spoke of decreased collisions *with other molecules* leading to a pressure drop instead of collisions with the container walls and particularly with the piston. Most candidates recognised correctly that an isothermal change implies no change in average molecular KE. In (d), again, many got the point but forgot to draw the straight line through the origin or drew a curve instead.
The explanation in (e) was generally satisfactory though few mentioned **both** the increased mean velocity *and* the increased frequency of collision of the molecules as factors contributing to a bigger rate of change of momentum at the piston (thus bigger pressure). For the isochoric change in (g) a large number of candidates simply doubled the Celsius temperature to get 40ºC.

Part 2 *A car rolling downhill*

This part defeated all but the most able students. Whilst kinematics is usually a strength for candidates at SL, this question involving energy concepts (rather than equations of motion, which many tried unsuccessfully to use) proved very difficult for many candidates. The most common problem was the failure to recognise the necessary use of work and energy concepts and the attempted use of $F=ma$ and uniformly-accelerated kinematics. Some used original and novel approaches which were awarded full marks. Several took the value they were supposed to find (750N) and used dubious circular arguments to show the answer was 750N. A good number of candidates recognised that air resistance was at work in (c), and that it was not constant because of the changing speed of the car.

QUESTION B3

Part 1 *Transformers and power transmission*
It should have been apparent, both by the space allowed and the number of marks allocated [5] that the description of the transformer needed to be comprehensive. Many candidates offered a very poor sketch, without labels, and the vaguest description of "voltage-in, voltage-out". There were some diagrams connecting primary coils to a battery, and many in which the role of the soft iron core was nowhere mentioned, as if it did not exist. Most appreciated that induction was at the heart of the process even though their explanations were unclear or incomplete. A few had the general idea of the reason for transmission at high voltages, but were unclear as to exactly how it was achieved. The output current in (c) was as often reported as 1000A as it was correctly given as 0.1 A.

Part 2 *Properties of circular waves on water*

This part of Question B3 was generally well done. The defining criterion for a transverse wave (mutually perpendicular directions for the motion of the medium and the wave direction) caused problems for many candidates who were vague about this. Similarly, there was incomplete understanding of the diminishing amplitude with the area of a propagating circular wave. They knew that amplitude **would** diminish but couldn't explain **why.** The use of $v=f\lambda$ *to* calculate the speed of ripples was always correctly done. The reflection of circular wavefronts from a barrier was much better understood, although many students located a position where the reflected waves appeared to originate from the surface of the barrier itself.

Recommendations and guidance for the teaching of future candidates

The above comments on specific questions show the areas of the syllabus examined with which candidates often have difficulty.

In general when preparing candidates for the examination they should be encouraged to:

- Take note of marks allocations – they are indicators of the "weight of importance" the answer carries in the overall allocation of marks.
- Read questions *very* attentively and attempt to focus answers to what has been asked. This can be helped by frequent practice at past-paper questions, marked by teachers *against the published markschemes.*
- When a situation involves the application of several forces, a free-body diagram can be helpful.
- The drawing of, and concepts behind the free-body diagram need continued emphasis in the classroom.
- In answering questions students should be encouraged to make remarks which indicate what they are doing or where they are going. Similar to REM comments in a computer program, these help the reader, at a later stage, follow the logic of the writer's thoughts and makes it simpler to award partial marks for partially successful attempts at the answer. Many students launch into a proof, for example, covering the page with formulae and equations and then fail to reach the answer. If they said where they were going at the beginning, it would be easier to follow their working and to give credit where it is due.
- Students need to recognise, through constant practise and reminders, that thermodynamics calculations always use the Kelvin temperature scale

Candidates should always read questions and graphs very carefully so that they take full advantage of the information given. This means in respect of graphical information that they should carefully identify variables and units on the scales of graphs.

When answering the examination candidates should give careful consideration to the selection of a Section B question. It was apparent in this component that many rushed gladly into B2 Part 1, and then discovered that Part 2 was beyond them. They should be encouraged to read the questions carefully before making a selection. When answering the different sub-sections of the questions it is important that they take the mark allocation into account for the section since this is a good guide to the length and/or complexity of the answer expected.

The use of past examination questions should be adopted early on in the course. Where possible whole questions or parts of questions should be used to reinforce learning and understanding when each syllabus topic or sub-topic is completed.

Standard Level Paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-4	5-9	10-12	13-17	18-22	23-27	28-40

General comments

The number of comments received from teachers was limited but greatly appreciated by the examining team. The majority of those that did comment felt that the paper was of a similar standard in comparison to last year's paper but some felt it was a little more difficult. The vast majority felt that the paper was of an appropriate level of difficulty, and rated the clarity of wording and the syllabus coverage either 'satisfactory' or 'good'. All rated the presentation of the paper as satisfactory or good.

Option A was attempted by more than three quarters of the candidates, although performance was often quite poor. Option H was also very popular, whereas options B, C, and D were not chosen often. Option E was rarely chosen although the questions were quite straightforward.

The areas of the programme which proved difficult for candidates

As in previous years, there were few attempts at Option B (Nuclear Physics), Option C (Energy extension), Option D (Medical Physics) and Option E (Historical Physics). This may suggest that these Options are perceived as difficult to teach or that the questions were not very accessible. In a November session where the number of candidates globally is relatively small, it is difficult to generalise about why certain Options are not tackled.

