November 2015 subject reports

Physics

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 15	16 – 28	29 – 40	41 – 49	50 – 59	60 – 68	69 – 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 15	16 – 27	28 – 36	37 – 46	47 – 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

The range and suitability of the work submitted

The current IA system has become all too familiar to teachers, and many are cutting corners with just two investigations that assess each criterion. Given this, the range of practical work was acceptable. Most schools had a comprehensive practical program covering most of the syllabus and teachers were assessing appropriate investigations. Mechanics was naturally the most common area for investigations. The quality of candidate's work varied but overall was good and appropriate for high school level. Candidates who were academically weak still demonstrated enthusiasm and determinism with their investigations. All candidate reports were word-processed and most graphs were drawn using graphing programs. There was some use of ICT in various investigations. Overall, the majority of schools are doing a satisfactory job of implementing practical programmes.

Candidate performance against each criterion

Design

The majority of schools used appropriate and well-established design prompts. Unfortunately, most schools only allowed two opportunities for the candidate to design an investigation. In a few cases candidates had two independent variables without realizing it. Teacher guidance at the planning stage would have helped the candidates realize this.

Data Collection and Presentation

Candidates often earned high marks under the DCP criterion. Raw data always has uncertainty, and the candidate should address this, even if a digital measurement uncertainty is taken as the least count. 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. Examples like this cannot earn full marks.

IA Conclusion and Evaluation

This continues to be the most difficult criterion for candidates. 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 aspect 1 a complete, as many times moderators had to change a complete to a partial. Overall, aspect 1 more often than not was not able to reach a complete. CE is best assessed when candidates also have designed and performed the investigation themselves.

Recommendations for the teaching of future candidates

- 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 schools correctly appreciate errors and uncertainties, this remains one of the weaker areas for some schools. Occasionally, graphs looking for a trend line connected the scatter data points. This is clearly inappropriate. Also, occasionally, the scatter of data suggested a curve, but candidates (without thinking) forced a linear best-fit line. Teachers need to address the appropriate treatment of uncertainties in lab work as well as on graphs.
- The November 2015 examination session will be the last session with the current IA criteria. See Further comments below.

Further comments

Starting in May 2016 there will be entirely new expectations, new criteria and new requirements for internal assessment. The issue of personal engagement and the overall communication of the IA report will be assessed as well as the more traditional skills of the exploration or investigation plan, analysis and data processing, and an appropriate conclusion and evaluation. There will be a greater emphasis on teacher guidance and for the candidate to set their investigation into a relevant scientific context. It is highly recommended that teachers familiarize themselves with the changes and new expectations early on in the course of study. There is support online with the OCC and there are numerous face-to-face and online teacher-training workshops.

Note. *Previous reports contained details about when the moderators did not change a mark, moderated up and moderated down. This information is no longer relevant to this report because November 2015 was the last iteration of the current IA system. Hence this report is much shorter than before.*

Higher and standard level paper one

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 10	11 – 14	15 – 19	20 – 22	23 – 25	26 – 28	29 – 40

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 7	8 – 9	10 – 11	12 – 13	14 – 16	17 – 18	19 – 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.

Multiple choice questions require specific skills distinct from those required to succeed in papers 2 and 3. These papers *together* aim to provide a valid and complete assessment of the syllabus. The relevant skills for paper one need to be taught. We expect candidates to be able to think quickly, make estimates, consider units, use proportionality and recognise clearly absurd suggestions. Further elaboration of the required skills is to be found at the end of this report.

Only a small percentage of the total number of teachers or the total number of centres taking the examination returned G2 forms. For SL there were 27 responses from 230 centres and for HL there were 20 responses from 286 centres. While we thank those who took the trouble to provide G2 feedback, we would continue to urge all centres to contribute; comments from teachers are carefully considered and inform the process of setting realistic and fair grade boundaries given the nature of the paper.

The replies received indicated that the November 2015 papers were generally well received, with many of the G2 forms received containing favourable comments. 70% of the HL respondents and 73% of the SL respondents felt that the paper was of an appropriate difficulty. Compared with last year's paper it was deemed to be more difficult by about 55% of the HL respondents and 42% of the SL respondents. But the mean mark for the HL paper was the same as last year, with the SL being 1.3 marks lower. Interestingly the predicted grades were the same for November 2014 and November 2015.

With few exceptions, teachers thought that the presentation of the papers and the clarity of the wording were either satisfactory or good, although there was a feeling from a minority of respondents that the papers were occasionally too wordy putting second language learners at a disadvantage.

