November 2012 subject reports

PHYSICS

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 15	16 - 29	30 - 41	42 - 51	52 - 61	62 - 71	72 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 13	14 - 25	26 - 36	37 - 45	46 - 55	56 - 65	66 - 100

Higher and standard level internal assessment

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 8	9 - 16	17 - 22	23 - 27	28 - 33	34 - 38	39 - 48

General comments

The IA Moderation is well established. Centres know the required paperwork and they more often than not perform established IA investigations. There were no significant problems this session. There were a variety of 4/PSOW forms but they all included the required information and were completed correctly. The majority of candidate reports were word-processed and graphs were drawn on graphing programs. There was some use of ICT, including one investigation that used FFT analysis to determine the rotation rate of an electric motor.

The range and suitability of the work submitted

Most centres had a comprehensive practical program and teachers are assessing appropriate work. Although mechanics has traditionally been the main focus of practical work, there is a range of hand-on activity in all major physics topic areas. The difficulty of investigations is consistently at the high centre level. Indeed, this exam session the quality of IA work was exceptional.

Candidate performance against each criterion

Design (D)

The vast majority of centres used appropriate and well-established design prompts. In a few cases, however, the prompts were not appropriate, such as asking a candidate to design an investigation to measure the specific heat capacity of water, or when the teacher provided both independent and dependent variables. Good design prompts are ones that have candidates looking for a function between two variables, not a specific value. Candidates need to be reminded that for a complete under design that variables need to be defined (and a vague statement like "I will measure the time" needs to be clarified as to just how this will be done). Operational definitions help in the design of a method as well. This comes under the ability to control variables. No hypothesis is needed under design, and the better design investigations are one where the candidate does not know the theory or relevant equation. Design is not a research or textbook based activity.

Data Collection and Presentation (DCP)

Candidates earned the highest marks under the DCP criterion. The vast majority of candidates are making good use of ICT, and word processing their reports and using graphing software. This is to be encouraged. Raw data always has uncertainty. Moderators are looking for a brief statement to why the candidate gives a particular value of uncertainty, and this holds for both raw and processed data. When assessing DCP, candidates are expected to have produced graphs. There were some cases where graphs would have been relevant but candidates just made calculations. These cases cannot earn complete for DCP aspect 3. Teachers need to be aware of this expectation. Also, it is important that the candidate (and not the teacher) decides what quantities to graph and how to process the data.

Conclusion and Evaluation (CE)

Under CE aspect 1, candidates need to think beyond the given data in order to provide a justification based on a reasonable interpretation of the data. Such insight might look at the extremes of the data range, the origin of the graph, the y-intercept, for some physical meaning. Candidates might even give the overall relationship some physical interpretation (perhaps a hypothesis). Teachers need to look for this when awarding a complete for aspect 1, as many times moderators adjusted a 'complete' to a 'partial'. If candidates perform a standard and well-established physics lab, and CE is assessed, then it is unlikely that they can really come up with weakness or improvements. CE is best assessed when candidates also have designed and performed the investigation themselves. Many candidates construct two parallel columns corresponding to CE aspects 2 and 3. This helps the candidate make their ideas clear.

Recommendations for the teaching of future candidates

- Many centres are allowing candidates only two opportunities to earn their best marks. It is recommended that after candidates become familiar with the expectations of IA, that they have a number of opportunities to be assessed, perhaps 3 or 4 from which the highest two of each criterion are used for their IA mark.

- Because the IA mark is part of the candidates overall IB grade, it is important that candidates work on their own. They must collect their own data, decide on how to process it and write the report on their own. Group work is not allowed.

- Although many centres correctly appreciate errors and uncertainties, this remains one of the weaker areas for some other centres. Teachers need to address the appropriate treatment of uncertainties in lab work.

Further comments

This was a smooth running and successful examination session. There was little need for major moderation.

The one key point is that teachers must assign appropriate tasks when assessing IA. Only a few centres failed to appreciate this.

Teachers are reminded a design investigation is not meant to be a research project, and that under design no hypothesis is expected.

Higher and standard level paper one

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 16	17 - 23	24 - 27	28 - 30	31 - 34	35 - 40

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 11	12 - 16	17 - 18	19 - 20	21 - 22	23 - 30

General comments

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

Only a small percentage of the total number of teachers or the total number of centres taking the examination returned G2's. For SL there were 30 responses from 151 centres and for HL there were 27 responses from 212 centres. With such a low percentage response rate it can only be inferred that the majority of centres were satisfied with the two papers this year. Of those commenting, it was clear that the November 2012 papers were generally well received, with many of the G2's containing favourable comments. The majority of the teachers who commented on the papers felt that they contained questions of an appropriate level; nearly all felt that the HL paper was in line with that of last year but there was a slight feeling that the SL was a little easier. One teacher found the HL paper to be considerably easier than previous papers.

All responses indicated that the presentation of the papers and the clarity of the wording were either satisfactory or good.

Statistical analysis

The overall performance of candidates and the performance on individual questions are illustrated in the statistical analysis of responses shown below. 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 a grey cell. 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 easier question. The *discrimination index* is a measure of how well the question discriminated between the candidates of different abilities. In general, a higher discrimination index indicates that a greater proportion of the more able candidates correctly identified the key compared with the weaker candidates. This may not, however, be the case where the difficulty index is either high or low.