Other areas of difficulty identified by the examining team include:

- Principles of scaling.
- Definitions of quantities (e.g. magnitude, brightness, inertial observer etc)
- Algebraic manipulation
- Images at infinity
- Intensity distribution of light formed by a diffraction grating

The levels of knowledge, understanding and skill demonstrated

A large majority of candidates chose Option A (Mechanics Extension) though the success rate for A1 and A3 was not high. About half of all candidates chose Option H and it is pleasing to note that the general quality of ray diagrams seems to have improved in this session. The astrophysics option (F) was in general well answered.

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

It should be borne in mind that there were a pleasing number of candidates who showed a firm grasp and understanding of the topics addressed by the different option questions. The comments below refer to the main areas of weakness shown by candidates who fail to achieve this level of performance.

A Mechanics Extension

This was a very popular option.

QUESTION A1 *A swinging ball*

Some candidates found this question very straightforward, but many gave very confused answers. It was very common to see correct numerical answers given that contradicted earlier physical explanations. The majority got off to a bad start by stating that the ball was in equilibrium even though it was undergoing circular motion. The free body diagrams were often inconsistent with the explanations given and the impression was that most candidates did not consider the length of the arrows to be relevant. Many added a third "motion" force to the left. The calculations tended to be done better. Having said that, many incorrectly used the equations of linear motion to calculate the speed of the ball. Since it gave the correct numerical answer, they were satisfied that they had answered the question. Many could calculate the centripetal acceleration of the ball even if they had earlier stated that the net force on the ball was zero. It was very rare to see a correct answer for the tension in the string.

QUESTION A2 *The oscillations of a mass on a spring*

The majority were able to gain full marks on this question, though some lost marks through carelessness. A minority had no idea and were clearly guessing.

QUESTION A3 *Gravitational potential and gravitational field*

The candidates found this question very hard indeed. Most did not use the graph at all and attempted some sort of substitution into Newton's Law of Gravitation. Often data to do with the Earth (as opposed to the planet under consideration) was substituted. Those that did use the graph tended to just read one value (typically the potential at the surface) from the graph. Few correctly included the mass of the spaceship. Many were, however, able to gain marks for the final question but a surprising number thought that a moon of significant mass would imply a greater energy requirement for the spaceship. Explanations were frequently less than convincing.

B Atomic and nuclear physics extension

Rather few candidates chose this option and in general responses were surprisingly poor, particularly to the second question.

QUESTION B1 *Radioactive decay of an isotope of Uranium*

Some candidates seemed to find this question straightforward, but a significant number were confused by the way the data was presented in the grid.

QUESTION B2 *Particle nature of light and the wave nature of electrons*

The calculations in this question were not done well at all. Many candidates seemed to substitute into unsuitable equations in the data booklet. Indeed it was rare to see the de Broglie relationship used at all in the last question even though the question asked for the de Broglie wavelength to be determined. The weaker candidates had particular problems with the multi-stage nature of the calculation. The descriptive sections were not done well and candidates appeared to have limited knowledge and /or poor understanding of the principles involved. Candidates should be encouraged to write succinctly. Far too frequently, the salient points had to be searched for in overlong text. Another common fault was for candidates to provide an answer that was merely a paraphrase of the question.

C Energy extension

Very few candidates attempted this option.

QUESTION C1 *Heat engine*

Most candidates were unable to explain the difference between a heat engine and a heat pump and thus it was not surprising if the calculations in the later sections of the question also appeared muddled. Some credit was gained for appropriately applying the first law of thermodynamics.

QUESTION C2 *An active solar heater using solar panels*

The operation of an active solar heater was not well known, but some candidates went on to successfully calculate the area of solar panels required from some given data. The calculations were, however, often very difficult to follow and laid out in a very illogical and unclear way. Many also had difficulty recalling appropriate disadvantages in using solar panels for heating water.

D Medical Physics

Option D was not very popular and generally not well done.

QUESTION D1 *Human giant*

Many candidates got off to a poor start in this question by not adequately showing how to calculate the stress in the leg bones even though it seemed that they had some understanding of how to proceed. The majority of candidates, however, calculated a correct value for the stress when running though many lost the mark by omitting the unit. The mathematics of part (c) defeated many. Typically candidates failed to realise that the volume is proportional to x^3 and the area to x^2. Very few correct answers were seen for the estimate of the maximum height. In fact estimates varied up to 1000 metres with no comments made from the candidate. Very few sensible suggests for the overestimate of the maximum height were forthcoming. A common comment referred to the amount of food that had to be eaten.

QUESTION D2 *Forces and the arm*

Forces representing the weight of the ball and the tension of the biceps were usually correctly shown by candidates. However, most candidates failed to include the reaction force at the elbow. Partial credit was very rarely awarded for the calculation with answers being either completely correct, very confused or left blank.

QUESTION D3 H*earing loss*

The general impression was that many candidates were unfamiliar with the terms *air conduction* and *conductive hearing loss*. There were some good and well set-out calculations of the sound intensity but there were others that indicated a total lack of an appreciation of the formula for hearing loss.

E Historical Physics

This option had limited popularity. Those that did undertake it generally showed a hazy understanding of caloric theory and its application. Few scored high marks on models of the Universe, as there was a tendency to write an explanation of the Aristotelian or a description of the Copernican model instead of an explanation of the particular observation addressed by the question.