Statistical analysis

The overall performance of candidates and the performance on individual questions are illustrated in the statistical analysis of responses. These data are given in the grids below. 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 shaded 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 easy question. The *discrimination index* is a measure of how well the question discriminated between the candidates of different abilities. In general, a higher discrimination index indicates that a greater proportion of the more able candidates correctly identified the 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	208	32	746	387	1	54.29	0.14
2	104	369	527	373	1	38.36	0.53
3	26	99	69	1179	1	85.81	0.26
4	222	125	705	315	7	51.31	0.55
5	1124	224	10	15	1	81.8	0.36
6	204	318	281	565	6	41.12	0.49
7	106	662	557	43	6	48.18	0.43
8	53	714	525	81	1	51.97	0.52
9	1059	63	164	88		77.07	0.31
10	310	94	695	274	1	19.94	0.21
11	173	45	53	1102	1	80.2	0.24
12	716	164	395	94	5	52.11	0.57
13	105	132	854	282	1	62.15	0.50
14	162	892	85	234	1	64.92	0.48
15	671	217	271	212	3	48.84	0.43
16	903	243	154	64	10	65.72	0.48
17	366	63	875	68	2	63.68	0.51
18	61	54	51	1207	1	87.85	0.12
19	457	430	372	110	5	27.07	0.16
20	1019	124	139	82	10	74.16	0.45
21	157	133	851	232	1	61.94	0.58
22	20	11	146	1196	1	87.05	0.20
23	97	131	262	883	1	64.26	0.60
24	173	552	570	71	8	40.17	0.51
25	88	21	252	1009	4	73.44	0.01
26	813	57	203	300	1	59.17	0.39
27	47	1151	92	80	4	83.77	0.33
28	299	743	122	202	8	54.08	0.54
29	553	266	350	203	2	40.25	0.33
30	221	174	651	323	5	47.38	0.52
31	700	232	107	331	4	16.89	-0.10
32	485	236	439	206	8	31.95	0.24
33	218	808	145	200	3	58.81	0.54
34	784	212	143	229	6	57.06	0.49
35	48	89	478	758	1	55.17	0.29
36	99	747	284	238	6	54.37	0.57
37	432	160	170	598	14	43.52	0.74
38	887	415	46	24	2	64.56	0.17
39	119	885	134	233	3	64.41	0.47
40	131	70	1090	77	6	79.33	0.33

Number of candidates: 1374

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	181	55	801	232	2	63.02	0.24
2	352	417	301	186	15	32.81	0.26
3	91	754	411	13	2	59.32	0.46
4	69	182	105	914	1	71.91	0.46
5	252	173	496	341	9	39.02	0.27
6	126	411	453	276	5	35.64	0.24
7	826	373	27	42	3	64.99	0.54
8	593	101	152	411	14	46.66	0.59
9	850	36	342	42	1	66.88	0.32
10	134	428	618	78	13	33.67	0.19
11	417	114	485	249	6	38.16	0.17
12	529	347	183	203	9	41.62	0.46
13	613	464	141	36	17	36.51	0.45
14	231	82	99	856	3	67.35	0.26
15	431	182	507	147	4	33.91	0.43
16	112	436	614	100	9	48.31	0.44
17	432	319	448	71	1	35.25	0.23
18	214	387	148	514	8	30.45	0.41
19	361	420	379	97	14	29.82	0.08
20	455	106	105	587	18	46.18	0.48
21	58	20	194	995	4	78.28	0.27
22	181	340	618	104	28	26.75	0.19
23	495	206	126	435	9	34.23	0.25
24	569	120	265	311	6	44.77	0.36
25	80	834	173	177	7	65.62	0.46
26	596	275	170	218	12	46.89	0.49
27	56	193	496	518	8	40.76	0.40
28	181	550	240	288	12	43.27	0.38
29	488	219	181	353	30	27.77	0.46
30	191	395	389	262	34	30.61	0.21

Number of candidates: 1271

Comments on the analysis

Difficulty

The difficulty index varies from about 17% in HL and 27% in SL (relatively “difficult” questions) to about 88% in HL and 78% in SL (relatively “easy” questions). The papers gave an adequate spread of marks while allowing all candidates to gain credit.

Discrimination

All questions except HL Q31 had a positive value for the discrimination index. Ideally, the index should be greater than about 0.2. This was achieved in the majority of questions. However, a low discrimination index may not result from an unreliable question. It could indicate a common misconception amongst candidates or an easy question (with a high difficulty index).

“Blank” response

In both papers, there were a number of blank responses throughout the test with a slight increase towards the end. This may indicate that some candidates had insufficient time to complete their responses, while others left the questions they were unsure of. **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, some of the “distractors” should be capable of elimination, thus increasing the probability of selecting the correct response. If candidates concentrate on selecting the correct response – instead of working out the correct answer (as they might in paper 2) then there should be adequate time to complete all the questions and check the doubtful ones.

It should be stressed that, whereas the average time per question is 1.5 minutes, some questions – often of a conceptual nature – can be completed in less than 30 seconds, leaving extra time for the more problematical items.