HL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	13	1009	19	10	1	95.91	0.1
2	36	148	54	812	2	77.19	0.51
3	291	18	13	727	3	69.11	0.47
4	367	26	514	144	1	34.89	0.49
5	306	36	89	620	1	58.94	0.69
6	66	41	828	116	1	78.71	0.43
7	606	327	82	33	4	57.6	0.51
8	899	24	108	21		85.46	0.24
9	117	474	409	41	11	45.06	0.62
10	99	32	48	871	2	82.79	0.3
11	98	105	210	636	3	60.46	0.57
12	84	871	52	45		82.79	0.35
13	739	112	120	79	2	70.25	0.6
14	54	102	410	485	1	46.1	0.72
15	61	262	609	117	3	57.89	0.71
16	50	662	178	160	2	62.93	0.6
17	129	44	200	677	2	64.35	0.64
18	201	246	537	64	4	23.38	-0.07
19	91	55	163	740	3	70.34	0.58
20	43	87	91	829	2	78.8	0.42
21	588	16	415	32	1	55.89	0.22
22	765	158	91	37	1	72.72	0.44
23	75	48	232	696	1	66.16	0.62
24	96	33	859	63	1	81.65	0.36
25	37	798	70	143	4	75.86	0.53
26	71	588	230	158	5	55.89	0.58
27	903	18	66	62	3	85.84	0.25
28	941	76	7	27	1	89.45	0.28
29	117	721	207	5	2	68.54	0.53
30	428	41	72	503	8	40.68	0.53
31	76	123	763	85	5	72.53	0.52
32	16	824	180	23	9	78.33	0.41
33	47	92	814	95	4	77.38	0.51
34	686	211	34	112	9	65.21	0.65
35	209	145	578	111	9	54.94	0.35
36	189	458	101	299	5	43.54	0.45

37	695	168	96	86	7	66.06	0.58
38	40	61	910	36	5	86.5	0.29
39	113	35	819	81	4	77.85	0.4
40	21	954	21	48	8	90.68	0.17

Number of candidates 1052

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty index	Discrimination index
1	32	843	30	27	4	90.06	0.23
2	223	153	519	39	2	23.82	0.2
3	89	310	68	468	1	50	0.63
4	62	35	768	69	2	82.05	0.36
5	165	58	448	265		17.63	0.21
6	425	78	132	298	3	31.84	0.55
7	65	297	530	41	3	56.62	0.42
8	373	18	13	526	6	56.2	0.4
9	78	200	258	398	2	42.52	0.48
10	590	202	46	97	1	63.03	0.43
11	135	666	38	96	1	71.15	0.51
12	41	68	188	636	3	67.95	0.27
13	23	34	851	28		90.92	0.19
14	694	56	109	75	2	74.15	0.44
15	497	178	119	140	2	53.1	0.63
16	99	49	755	30	3	80.66	0.36
17	114	396	269	152	5	28.74	0.44
18	65	397	181	292	1	42.41	0.43
19	51	132	112	639	2	68.27	0.48
20	67	430	145	289	5	45.94	0.27
21	161	99	246	424	6	45.3	0.66
22	84	20	810	20	2	86.54	0.24
23	666	172	20	75	3	71.15	0.64
24	101	83	95	649	8	69.34	0.47
25	142	96	670	24	4	71.58	0.26
26	61	614	85	168	8	65.6	0.63
27	258	83	533	56	6	56.94	0.48
28	715	34	97	86	4	76.39	0.34
29	545	197	143	48	3	58.23	0.51
30	127	37	650	119	3	69.44	0.41

Number of candidates 936

Comments on the analysis

Difficulty

The difficulty index varies from about 23% in HL and 18% in SL (relatively ‘difficult’ questions) to about 96% in HL and 91% in SL (relatively ‘easy’ questions). The majority of items were in the range 45% to 75%. These statistics indicate that the candidates found these papers in line with the November 2011 papers. The papers gave an adequate spread of marks while allowing all candidates to gain credit.

Discrimination

All questions with the exception of HL Q18 had a positive value for the discrimination index. Ideally, the index should be greater than about 0.2. This was achieved in all but three questions at HL and all questions at SL. 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 (it will be seen in the statistics that the easier questions often have a lower discrimination index).

‘Blank’ response

In both papers, the number of blank responses was randomly distributed throughout the test, indicating that there was no timing problem with either question 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. In general, candidates should be able to eliminate some of the ‘distracters’, thus reducing the element of guesswork.

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. Feedback will be given only on selected questions, i.e. those that illustrate a particular issue or drew comment on the G2’s.

SL and HL common questions

SL Question 3 and HL Question 2

Response B proved to be a popular distracter, particularly at SL, with candidates failing to spot that squaring the time doubles its uncertainty.

SL Question 5 and HL Question 4

Response C was the most popular one at both levels. The magnitude of the gradient is the acceleration due to gravity, which of course is constant close to the Earth’s surface.

SL Question 6 and HL Question 5

At SL more candidates thought that there was zero change in momentum (Response A) than the correct 2*mv* (Response D). This was a popular choice at HL too but the majority recognised this standard piece of bookwork.

SL Question 8 and HL Question 3

Most candidates recognised that 19 N could not be achieved with these three forces but a sizeable proportion at both levels believed that they could not be added to total zero.

SL Question 14 and HL Question 8

A minority of candidates at both levels opted for response C believing that internal energy is only the kinetic energy of any substance; this is only true for ideal gases.

SL Question 17 and HL Question 15

Candidates needed to recognise that the path difference needs to be equal to an odd number of half-wavelengths for destructive interference to happen. With a path difference of 0.60 m this is true only for wavelength of 0.40 m giving a half-wavelength of 0.20 m and thus three half-wavelengths occurring.

SL Question 21 and HL Question 19

The GeV prefix was apparently unknown by a significant number of candidates at both levels.

SL Question 29 and HL Question 22

Response B with many particles being significantly deflected was a common choice of candidates at both levels; A shows the clear majority of particles passing through the foil undeflected.

HL Questions

Question 7

Response B was popular here despite D not being so. This would mean that the accelerating force would be the same on the skier and the boat despite significant difference in mass and both moving together.

Question 9

With energy being supplied at a constant rate, the time for each of the processes was proportional to the energy supplied. Thus for the melting the time was 300 s and for the heating the liquid was 400 s. With a temperature rise of 40 K and the same mass the ratios are (300 x 40)/400 = 30 K.