F Astrophysics

QUESTION F1 *Apparent Magnitude, apparent brightness and luminosity of two stars.*

Only a very few candidates could explain the difference between apparent magnitude and apparent brightness. Some candidates thought that the definitions had to do with the size of a star whereas others tried to relate brightness to the power radiated per unit surface area of the star. Most candidates correctly identified Aldebaran as appearing to be the brightest star and the star with the greatest luminosity. However the reasoning given for their choice was often suspect. A substantial number of candidates failed to correctly label the vertical axis on the Hertzsprung-Russell diagram but the majority were able to identify the respective regions where Aldebaran and Procyon could be found. The calculation of the ratio of brightnesses was often done not as a ratio but as two distinct calculations, typically with much confusion of units.

QUESTION F2 *Galaxies*

Whereas a significant number of candidates demonstrated a good knowledge of the Doppler effect and the significance of the red shift, there were others who clearly did not understand these concepts. A lot of straight lines were drawn that did not go through the origin. Many candidates realised that Hubble’s constant is found by determining the gradient but often a mark for the units was lost.

Option G Special and General Relativity

At Higher Level this is always a popular choice, and its popularity at Standard Level is growing. This session it was a popular option at both levels.

QUESTION G1 *The relativistic motion of pions*

Most candidates understood what was meant by an inertial observer but a surprisingly large number of candidates repeated the stem postulate for the other postulate of Special Relativity. Several candidates did not understand that the proper time is the time measured in the pion’s reference frame even though they used this to calculate correctly the average time for decay in the laboratory reference frame.
Some candidates used the contracted length to calculate the distance travelled by the pions and most candidates had difficulty in arguing the problem from the pion’s point of view.

QUESTION G2 *The principle of equivalence*

This was often answered quite well but some candidates thought that gravity and inertia were the same thing even though they correctly argued, at the end of the question, the two different viewpoints of the spacemen.

Option H Optics

This was one of the most popular Options on the paper but unfortunately it was generally not done well.

QUESTION H1 *The astronomical telescope*

For the bi-convex lens, the markscheme asked for a little bit more than just "stars are a long way away"; some explanation was required as to why this would produce parallel rays, such as the wavefronts would be parallel or the star is effectively at infinity. Ray diagrams were usually satisfactory but very few candidates could correctly identify the position of the principal focus. They were clearly not familiar with the situation where parallel rays are inclined at an angle to the principal axis.
Not many candidates could correctly complete the ray diagram for the astronomical telescope or correctly place the position of the two principal foci. However, most candidates knew the correct position of the eye.

QUESTION H2 *The diffraction grating*

Very few candidates could correctly mark the path difference and so were unable to derive the condition $d\sin\theta = n\lambda$. However, a significant number of candidates were able to correctly calculate the first angle of diffraction and also realised that the maximum value of θ is 90^0 in order to calculate the number of principal maxima. Intensity diagrams were invariably poor and often carelessly drawn with the intensity never shown to be zero; the intensity distribution for the double or single slit was often given.

The type of assistance and guidance that teachers should provide for future candidates

In this examination, as in previous years, it was particularly evident that many candidates are able to make reasonable attempts at mathematical calculations but often failed to be able to explain the ideas and the concepts in reasonable detail. It should be stressed again that candidates could be encouraged to practise summarizing Physics explanations by identifying the key or essential elements in a logical and organised manner. Many candidates obviously have had the opportunity to practice working through past IB papers but fewer seemed to have had practice at reviewing their answers in the light of past mark schemes. A particular weakness is in the length of the answers provided and candidates should be encouraged to write succinctly. Extra correct material will never be penalised, but it is a general observation that long answers often end up containing some contradictions or misconceptions and not scoring as highly a shorter and more concise descriptions. Equally important but often forgotten by candidates under the pressure of an examination is that answers should provide something more than just a rearrangement of the information provided in the question.

Suggestions identified by the examining team include:

- Practice at the manipulation and interpretation of unfamiliar data – particularly if presented in graphical form.
- Students could gain confidence and fluency by going through the syllabus in detail to check their understanding – all too often a good paper contains a poorly answered section.
- More practice at descriptive answers. Calculations are often done well as compared with descriptions that tend to be muddled or confused.

As a general rule the following points should be observed.

- It is important that Options are not left until the end of the course. This can lead to their study being rushed and to incomplete syllabus coverage.
- The time available for the study of the Options should be allowed for and carefully integrated into the programme as a whole.
- If candidates study an Option on their own then it is important that their progress is carefully monitored and that adequate support is given.
- In preparing candidates for an examination in physics always ensure that they are given clear and unequivocal definitions of physical quantities.
- Concepts are explained carefully and their logical connections emphasised
- They are tested frequently on their ability to recall and comprehend the material covered in lessons.
- The ability to apply their recently acquired knowledge is tested before moving on to the next topic.
- As each section of the syllabus is completed, they should gain experience in examination technique by answering questions from past papers relevant to the topic just completed.

Higher Level Paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-11	12-23	24-37	38-47	48-58	59-68	69-95

Areas of the program and examination which proved difficult for candidates

As in previous years many candidates found thermodynamic concepts difficult to understand. The question based on the electric generator also proved to be difficult although, in an attempt to assist candidates, expressions were given in the questions paper. However, where the answer is given, this does place more emphasis on candidates to explain their derivations.