Question 11

There were two aspect to this – adiabatic means no thermal energy transfer (ruling out A and B); expansion means work done on the surroundings and loss of internal energy to do the work. D is the only response matching this.

Question 14

Not enough candidates recognized that intensity depends upon the square of the amplitude. Option C was nearly as popular as the key D.

Question 16

Candidates often find this to be difficult. In a standing wave each particle has its own amplitude with that at the nodes being zero and that at the antinodes being a maximum. For a progressive wave all particles follow on from their neighbours and have the same amplitude.

Question 18

Candidates found this question to be the most challenging on the paper. At the Brewster angle the reflected light is plane polarized but that does not mean that the transmitted (refracted) light is plane polarized. There will still be some light in the same plane of vibration as the reflected light but there will now be less of it. The transmitted light is therefore partially plane polarized.

Question 21

Too many candidates really don't understand the concept of resistance. It is simply the ratio of the voltage to the current and not the gradient of a *V-I* graph as many candidates believed.

Question 26

Given the prominence of units in the course, fewer candidates should have chosen wrong options. The only unit needed to be converted to base units was the joule (N m = $kg\,m^2\,s^{-2}$). In this case m^2 cancels with m^{-2} leaving $kg\,s^{-2}\,K^{-1}$.

Question 30

This is an application of Lenz's law that needs to be fully understood. The conventional current implies a south pole at the left end of the coil and so must oppose the motion of the magnet. The magnet must either be moving away from the coil or the coil must be moving away from the magnet.

Question 34

Photons are emitted so the wavelength of the light is shorter than the threshold wavelength. Doubling the wavelength might make it greater than the threshold and so this is the only option which may result in no electrons being emitted – the intensity of light (that is, the number of photons per second) has no influence on this.

Question 36

The continuous spectrum for beta emission is the key here. A continuous spectrum is not characteristic of discrete energy levels (but alpha and gamma occur with distinct energies and therefore must be related to nuclear energy levels).

SL Questions

Question 2

Option C was more popular than the correct response A. Candidates failed to recognize that the spread shown indicated that there were random errors in addition to the clear systematic error.

Question 7

A clear majority of candidates recognized that both a sine and a cosine would be involved but a high proportion was unable to correctly perform the resolution.

Question 9

B and C proved to be effective distracters here. The ball would be at rest at the highest point after the bounce and with the bounce occurring at ABC (which would be a very steep negative slope on a larger scale). The correct response can only be D.

Question 10

Looking at the units helps here: with force in N and velocity in m s^{-1} the product will be in N m s^{-1} or J s^{-1} that is, W; so the correct response must be power.

Question 18

The series resistor gives combined resistance of 2*R.* This is in parallel with *R* means that the total must be smaller than either so must be less than *R* (thus ruling out C and D). Using the parallel formula gives $\frac{1}{R_t} = \frac{1}{2R} + \frac{1}{R} = \frac{3}{2R}$ o $R_t = \frac{2}{3}R$.

Question 20

Many candidates opted for D, failing to see that the wire is a resistance wire and will drop voltage along its length.

Question 27

This was a slightly unusual question in that the inverse square law is usually used by starting close to an object and then moving away; here it was used in reverse. Nevertheless, one distance was four times further than the other and so the intensity ratio would be 1:16 with it therefore being 16 times greater for the planet closer to the star.

Recommendations and guidance for the teaching of future candidates

- Candidates should make an attempt at 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 emphasized that an incorrect response does not give rise to a mark deduction.

- When preparing the candidates for Paper One it can be a good strategy to encourage candidates to practise papers by treating them as open ended questions and thus writing explanations of why distracters are incorrect or else performing calculations in detail to explain why a key is the correct response.

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

- Candidates should be aware of the content of the Physics Guide where much information regarding what is expected in definitions can be found.

- The proportion of questions covering a particular topic is generally in line with the proportion of time allocated for teaching that topic, as specified in the Guide. It is injudicious to rush the study of any particular topic since there are likely to be non-trivial questions on that topic include in the question papers.

Higher and standard level paper two

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 21	22 - 31	32 - 41	42 - 50	51 - 60	61 - 95

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 4	5 - 8	9 - 12	13 - 17	18 - 22	23 - 27	28 - 50

G2 forms were received from 35 SL teachers and from 32 HL teachers. This small number from the examination as a whole indicated that about 70% thought the level of difficulty of the paper was appropriate. About 25% felt that it was too difficult. These statistics were almost identical at both levels.

This was reinforced by the comparison with last year's papers in which 32% at HL (40% at SL) found the paper a little more difficult, and 20% at HL (17% at SL) found it much more difficult. The clarity of wording was regarded as satisfactory or good by all but 3 centres at HL (2 at SL) and the presentation of the paper was regarded as satisfactory or good by all respondents.

In the specific comments, some correspondents referred (as in past sessions) to the frequency with which Topic 8 questions appear, whereas others complained that the greenhouse effect was not represented at HL. Teachers should realise that Topic 8 has many teaching hours devoted to it and this has to be represented in the structure of the examinations. Equally, there have been a number of questions about the specifics of the greenhouse effect over past sessions and it is unrealistic to expect paper writers to focus on this topic in every test.

General comments

Many examiners commented on the very poor standard for the quotation of units. This was observed at all levels in the examination. Candidates going on to study or work in the sciences or engineering will find that their inability to develop these skills at this secondary level will not serve them well in tertiary education or training.

Candidates are also becoming more casual in their use of powers of ten in calculations. Calculations carried out on a calculator are best checked if time is available.