The feedback from teachers was generally very positive. Of the replies received, 85% of teachers thought that the paper was of the appropriate level of difficulty and syllabus coverage was thought to be satisfactory. Replies rated the clarity of wording and the presentation of the paper to be satisfactory or good. A clear majority rated the paper to be good in all aspects.

In general candidates appeared to allocate their time appropriately and there was no evidence that candidates were disadvantaged by lack of time. However, candidates should be encouraged to pay attention to the number of marks allocated to each sub-section of a question and to the space available for their response. All too often, for example, a three-mark subsection would be answered in a few words that contained only one relevant piece of information. On the other hand, candidates would write all they knew in a one line answer, spilling out to complete numerous lines of closely-written sentences.

Most candidates made significant digit errors or unit errors and so lost a mark.

The majority of candidates showed the steps in calculations. Explanation is important in thsat it enables candidates to take advantage of "error carried forward" marks where their work is not entirely correct.

Section A was compulsory and there was a choice of questions in Section B.
The vast majority of candidates correctly followed the rubric and answered the required number of questions. However, a few answered more than two questions in Section B and did not indicate on the front of the question paper which questions they wanted to be considered. Under these circumstances, the examiner marks the first two questions answered and ignores any further answers. In Section B, question B2 was not popular.

The levels of knowledge, understanding and skills demonstrated

Some candidates had a very sound knowledge of the content of the syllabus and showed a good level of skill when applying this knowledge. At the other end of the scale, some candidates appeared to have little or no understanding of the concepts addressed by the questions.
Weaker candidates would benefit by writing down relevant equations where they are asked to apply their knowledge.

Candidates should realise that, although *sketch* implies that a simple, freehand drawing is acceptable, care should be taken over proportions and the clear exposition of important details. Far too frequently, important aspects were not apparent as a result of poorly drawn sketches. and thus candidates lost marks unnecessarily.

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

SECTION A

QUESTION A1 *Projectile motion*

(a) Although a minority did not appreciate that the initial velocity would be the horizontal velocity, the majority of candidates did arrive at the correct result.
(b) An understanding as to why the planet's atmosphere had no effect was apparent in very few scripts. Frequently, candidates either gave a qualitative comment about the shape of the curve or they referred to the vertical acceleration (again, without any quantitative justification). What was expected was a reference to the constant separation of the dots in the horizontal direction leading to the idea that there can be no resistive force because the velocity in that direction is constant.
(c) With few exceptions, a reference was made to g being affected by the mass of the planet. Some gave only one reason, but many did give the radius as a second reason although references to an atmosphere were not uncommon.
(d) With few exceptions an arrow was drawn between E and F for the displacement. However, when drawing the components a significant number either failed to mark the directions or drew a vector triangle, rather than give the components.
(e) The majority of candidates arrived at the correct answer for the vertical component of the velocity. Others did not attempt the calculation or tried to use one of the equations of motion.
(f) Although there were many correct responses, it was common to find that the unchanged nature of the vertical motion was not appreciated - the vertical displacement was shown as being halved at each time.

QUESTION A2 *Portable radio power supply*

In common with previous sessions, the electricity question caused difficulty for a disproportionate number of candidates.

(a) It was common to find that the p.d.across R was assumed to be the same as that across the radio.
(b) More able candidates calculated the power dissipation in R and then chose the rating above that. Frequently, no justification was given. Some calculated an incorrect power whilst others did not appear to know how to approach the task.
(c) There were very few correct responses. Most assumed that the resistor would behave as a fuse. That is, if the rating were to be too small, there would be damage caused to the radio, rather than the resistor overheating.
(d) Some answers were based on an attempt to determine the combined resistance of the parallel combination. Consequently, the number of abandoned attempts was high. Very few realised that the ratio of the p.d.'s would be the ratio of the resistances because the current would be the same in both resistors.

QUESTION A3 *X-Ray spectra*

Although this question was attempted by most candidates, marks were low because they appeared not to understand the mechanisms involved.

(a) Very few candidates made reference to the total electron energy being converted into the energy of a single photon. Candidates spent much of the answer space paraphrasing the question or making reference to discrete energy levels in atoms.
(b) Most candidates attempted this part of the question. An equation relating the accelerating potential difference to minimum wavelength was quoted and, in general, the substitutions were appropriate.
(c) In (i), those who did attempt an answer frequently made reference to 'larger atoms'. De-excitation of electrons between energy levels was rarely mentioned. In (ii), most attempts showed the same minimum wavelength. Answers to part (iii) were usually based on 'atomic weight' rather than differences in energy levels between the two elements.

SECTION B

QUESTION B1 Part 1 *Thermodynamics*

(a) Most candidates plotted the point correctly but frequently, a line was not drawn to indicate the process.
(b) In a significant number of scripts, the pressure decrease was attributed to fewer collisions between molecules. Candidates frequently made reference to 'more space' (rather than the more precise 'fewer molecules per unit volume'). Also, many mentioned 'fewer collisions' rather than 'fewer collisions per unit time'.
(c) It was clear that the level of understanding of processes involved in this isothermal change was very varied. In part (i), candidates were equally divided as to whether work is done on or by the gas. In (ii) and (iii), there appeared to be a large element of guesswork as to any internal energy change or direction of thermal energy flow respectively.
(d) Some candidates merely said that work done is related to thermal energy transfer, without being specific or giving any reasoning. For full credit, some reasoning was expected.
(e) As in (a), most candidates did give a correct plot for the point but frequently, the graph was not sketched for this change.
(f) A significant minority made reference to increased vibrations of gas molecules. However, the majority did refer to increased speed with the rise in temperature. The consequence on pressure was usually attributed to 'more collisions', with no reference to 'per unit time'. A reference to the increased magnitude of each impulse on collision with the wall was rarely seen.

(g) As for (c), candidates were divided in their opinions as to whether work is done when the volume does not change and also whether the internal energy of the gas changes.
(h) Many candidates used some form of the equation of state and came to the conclusion that the temperature would double. However, there were numerous situations where the temperature was not converted from degrees Celsius to Kelvin.

Part 2 *Pendulum collision*

(a) In part (i), the majority of candidates made reference to energy conservation and obtained a correct expression for the speed. However, a significant minority did not refer to a particular value for h. In (ii), those candidates who were successful in (i) did, in general, arrive at an answer for the speed after the collision. A number did not substitute the answer to (i) into the derived equation in (ii).
(b) Many candidates quoted conservation of momentum, rather than conservation of energy.
(c) Either candidates realised that the collision is inelastic or that the ascending mass is greater than that descending.

QUESTION B2: Part 1 *Electric Generator*

(a) There was serious doubt as to the nature of the force acting upwards on the rod. In many scripts, the force was attributed to friction.
(b) The failure to identify correctly the forces in (a) meant that many candidates did not appreciate why the rod reaches a terminal speed.
(c) In many answers, Mg and BIL were equated in order to obtain the given equation. However, although candidates were asked to 'show' the result, there was little evidence of any explanation in this derivation.
(d) The majority of candidates were able to give the expression for magnetic flux in (i) and then to derive successfully the expression for the e.m.f. in (ii).
(e) Candidates were expected to substitute two given expressions into the equation $E = IR$. This was achieved in only a minority of scripts.
(f) A disadvantage was given in the majority of scripts although reasoning was not always clear.

Part 2 *Circular waves*

(a) Definitions of a transverse wave were frequently less than satisfactory.. Most answers involved a 'displacement normal to a wave motion'. What was meant by 'wave motion' was not made apparent.
(b) In most scripts, the calculation of the speed was accomplished via the equation $v = f\lambda$, and the substitution was appropriate. In (ii), the explanation was frequently given in terms of energy loss 'due to friction' rather than the spreading out of the energy over a larger area as the wave progresses outwards. In (iii), most candidates did show a sinusoidal wave. However, the wavelength was not always appropriate and frequently, the change in maximum displacement with radius was not indicated.
(c) In (i), the wavefront was usually drawn satisfactorily although the centre of the wavefronts left much to be desired. In (ii), two rays were usually drawn with adequate precision. However, candidates were seldom successful in part (iii). Either they did not attempt that part or the location of the image was faulty. Surprisingly, many showed the image on the back surface of the barrier.

QUESTION B3: Part 1 *Iron bridge*

(a) Without exception, expansion was mentioned. The subsequent effects, if there were no gaps, included buckling, cracking, crumbling and snapping.

(b) In general, the total expansion was calculated correctly and there were some fully correct answers for the gap widths. However, the majority of answers were concluded with the calculation of the expansion produced in a single span of 25 m.
(c) Candidates did not appear to appreciate the concept involved with the potential energy graph. Many could give little more than that, when temperature rises, the 'vibrations are greater' leading to bigger forces of repulsion between the atoms. Some thought that energy would be constant and so, if kinetic energy increases with temperature then potential energy would decrease. Very few mentioned atomic vibrations with the shift in the mean position as the amplitude increases.

Part 2 *Radioactive decay*

(a) With very few exceptions the curves drawn were acceptable.
(b) The estimate of the activity and the determination of the half-life were usually satisfactory, with adequate explanation.
(c) Most sketches were acceptable. However, some did extended the curve without considering the activities at 9 days and 12 days. Consequently, these curves were inappropriate and, in some cases, the curves either levelled out or began to rise.

Part 3 *The Doppler effect*

(a) In part (i), most candidates successfully used the simple wave equation to determine the wavefront separation. In (ii), the frequency was given correctly in most scripts.
(b) (i) Although a sketch was all that was required, some diagrams were so poorly drawn that the relevant features could not be distinguished. A number of candidates merely drew arcs of circles in front of the car. In (ii), the speed was given correctly by most candidates.
(c) It was quite common to find that candidates completed (ii) and then used their result in order to answer (i). This approach was quite acceptable. Where a Doppler formula was quoted in (ii), the form quoted was not always relevant to this situation.

QUESTION B4: Part 1 *Satellite orbits*

(a) Vectors were nearly always drawn in the correct directions and, in most scripts, the lengths were about equal. However, other vectors that may have represented velocity were often included.
(b) Candidates usually stated that the height is small, but then many failed to make any comparison with the radius. Vague statements as to the effect on g were common, and these were made without any direct reference to an equation for g.
(c) Considerable difficulty was apparent as regards the selection and/or manipulation of the equations in order to arrive at the desired result. Consequently this section of the question was done poorly.
(d) As in (c), but even more so, the majority of answers consisted of a number of equations, some incorrect, that could not be linked by the candidates. There were very few clear concise answers.
(e) Surprisingly, many answers did not commence with the equation given in (d). Candidates do appear to have considerable difficulty where the most appropriate means of dealing with the problem is by ratios.