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

The examining team identified the following areas:

- Distinguishing between force and momentum
- Diffraction effects in white light
- Explanations of magnetic effects
- Complete explanations of transformer action
- Calculations and deductions involving wavefront refraction

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

It was pleasing to see the following skills demonstrated:

- Electrical theory and calculations
- Ideal gas theory and entropy
- Basic photoelectric theory and calculation
- Thermal energy transfer calculations

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

Section A

A1 [HL and SL] Data analysis question

a) **[SL (a)(ii)]** Lines of best-fit through the data points were divided between curves (albeit at times poorly drawn) and straight lines that could not be made to fit the criteria of being close to data points and through the error bars. Candidates made the error of assuming that the word “line” in the question always means “straight line”.

a) (i) **[SL only]** The error bars were usually drawn to an appropriate length.

b) The explanation of whether the data support the hypothesis was well answered by a large majority of candidates irrespective of their success or otherwise in the previous part question.

c) Uncertainty calculations were on the whole well done, but some failed to take account of the factor of 3 in the calculation. Some also failed to calculate the final uncertainty, leaving the answer as a percentage or fractional value.

d) (i) This part was much more mixed with poor work. Candidates were required to use the gradient in their determination. The gradient needed to be taken from a large triangle based on the printed grid. As the graph had a false origin, candidates who worked from a single data point could not receive credit.

(ii) About one-quarter of the candidates were able to provide an appropriate unit.

A2 [HL] and B1 Part 1 [SL] Momentum change

This question proved difficult for many. Candidates at all levels and in both papers were able to progress with (b) but found matters more difficult in (c), which featured physics that had not been tested for some time.

a) Many statements of the law of conservation of momentum were unsatisfactory. The bald statement "*momentum is conserved*" does not gain credit unless it is supported in some way. As is often the case, many candidates forget to qualify the law by referring correctly to the required absence of a net external force.

b) (i) Although there were many correct answers that gained full credit, the level of explanation was low with many solutions that consisted of a line of numbers with an answer.

(ii) Again, except for the weakest candidates, many had recourse to an equation from the Data booklet and gained full credit although it was not always obvious that they were calculating a rate of change from their working. Candidates were given the benefit of the doubt here.

(iii) There are two aspects to the total vertical force that the gravel exerts: the total weight of the gravel that has arrived in 5.0 s and the force due to the arriving gravel. Most candidates neglected the second component with only the very best candidates gaining all three marks. It was much more common to the see a correct value for the weight of the gravel that had already landed.

c) The question now moved to a consideration of the horizontal motion of the conveyor.

(i) Again, this was straightforward and the mark was gained by many who simply used the data booklet equation to gain the kinetic energy value.

(ii) This part was not so well done. It was a rare candidate who was able to see that the power is related to the *force* × *speed* (another data booklet equation) and to apply this correctly. Correct answers were rare.

(iii) Only a simple explanation was required, but the stock answers of "*friction*" or "*air resistance*" were not enough. Examiners required a recognition that half of the energy goes into acceleration of the gravel up to its final speed or into increasing the internal energy of the gravel.

A3 [HL only] Diffraction and interference

a) A relatively straightforward question (that has been set a number of times before) was only moderately well answered. Loss of marks was incurred by using factors of 1.22 or by quoting the double-slit interference equation from the data booklet. This was a single slit case as the diagram clearly indicated.

b) (i) Although there were very many good statements of the Rayleigh criterion for resolution, some candidates omit to tell the examiner that the criterion refers to a diffraction pattern. Some candidates also misunderstand the question "State what is meant by...". This formulation requires a statement of the criterion not a general statement that "the criterion is about resolution".

(ii) The structure of the question should have given the clue that this part was a numerical test of the candidate's ability to use the Rayleigh criterion. It was not a test of double-slit interference and there were many confused accounts of the calculation here.

c) A number of possible responses were accepted here, but the majority of the candidates could generally only refer to the appearance of coloured edges to the subsidiary maxima.

A4 [HL] and B3 Pt 1 [SL] Electrical lighting system

This question was well done by very many candidates with good marks scored throughout the range of abilities.

a) Although the vast majority recognise the basis of Ohm's law, some lost the mark through forgetting that the law only applies when the temperature (or the physical conditions) remain unchanged.

b) (i) This was well done; almost all candidates were able to arrive at the required integer number of lamps (and rounded down rather than up!).

(iii) **[HL]** Again, calculations here were pleasingly done and in many cases well set out. Examiners were pleased to see that candidates are so clearly at ease with extended calculations such as this.

[SL] Although most candidates understood that the resistance of the LDR increased in darkness, few were able to interpret the consequences of this in terms of the potential divider.

A5 [HL] and A2 [SL] Magnetic fields

a) **[SL only]** Few candidates recognised that a magnetic field arises *when charge moves*.

a) **[(b) SL]** The diagrams of the magnetic field around a long straight conductor were well drawn (if mostly in freehand). The intention of the candidates was clear. About half of the candidates indicated with their diagram that the field strength decreases with distance from the conductor (even though this was not a marking point on this occasion).

b) (i) **[(c)(i) SL]** This part question revealed many misconceptions by the candidates about the underlying basis of magnetic force. Explanations on the correct basis were usually poor and failed to state the essentials of the physics: (1) the field of one turn extends to (and beyond) the position of the next turn, (2) a direction rule indicates the direction of the magnetic force on the wire turn. However, it was clear that many simply do not understand the origin of magnetism. Too often examiners saw descriptions that were essentially statements that the positive charges in one wire attract the electrons in the other wire.

(ii) **[(c)(ii) SL]** About half of the candidates were able to carry through the straightforward calculation as a balance between the weight of the wire and the magnetic force from BIl.

Section B

B1 HL

B1 Part 1 Gas processes

This part was well done by very many. Explanations and calculations were usually clear and there was a pleasing response to the entropy explanation.

a) Very many candidates were able to calculate the number of moles correctly. The handful of errors normally involved powers of ten.

b) (i) Many recognised that a calculation was required to show that the change was not isothermal. The test could be carried out in a number of ways; all were seen and many were well explained.

(ii) The speed of the compression was recognised as the rationale for the adiabatic nature of the change and the inability of the system to transfer internal energy in the time was seen as the underlying physical reason.

(iii) The only failure here was that candidates commonly failed to state clearly what their symbols meant and simply launched into a solution in which the examiner had to make some deductions about the signs and meanings of some of the quantities. Candidates should make their solutions crystal clear to the examiners.

(iv) Around half of the candidates could not see how their answer to (iii) (with an error carried forward where appropriate) could be taken forward (in a simple way) to determine the change in kinetic energy of a single air molecule. They had forgotten that they had previous answers to (a) and (b)(iii).

c) This difficult part was well done. There was a common recognition that entropy is associated with disorder and that compresses the gas and reduces the disorder. Many could then go on to use the concept of increasing disorder to deduce the effect on the surroundings.

B1 Part 2 Projectile Motion

a) (i) Many calculated the area under the graph (by assuming that the rocket reached a final vertical speed of 35 ms^{-1}). Fewer realised that the rocket did not quite reach the final speed and therefore did not quite reach the final height. This lost a mark.

(ii) This was an extended calculation in which candidates needed to calculate (1) the final vertical speed of the rocket after falling 170 m, (2) the vector sum of the horizontal and vertical speed components to find the velocity, and (3) the impact angle at which the rocket strikes the surface. Most candidates omitted the third step.

b) This was a calculation derived from Topic 6 in which candidates needed to recognise that the value of *g* at the orbit is significantly reduced from the value at the surface. So a simple use of *mg* was not appropriate. This error was incurred by many.

B2 HL

B2 Nuclear power and the transmission of the electrical energy generated by it

a) About half of candidates were able to state two separate safety problems. The remainder were usually able to find one (or to quote two separate statements that were too similar to be given two marks).

b) Enrichment is a Topic 8 area of study. It was common to see candidates recognising that uranium-235 is required for the fission in the reactor and that it is rare in the mined ore. It was less common to see a third point (a number are available including the problem of absorption of neutrons by uranium-238).

c) (i) **[HL only]** It was disappointing to see that these easy three marks were not accessed by many candidates. Scores of 1 and 2 (even 0) were quite common.

A3 (a**) [SL only]** Candidates were given the beta particle symbol and asked to deduce the remainder. This was well done.

(ii) **[HL only]** This calculation was well done. Candidates are clearly well practised in carrying through these challenging exponential calculations.

A3 (b) **[SL only]** Most candidates recognised that four half-lives had occurred but it was common to then equate this to 1/16 rather than 15/16.

A3 (c) **[SL only]** Candidates usually scored one out of the two marks available. Answers were not incisive and dealt in vague generalities about the effects of radiation.

d) Candidates did not get to the heart of this question and often simply repeated that the neutrons are absorbed by the waste products (stated in the question). The simple mathematics that reducing the number of uranium atoms reduces the rate of fission and hence the production of energy was lost on many. Similarly, few deduced the impact of the generation of two or more waste-product atoms on the fuel rod (it increases in volume) and therefore needs to be removed before serious distortion has occurred.

e) (i) The explanation of the generation of current in an ac transformer was only moderately done. Although candidates had a reasonable idea of what happens, too many details were poorly expressed. For example, candidates jump too quickly to a statement that "*current is induced in the secondary*" without recognising the step of the generation of an induced emf and its interaction with the resistance in the secondary circuit.

(ii) Many correct answers were seen.

(iii) As in (i) there were missing steps even in correct, high-scoring answers. A simple statement that *power loss* $\propto$ *current*^{2} neglects the influence of cable resistance which is worth additional credit. Teachers are referred to the published mark scheme for a treatment of the question.

(iv) Many were able to calculate the fraction of power lost in the cables, but sometimes the ratios were quoted the wrong way round. Candidates need to take care in this respect.

B3

B3 Pt 1 [HL] and B2 Pt 1 [SL] Wave motion

a) Many understand perfectly, in wave theory, the nature of the ray and the wavefront and the relationship between them. Indeed, those who could not discuss the ray and the wavefront could quote the relationship with ease.

b) (i) The wavefront in medium Y was well drawn with only a few wayward lines that were not parallel to the drawn wavefront.

(ii) This was poorly done, both in terms of understanding and explanation. Those who used wavelength determinations (with a ruler) from the diagram fared much better than those who measured angles (with a protractor). Candidates using angles usually became confused as to what the angles referred to (incidence or refraction) whereas the direct wavelength method links directly to the definitions of refractive index.

c) Descriptions of the differences between transverse and longitudinal wave were surprisingly poor. Although the candidates clearly have a vague idea of the differences (usually in terms of the motion of the "*particles*" or "*air*") they find these concepts very difficult to put into words. Examiners needed (for full credit) to see clear reference to the direction of oscillation of the particles of the wave in terms of its relationship to the direction of propagation of energy by the wave.

d) (i) Frequency calculations were mixed with a disappointing number of failures due to a misunderstanding of the relationship between time period and frequency and a large number of power of ten errors.

(ii) Many were able to locate M on the graph (at an *x*-axis crossing) but predictably many chose a peak or trough of the graph.

(iii) Few good solutions to this problem were seen. Two routes are possible: a determination of the area under the graph, or calculations using, for example, the maximum speed of the particle in Y. Few of the former were seen (but were often well done). The calculation route was, for many, full of error in the manipulation of the algebra and the correct substitution of data.

B3 Part 2 [HL] Electrons

a) (i) Explanations of aspects of the photoelectric effect are quite common in the examinations and this was evident here in that most candidates could gain one or two marks for relevant statements about the photons and electrons. Good candidates commonly gained all three marks for good and clear explanations of the effects.