Part 2 *Oscillations*

a) Many definitions were based on 'to-and-fro' motion when what was required was a clear and concise statement. Reference should be made to the force acting on the particle and the relationship with displacement from the mean position.
b) Many candidates drew sinusoidal curves. Of those who did draw a straight line, the majority drew them with the correct gradient.

c) The positions were, in general, marked correctly by those candidates who had drawn a correct graph.
d) Saw-tooth waveforms and various sinusoidal curves were not uncommon. There appeared to be little thought given by many candidates as to the phase of the sinusoidal variation.
e) As in (c), the positions were, in general, marked correctly by those candidates who had drawn an appropriate graph.
f) The calculation of the acceleration was completed successfully by a surprisingly large number of candidates.

Recommendations and guidance for the teaching of future candidates

The above comments on specific questions show the areas of the syllabus examined with which candidates often have difficulty.

In general when preparing candidates for the examination they should be encouraged to:

- learn clear and unequivocal definitions of physical quantities.
- understand the logical connection between concepts.
- be able to recall and comprehend material covered in lessons. (This can be achieved by frequent testing).
- gain experience in examination technique by answering questions from previous examinations.

Furthermore

- candidates should be encouraged to attempt all parts of questions.
- where sketch graphs and diagrams are involved, these should show any important features.
- candidates should be advised that, when giving an answer, there is not need to repeat, or paraphrase, the question. Much time can be wasted in this exercise.
- candidates should realise that the topics examined may be taken from anywhere within the prescribed syllabus of work. Consequently, they should develop a thorough understanding of
- all the work, and not attempt to be selective.
- where mathematical expressions are derived or used, it is important to write down the work in a logical manner, so that links between various stages in the work become apparent.

Higher Level Paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-13	14-19	20-26	27-33	34-40	41-60

General comments

The number of comments received from teachers was limited but greatly appreciated by the examining team. The majority of those that did comment felt that the paper was of a similar standard in comparison to last year's paper but some felt it was a little more difficult. The vast majority felt that the paper was of an appropriate level of difficulty, and rated the clarity of wording and the syllabus coverage either 'satisfactory' or 'good'. All rated the presentation of the paper as satisfactory or good.

The areas of the programme which proved difficult for candidates

As in previous years, there were few attempts at Option D (Medical Physics) and Option E (Historical Physics) although the questions were straightforward. This may suggest that these Options are perceived as difficult to teach or that the questions are not very accessible. In a November session where the number of candidates globally is relatively small, it is difficult to generalise about why certain Options are not tackled.

Other areas of difficulty identified by the examining team include:

- Principles of scaling.
- Definitions of quantities (e.g. magnitude, brightness, inertial observer etc)
- Algebraic manipulation
- Relativistic momentum calculations
- Images at infinity
- Intensity distribution of light formed by a diffraction grating
- Correct application of the lens makers equation
- Rayleigh Criteria

The levels of knowledge, understanding and skill demonstrated

About half of all candidates chose Option H and it is pleasing to note that the general quality of ray diagrams seems to have improved in this session. The astrophysics option (F) was in general well answered. There were some very good answers to G1 (relativistic motion of pions) and G2 (Principle of equivalence).

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

It should be borne in mind that there were a pleasing number of candidates who showed a firm grasp and understanding of the topics addressed by the different option questions. The comments below refer to the main areas of weakness shown by candidates who fail to achieve this level of performance.

D Medical Physics

Option D was not very popular and generally not well done.

QUESTION D1 *Human giant*

Many candidates got off to a poor start in this question by not adequately showing how to calculate the stress in the leg bones even though it seemed that they had some understanding of how to proceed. The majority of candidates, however, calculated a correct value for the stress when running though many lost the mark by omitting the unit. The mathematics of part

(c) defeated many. Typically candidates failed to realise that the volume is proportional to x^3 and the area to x^2. Very few correct answers were seen for the estimate of the maximum height. In fact estimates varied up to 1000 metres with no comments made from the candidate. Very few sensible suggests for the overestimate of the maximum height were forthcoming. A common comment referred to the amount of food that had to be eaten.

QUESTION D2 *Forces and the arm*

Forces representing the weight of the ball and the tension of the biceps were usually correctly shown by candidates. However, most candidates failed to include the reaction force at the elbow. Partial credit was very rarely awarded for the calculation with answers being either completely correct, confused or blank.

QUESTION D3 H*earing loss*

The general impression was that many candidates were unfamiliar with the terms *air conduction* and *conductive hearing loss*. There were some good and well set-out calculations of the sound intensity but there were others that indicated a lack of an appreciation of the formula for hearing loss.

QUESTION D4 *X-rays*
Some candidates confused mechanisms with processes and stated absorption as a cause of X-ray attenuation. Although many candidates answering this question recognised that □ is the slope of the graph, a large number of them omitted its unit. Manipulation of logarithms proved difficult and very few candidates recognised the safety issue involved in reducing the beam intensity.