(ii) This was not so well done. Most could not recognise the dependence of intensity on the number of photons arriving per second and tried to answer in terms of part (i).

b) (i) This calculation was well done by many.

(ii) This challenged many with its factor of 1 in 300 photons influencing the electron current. There were also many power of ten errors arising from the use of mm in the data for the question.

B3 P2 [SL] Satellites

a) Few candidates were able to state Newton's law of gravitation, with most giving vague descriptions of what the law relates to.

b) (i) The order of magnitude of the wavelength of microwaves was not well known. Many candidates gave no units, rendering their answer as meaningless.

(ii) This calculation was generally well done by those candidates recognising that they needed to utilise the speed of light.

c) (i) Few candidates were able to give a convincing explanation of this.

(ii) Most candidates failed to add the height of the satellite above the surface of the Earth to the radius of the Earth.

(iii) Few were able to attempt this part question.

(iv) Following on from (iii), this part question was rarely more than cursorily attempted.

B4

B4 [HL] and B1 Part 2 [SL] Oscillating water column (OWC) energy generation

a) (i) **[SL only]** Well answered by many, but weaker candidates gave flowing water answers that were not ocean based.

(i) **[SL (ii)]** Many were completely at a loss here and were describing hydroelectric power stations and tidal barrage systems. This did not gain credit. Those who recognised the device that was required omitted detail surrounding the internal mechanism and failed to draw sufficient attention to the trapping of air and its compression by the wave action. Most were more comfortable with use of the compressed air to turn turbines. The usual confusion between turbine and dynamo was seen again.

(ii) **[SL(iii)]** The marking scheme was generous and allowed steps to be omitted with full marks still possible. This was fortunate as candidates were poor at identifying all the transformations in the OWC.

b) (i) The calculation was mixed; some candidates were well trained in taking the multi-step through. Others however fell at the hurdles of calculating the energy required in the waves and identifying the correct equation in the data booklet.

(ii) **[HL only]** Disadvantages of moving the OWC were sometimes facile. Examiners saw many different statements but most did not gain credit.

(ii) **[SL only]** The Sankey diagrams were drawn adequately but too often failed to take into account the data in the question and so were unscaled; this did not attract full marks.

B4 Part 2 [HL] and B2 Pt 2 [SL] Pobeda ice island

a) (i) **[SL only]** Most answers did not refer to molecular motion and energy rather to the fact that solid ice has a fixed shape and liquid water takes the shape of its container.

a) (i) **[SL (ii)]** Many negotiated the two parts of the calculation (heat capacity to raise the ice to 0°C and latent heat to melt it) with skill to add the final energies together. Some missed out the melting phase and lost credit.

(ii) **[SL (iii)]** Some candidates (perhaps one-third) used a factor of 0.8, the albedo value, rather than 0.2 in their calculations. But having mounted this hurdle, many were able to estimate the time to melt the island. On this occasion there were fewer power of ten errors seen.

b) **[HL only]**

(i) The final part of the question moved to a consideration of a charge-coupled device (CCD) used to view the ice island. Candidates could usually score 2/3 for an outline of how the potential difference (pd) develops when energy arrives and electrons are transferred thus producing a charge and (because of capacitance action) a pd. Candidates should guard against re-stating the question as a major part of their answer. This happened here from time to time.

(ii) Candidates are now well used to these calculations and found parts of this calculation straightforward. However, only the most able were able to work through to a correct final answer. It was more usual to see a couple of marks gained for the calculation of the pd using capacitance.

Recommendations and guidance for the teaching of future candidates

- Spend as much time reviewing explanatory questions as calculation questions.
- Insist on calculations being set out in a logical and communicative fashion.
- Give adequate time to the teaching of all areas of Topic 8.
- Read the question carefully.

Higher and standard level paper three

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 20	21 - 26	27 - 31	32 - 37	38 - 60

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 3	4 - 7	8 - 11	12 - 15	16 - 19	20 - 23	24 - 40

General Comments

Virtually all candidates answered exactly two options as was required. Most centres clearly teach just two options. Those who answered options which were different from the centre norm were almost always unsuccessful.

The majority of candidates were able to keep their answers within the response box and extension sheets were used infrequently. The vast majority of candidates appeared to have sufficient time to complete their answers.

Some of the feedback from teacher's comments on the G2 forms is summarised below. These comments are appreciated by question setters. It would be useful to have responses in more detail and from more centres.

Higher Level

- 26 of 30 centres found the level of difficulty appropriate. 4 centres thought it too difficult. None thought it too easy.

- 20 of 29 centres thought the paper was of the same standard as last year. 8 centres thought it more difficult. 1 centre thought it easier than last year.
- No centre thought that the clarity of wording or presentation of the paper was poor. Most thought these were good or satisfactory.

- Option I (Medical physics) continues to grow rapidly in popularity at the expense of options F (Communications) and J (Particle physics). Options G (Electromagnetic waves), E (Astrophysics) and H (Relativity) remain popular options.

Standard Level

- 32 of 35 centres responding found the level of difficulty appropriate. 3 centres thought it too difficult. None thought it too easy.
- 29 of 34 centres thought the paper was of the same standard as last year. 5 centres thought it more difficult. None thought it easier than last year.
- No centre thought that the clarity of wording or presentation of the paper was poor. Most thought these were good or satisfactory.
- Options A (Sight and wave phenomena) and G (Electromagnetic waves) continue to be the most popular, whilst options C (Digital technology) and F (Communications) are chosen by few candidates.

In paper 3 the perception of the level of difficulty does depend somewhat on the options chosen, but overall the statistics show very minor differences as mentioned above.