E Historical Physics

This option had limited popularity. Those that did undertake it generally showed a hazy understanding of caloric theory and its application. Few scored high marks on models of the Universe, as there was a tendency to write an explanation of the Aristotelian or a description of the Copernican model instead of an explanation of the particular observation addressed by the question. There were some very confused ideas about entropy and disorder and about the Maxwell demon thought experiment.
Candidates either knew about the fundamental interactions and their exchange particle or they guessed showing clearly that they did not understand the term *interaction*.

F Astrophysics

QUESTION F1 *Apparent Magnitude, apparent brightness and luminosity of two stars.*

Only a very few candidates could explain the difference between apparent magnitude and apparent brightness. There was a lot of confusion here. Some candidates thought that the definitions had to do with the size of a star whereas others tried to relate brightness to the power radiated per unit surface area of the star. Most candidates correctly identified Aldebaran as appearing to be the brightest star and the star with the greatest luminosity. However the reasoning given for their choice was often suspect. A substantial number of candidates failed to correctly label the vertical axis on the Hertzsprung-Russell diagram but the majority were able to identify the respective regions where Aldebaran and Procyon could be found. The calculation of the ratio of brightnesses was often done not as a ratio but as two distinct calculations, typically with much confusion of units.

QUESTION F2 *Galaxies*

Whereas a significant number of candidates demonstrated a good knowledge of the Doppler effect and the significance of the red shift, there were others who clearly did not understand these concepts. A lot of straight lines were drawn that did not go through the origin. Many candidates realised that Hubble's constant is found by determining the gradient but often a mark for the units was lost. Many candidates tried to calculate the recession velocity from the full Doppler equation rather than the approximation.

QUESTION F3 *Stellar evolution*

Some candidates showed an excellent understanding of the processes and objects involved in the evolution of massive stars. However, quite a few candidates muddled up the chronological development but most did get the final fate of the star correct.

G Special and General Relativity

At Higher Level this is always a popular choice and there were some good answers.

QUESTION G1 *The relativistic motion of pions*

Most candidates understood what was meant by an inertial observer but a surprisingly large number of candidates repeated the stem postulate for the other postulate of Special Relativity. Several candidates did not understand that the proper time is the time measured in the pion's reference frame even though they used this to calculate correctly the average time for decay in the laboratory reference frame.
Some candidates used the contracted length to calculate the distance travelled by the pions and most candidates had difficulty in arguing the problem from the pion's point of view.

QUESTION G2 *The principle of equivalence*

This was often answered quite well but some candidates thought that gravity and inertia were the same thing even though they correctly argued, at the end of the question, the two different viewpoints of the spacemen.

QUESTION G3 *The energy and momentum of colliding protons*

Many candidates found this question difficult. Most were able to show that the minimum energy of each proton was 1860 MeV but only a very few appreciated that this is based on the assumption that the kinetic energy of the particles after collision can be ignored.
Not many candidates were able to correctly calculate the accelerating potential and whereas, several knew the correct approach to finding the momentum, they invariably struggled with the units.
Very few of the candidates realised that if a beam of protons collides with stationary protons, then to conserve momentum, the stationary protons must recoil and so are given kinetic energy by the collision.

H Optics

This was one of the most popular Options on the paper but unfortunately it was generally not done well.

QUESTION H1 *The astronomical telescope*

For the bi-convex lens, the markscheme asked for a little bit more than just “stars are a long way away”; some explanation was required as to why this would produce parallel rays, such as the wavefronts would be parallel or the star is effectively at infinity. Rays diagrams were usually satisfactory but very few candidates could correctly identify the position of the principal focus. They were clearly not familiar with the situation where parallel rays are inclined at an angle to the principal axis.
Not many candidates could correctly complete the ray diagram for the astronomical telescope or correctly place the position of the two principal foci. However, most candidates knew the correct position of the eye.

QUESTION H2 *The diffraction grating*

Very few candidates could correctly mark the path difference and so were unable to derive the condition $d \sin\theta = n\lambda$. However, a significant number of candidates were able to correctly calculate the first angle of diffraction and also realised that the maximum value of θ is 90^0 in order to calculate the number of principal maxima. Intensity diagrams were invariably poor and often carelessly drawn with the intensity never shown to be zero;the intensity distribution for the double or single slit was often given.

QUESTION H3 *Short-sightedness and its correction*

Some candidates confused long and short-sightedness and did not seem to be familiar with the real is positive sign convention. The arithmetic in the problem defeated a lot of candidates.

QUESTION H4 *Optical resolution*

This was rarely well answered. A few candidates understood the topic well but the rest either left the question unanswered or resorted to guesswork, particularly in the problem where the diffraction equation from question H2 was often used.

The type of assistance and guidance that teachers should provide for future candidates

In this examination, as in previous years, it was particularly evident that many candidates are able to make reasonable attempts at mathematical calculations but often failed to be able to explain the ideas and the concepts in reasonable detail. It should be stressed again that candidates could be encouraged to practise summarizing Physics explanations by identifying the key or essential elements in a logical and organised manner. Many candidates obviously have had the opportunity to practice working through past IB papers but fewer seemed to have had practice at reviewing their answers in the light of past mark schemes. A particular weakness is in the length of the answers provided and candidates should be encouraged to be able to write succinctly. Extra correct material will never be penalised, but it is a general observation that long answers often end up containing some contradictions or misconceptions and not scoring as highly a shorter and more concise descriptions. Equally important but often forgotten by candidates under the pressure of an examination is that answers should provide something more than just a rearrangement of the information provided in the question.

Suggestions identified by the examining team include:

- Practice at the manipulation and interpretation of unfamiliar data – particularly if presented in graphical form.
- Students could gain confidence and fluency by going through the syllabus in detail to check their understanding – all too often a good paper contains a poorly answered section.
- More practice at descriptive answers. Calculations are often done well as compared with descriptions that tend to be muddled or confused.

As a general rule the following points should be observed.

- It is important that Options are not left until the end of the course. This can lead to their study being rushed and to incomplete syllabus coverage.
- The time available for the study of the Options should be allowed for and carefully integrated into the programme as a whole.
- If candidates study an Option on their own then it is important that their progress is carefully monitored and that adequate support is given.

In preparing candidates for an examination in physics always ensure that:

- they are given clear and unequivocal definitions of physical quantities.
- concepts are explained carefully and their logical connections emphasised
- they are tested frequently on their ability to recall and comprehend the material covered in lessons
- the ability to apply their recently acquired knowledge is tested before moving on to the next topic
- as each section of the syllabus is completed, they should gain experience in examination technique by answering questions from past papers relevant to the topic just completed.

Internal Assessment

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-4	5-7	8-10	11-13	14-15	16-18	19-24

General Comments

This year proved to be a most satisfying year in moderation. The majority of schools followed the paperwork correctly, and they clearly indicated the sample work that was to be moderated. Many schools are teaching rich and diverse courses in physics with good practical programs.

However, there were a number of mistakes because instructions were not carefully followed. Some schools sent in the entire portfolio of the students work, other schools forget to include the written or spoken instructions given to the students, and some schools forgot to include evidence of a Group 4 Project. There were also a number of schools not covering the major syllabus topics in their practical program, and other schools not meeting the minimum time requirement, and some schools providing a weak or limit practical program. The variety of work covered the entire spectrum from mediocre to excellent.

The Range and suitability of work submitted

Many schools are assigning and assessing very good physics practical work. I was impressed overall by the physics that is being taught. Some schools offer a limited range of experiments, often missing out one or both options, or an entire topic. Mechanics is often overemphasized at the cost of leaving out other topics. There are a few schools that still follow 'fill in the blank' worksheets. And there were a few schools that had only traditional labs with detailed instructions, leaving nothing for the student to contribute to the design or method of the investigation.

Candidate performance against each criterion

Planning (a): Once again, this is still the most trouble for many schools. The good news is that more schools than previous years are giving students good planning topics. Often research questions were assigned to the student, and hence one aspect was moderated down to "not-at-all". The open-ended nature of this criterion needs to be emphasized to both teachers and students. Defining a hypothesis and explaining it are often very difficult for students. Finally, teacher's instructions must be given in order to properly moderate this criterion. Many schools were moderated down because of their failure to properly provide students with satisfactory planning topics.

Planning (b): This was reasonably done in many cases. There are still schools giving out standard equipment, setting up standard methods, etc. and so these samples were moderated down. The success of planning (b) often depends on the topic assigned under planning (a). Students should be encouraged to sketch diagrams of the equipment and set-up. Both Pl(a) and Pl(b) should evoke different responses from different students within the same class.

Data Collection: This is often well done, with the exception of appreciating uncertainties. Very few students acknowledge errors or report estimated uncertainties in their raw data. Teachers often award full achievement levels here and these cases were moderated down. Many schools are not teaching this topic, and many schools don't emphasis the correct use of significant figures. Data should be presented in a neat table with a mention of units and uncertainties.

Data Processing and Presentation: This criterion is often done well. Teachers must be careful when assessing this, however, and not tell the students to draw, for instance, a graph of distance against the square of time. The student must decide how to process their data. Only in a few cases were uncertainties indicated in graphs. Some students still connect the dots in their graphs. Many students are using computer software to process their results and, although this is acceptable, students must have control of the situation. Lack of appreciation for significant figures often appears here, as well as automatic line equations that are not relevant, or automatic uncertainty bars that are not justified, or automatic dot to dot line connection.

Conclusion and Evaluation: This could be one of the easiest areas to earn full points, but more often than not students do not seem to follow the aspects of the evaluation criteria. With just a little guidance here students could greatly improve their work. Often minor points are made, while overall relevance (the scope and limit of the investigation) is not addressed.

Recommendations for the teaching of future candidates

- Teachers and students should always have a copy of the IA criteria. Teachers need to keep these in mind when assigning and assessing investigations. Teacher must choose appropriate experiments to assess correctly the respective criteria.
- Be sure to include the instructions given to the students for each experiment including a summary of any verbal instructions.
- Errors and uncertainties need to be taught and emphasized. All raw data collection should include an estimate of uncertainty. There are no absolute measurements.
- Do not send in the student’s entire portfolio of work. Be sure to clearly indicate the work to be moderated on the 4/PSOW form and clearly mark the sample lab work for what criteria and achievement level it was assessed at.

If two or more teachers are involved in the assessment of IA, then it is imperative that the work is moderated internally before any samples are sent to the moderators.