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

General difficulties

- Highlighting key phrases or data in a question
- Choosing the appropriate data booklet formula or equation
- Knowing what the symbols represent in a data booklet formula or equation
- Powers of 10 and unit multipliers continue to pose noticeable difficulty
- Textbook statements of definitions, laws etc
- Careless arithmetic and algebraic errors
- Failing to rearrange algebra before substituting data
- Showing working in full in 'show that' questions
- Disorganised layout of working in all questions
- Paying attention to the number of marks awarded for each part question as often candidates
- Provide fewer key facts than is required
- Sequencing the presentation of facts to support an explanation or description

Higher level

- Apparent and absolute magnitudes
- Interpretation of HR diagrams
- Signal processing
- Operational amplifier circuits
- Details of the Doppler effect
- X-ray bremsstrahlung
- Relativistic kinematics
- Relativistic dynamics
- Logarithmic response of the ear
- Radiotherapy
- The wire chamber
- Deep inelastic scattering

Standard level (unique questions only)

- The meaning of 'photopic' and 'scotopic'
- Reflection of coloured light
- Doppler effect diagrams
- Explaining image resolution
- Absorption spectra
- Mobile phone networks

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

The best candidates have fully covered the syllabus and show good understanding, can manipulate equations, show *all* working in a *methodical* way and explain concepts with clarity. The weakest candidates fail to read the whole question, have poor knowledge of concepts, lack conciseness and clarity in answers, *do not* show all working or use the wrong equation. Clearly many candidates have studied past papers and are able to demonstrate good knowledge of the commonly tested parts of the syllabus. Candidates often perform far better with calculation questions than with questions requiring recall of laws, definitions, experiments and concepts. Weaker candidates may score all of their marks on calculations. Options A, B, E, and G at SL and E, H, G and I at HL are very popular and most candidates make a good effort to tackle these questions.

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

SL Only

Option A - Sight and wave phenomena

This was the most popular option at SL.

A1 The eye

(a) Candidates often failed to specifically mention *differences* between rods and cones. The meaning of photopic and scotopic is not always understood.

(b) The graph of rod sensitivity often failed to show greater sensitivity than for cones.

(c) Far too many candidates suggested that red light incident on a blue card produced magenta.

A2 The Doppler effect

(a) As usual, a few candidates referred to changing loudness as opposed to frequency. Diagrams were often poor, but many were able to score 2 out of a possible 3 marks.

(b) Many candidates were able to calculate the speed of the fire engine but some incorrectly used the formula for a moving observer.

A3 Polarised light

(a) Candidates were often unable to state what it was that vibrates in one plane.

(b)(i) Brewster's law seems well known and b)ii was a very easy 2 marks.

A4 Resolution

Many candidates were able to draw the overlapping diffraction patterns. Fewer mentioned diffraction occurring at the eye or explained clearly why images could not be resolved.

Option B - Quantum physics and nuclear physics

B1 Absorption spectrum and atomic energy levels

(a) *White* light was not often mentioned. Too many candidates explained how to produce an emission spectrum.

(b)(i) Most were able to describe the appearance of an absorption spectrum.

(ii)Many knew that absorption lines related to transitions between energy levels but often found it difficult to sequence their answers clearly.

(c) There were many correct calculations of wavelength, but also many basic arithmetic errors in calculating the difference between 2 fractions.

B2 Radioactive decay

(a) The positron and electron neutrino were usually identified.

(b) Several approaches were used to determine the age of the rock, most of them correct.

(c) The activity and mass of the sample were often correctly stated. Too many candidates referred to the 'amount' of sample or finding the decay constant.

B3 Neutrinos

Too many candidates just paraphrased the question or did not state that the energy released is quantised/ fixed. There were a good number of correct answers.

Option C - Digital technology

C1 CDs

(a)(i) A common question, but most answers lacked detail.

(b) A common mistake was to divide by 32 bits rather than multiply, but the question was done well overall.

C2 CCDs

(b) Many candidates failed to list the data given in symbolic form. Others failed to use the time of 30ms. There were few fully correct answers.

C3

This question is identical to question F4 in option F and the reader is referred to the comments in that question.

Questions C3 onwards were also on the HL paper. They are marked with * in that section.

Option D – Relativity and particle physics

D1 Relativity

This question was similar to question H1 in option H and the reader is referred to the comments in that question.

SL and HL combined

Option E - Astrophysics

A very popular option.

***E1 Stars**

(a)(i) Not many candidates referred to apparent magnitude in the definition of absolute magnitude.

(a)(ii) Colour or temperature was usually mentioned.

(a)(iii) The fact that the star has the same surface temperature as the sun was overlooked by many candidates.

(b)(i) This was answered well by candidates.

(b)(ii) Only about half of all candidates correctly put star B in the white dwarf region.

(c) Spectral lines were often not labelled.

***E2 Cepheids**

(a)(i) Most candidates knew that Cepheids expand and contract.

(a)(ii) In the calculation of stellar distance, many careless arithmetic errors occurred in evaluating the log expression, but many candidates found the correct distance of 445pc.

(b) A few candidates failed to realise that the stars were equidistant from Earth or incorrectly mentioned determining the surface area of the non-Cepheid.

***E3 Cosmology**

(a) and (b) were answered well by the majority, but too many candidates did not specifically mention *galaxies* in (b).

E4 [HL only] Stellar evolution

Both (a)(i) and (ii) were easy 'show that' questions, but many candidates showed no legitimate working.

(b)(i) The transition from red giant to planetary nebula was known to many as was the Chandrasekhar limit in (b)(ii).

E5 [HL only] Hubble's law

(a) Hubble constant calculations were done well.

(b) Not many candidates referred to the rate of expansion of the universe as being greater in the past.

Option F - Communications

This option was chosen by very few candidates.

***F1 Amplitude Modulation graph**

Not many candidates could interpret the data correctly and power of ten errors were common.

***F2 Digital signals**

(a)(i) was generally correct but in (a)(ii) almost no candidate could explain the function of the serial to parallel converter.

(b) Higher sampling frequency and more bits per sample were often mentioned, but not well explained.

***F3 Optical fibres**

(b) Lower attenuation of IR wavelengths was rarely mentioned.

(c)(i) Was done well.

(c)(ii) Candidates were often unsure about which power values to use.

***F4 The op-amp**

Candidates either did very well or had little idea about op amps.

***F5 Mobile phone systems**

(a) The reduction in signal strength with distance was rarely mentioned.

(b) This part question was poorly done.

Option G - Electromagnetic waves

A very popular option.

***G1 Interference**

All parts were well answered by the majority of candidates.

***G2 Magnifying glass and microscope**

(a) Near point was defined in many different ways.

(b) The lens diagram was well drawn.

(c) Many fruitless lines of algebra were sometimes seen because $v = D$ was overlooked.

(d) There were many errors in the microscope calculations due to confusion between the objective lens and eyepiece focal lengths. However there were also many correct answers - except for (iii), where the ratio of focal lengths was a popular choice for overall magnification.

***G3 Red sunset**

Some candidates struggled to organise their answers in a logical sequence, but most knew the details of Rayleigh scattering.

G4 [HL only] X-rays

(a)(i) Candidates could usually explain the characteristic spectrum but not the continuous spectrum.

(b)(i) The calculation of minimum wavelength was well done.

(b)(ii) A few candidates chose the complement of the grazing angle in the Bragg formula.

HL only

Option H – Relativity

This remains a fairly popular option.

***H1 Relativistic kinematics**

(a) Most candidates were unable to state that an event is a point or coordinate in space-time.

(b)(ii) Was done very poorly as proper time (the photon's) was rarely mentioned.

(c)(i), (ii), (iii) were all done well, but only a small minority of candidates obtained 60ns as the answer to (iv).

(d) **[HL only]** The Hafele-Keating experiment was well known to many, but a few candidates incorrectly described muon time dilation, Pound- Rebka or the Michelson-Morley experiment instead.

H2 Relativistic mechanics

(a)(i) and (ii) were usually done well.

(b)(i) Very few candidates determined values for the Y frame of reference, choosing instead the CM frame.

(b)(ii) Many candidates could find the energy of the Z particle, but often the energy of only one of the colliding particles was used.

H3 General relativity

(a) The principle of equivalence was well stated.

(b) The red shift of a gamma photon was usually well explained and calculated.

H4 Black Holes

(a) The escape velocity of *c* was usually correctly mentioned in the definition of the Schwarzchild radius.

(b) The curvature of spacetime is well known, but candidates often struggled to sequence their answers to the question in a logical way. Geodesics were rarely mentioned.

Option I - Medical Physics

This is now the third most popular option.

I1 The Ear

(a) and (b) were done well by the majority.

(c) Far too many candidates restated the question in attempting to explain the meaning of a logarithmic response.

(d) The intensity level calculation was done very well indeed.

I2 X-ray imaging

(a) Many candidates incorrectly defined attenuation coefficient in terms of half-value thickness.

(b) The derivation in was done well.

(c) There were a variety of valid approaches taken but a few candidates mistakenly used the values of 15 keV and 30 keV in their calculations.

(d) The difficulty of obtaining good contrast between the liver and surrounding tissue was quite well explained, but many stated that the liver was *completely* transparent to X-rays.

I3 Isotopes in medicine

(a) Was well answered as was the calculation of effective half-life in (b)(i).

(b)(ii) Candidates often struggled to think of 3 valid points to make about the choice of I-131 for the treatment of thyroid cancer.

(c) Estimating blood volume was an easy three marks for some, but was left unanswered by others who may have been overwhelmed by the quantity of data given.

Option J - Particle Physics

Very few candidates chose this option.

***J1 Quarks**

(a) This was an easy mark.

(b)(i) Answers in terms of the quark structure of an anti-kaon or the value of its strangeness were rare.

(b)(ii) The non-conservation of strangeness was usually overlooked. However the calculation of the range of the weak interaction was usually correct in (iv).

(c) Few correct answers were seen.

J2 Cyclotron and wire chamber

(a) The use of an AC pd across the dees of a cyclotron was known, as was the attractive force between the dees. Rarely was frequency mentioned.

(b) The available energy formula was used, but not always correctly.

(c) Candidates usually had a very vague idea of the function or operation of a wire chamber.

J3 Deep inelastic scattering

This was not well understood by candidates.

J4 The early universe

(a) Finding the temperature corresponding to colliding 7 TeV protons was usually done well.

(b) Candidates usually could not explain the dominance of matter over antimatter.

Recommendations and guidance for the teaching of future candidates

- The option topics allow candidates to experience some of the more challenging and interesting areas of Physics. However, the importance of the fundamental principles of the subject should not be underestimated. Definitions and statements of laws are sometimes poorly expressed or pure guesswork.

- In general candidates tend to perform less well on the descriptive parts of questions, these are often the cause of the difference between a mediocre and good grade. In setting private study exercises it is helpful for candidates to be given not only numerical questions but also plenty of extended response questions.

- Past question papers provide the opportunity for essential practice with the style of questions candidates will face. Giving candidates model answers (as well as past markshemes) allows them to understand what level of response is expected. These are often provided in IB Physics textbooks.

- The marking of key phrases in a question should be encouraged as so often an instruction or piece of information is missed.

- All candidates should be given the full IB Physics Subject Guide and Data booklet. Both are essential learning tools and very useful as revision checklists. The subject guide can be provided in teacher-annotated form, with textbook page references and past paper question references.

- Teachers need to have sessions, during revision, to explain the use of every equation and all items of data in the Data booklet.

- Wikipedia, Hyperphysics, CERN, NASA, Physics.org, outreach.atnf.csiro.au, phys.unsw.edu.au, etc, provide a wealth of online sources of information. These can be organised by teachers into a very valuable learning tool to supplement textbooks in the teaching of each of the options.