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

Candidate performance on the individual questions is provided in the statistical tables above, along with the values of the indices. For most questions, this alone will provide sufficient feedback information when looking at a specific question. Feedback will be given only on selected questions, i.e. those that illustrate a particular issue or drew comment on the G2 forms.

<u>SL and HL common questions</u>

SL Q4 and HL Q4

The forces have line symmetry about the tension, so C is the only possible answer.

SL Q10 and HL Q7

Think units.

The units of the answer are given as J kg^{-1} K^{-1}, which means that we need to divide energy by temperature (and mass, but that is already present in each response). C was the most popular option, but this is 120 (obtained by dividing 1800J by 10K and totally ignoring the container) so it must be incorrect. Thus it would be reasonable to subtract the energies given before dividing by 10K – giving the correct answer B.

Alternatively the candidate can write down the two relevant heat exchange equations and subtract them, but this takes longer.

SL Q19 and HL Q19

Think proportionality.

There were a few G2 comments suggesting that this question was too complex and took too much time, but this is only the case if candidates reach for equations before considering proportionality.

A simple sketch will show that if the new resistors are placed side by side (ie in parallel) then the new length is twice the previous length (leading to a doubling of the resistance) and half its cross-sectional area (leading to a further doubling of the resistance). So the correct response is C.

SL Q22 and HL Q24

Although it is convenient to use k in the equation for coulombic attraction, candidates need to be able to unpack this as $\frac{1}{4\pi\varepsilon_0}$.

SL Q24 and HL Q26

The question asks “What is the force?”, it does not ask “What is the nature/direction of the force?”. To distinguish the two it is probably best, when teaching, to use the adverb “centripetally” rather than centripetal. So we would say “The electrostatic force acts centripetally”. In this way the candidates understand that there are many different forces, all of which can act centripetally under certain conditions.

SL Q27 and HL Q35

The first option concerning the daily output of the Sun’s power caused some confusion. The question does not ask about whether such variations occur (they do!) but rather whether they would lead to a change in power incident upon the Earth. Clearly they would, leading to D as the correct response.

HL Questions

Q2

The clear statement that “air resistance is **not** negligible” indicates that the object has been released (otherwise it would be redundant), so C is the only possible answer.

Q6

Clearly when $\theta = 90^\circ$, $t = 0$, so A and C must be incorrect. The relevant equation of motion relating *s*, *v*, *a*, *t* includes $\frac{1}{2}$, so D must be the correct response.

Q10

The fridge is switched on and is within a closed system. This means that, as the fridge is consuming energy, the room will rise in temperature.

Q15

Look at the responses given before trying to work out the answer.

If there is “minimal” diffraction then candidates should know that the wavelength is less than the width of the slit. The only response that fits this requirement is A. There is a reminder on the first page of the paper that candidates should give the most appropriate or closest answer.

The closest alternative response is C, but candidates should know that if the slit is the same size as the wavelength then there will be noticeable diffraction.

Q17

The diagram clearly states that the angles are not drawn to scale. Despite this, many candidates chose response A, presumably as those angles looked as if they added together to make a right angle. But it was good to see that the majority of candidates were not fooled by appearances and selected the correct response of C.

Q20

As all the responses have the same significant figures this is clearly a question about powers of ten rather than an aeroplane flying through a magnetic field. The majority of candidates understood this and selected the correct response of A.

Q23

Think proportionality.

Clearly the masses of the Sun and Moon do not change so we are only considering the distances. Considering Newton’s inverse square law of gravitation, all that is needed is to switch the variables, r_s and r_m, and then square the ratio.

Q29

Most of physics is process oriented, but there are factual items of knowledge in the syllabus and these just have to be memorized. This question showed that there are many candidates who were unaware of the Davisson–Germer experiment.

Q31

More than half of the candidates chose A, suggesting that they did not understand that the emission spectrum contained evidence of all possible electron transitions. Normally with four energy levels this would involve 6 transitions, but in this case some of the transitions were identical – a fact that escaped most candidates even the most able.

Q32

The most popular response was A suggesting that candidates were either unfamiliar with the details of the mass spectrometer (a syllabus requirement), or that they thought that kinetic energy was a vector. It is, of course, scalar and so the correct response is C.

SL Questions

Q3

Think units.

If we want a speed then this can only be calculated from the area under the graph.

Q6

Think proportions.

Twice the impulse on twice the mass would lead to the same final speed. Kinetic energy is proportional to mass (and v^2, but that doesn't change) so C must be the correct response.

Q9

Think units.

The question asks about a change in temperature. And as we are not being asked about the specific thermal capacity (the word "specific" denotes "per kilogram") the only possible correct response is A.

Q11

Many candidates seemed to think that when two bodies of different temperatures are placed in thermal contact, then the "process" of energy transferral depends upon the temperatures involved. However, thermal contact involves thermal energy transfer by conduction only so cannot depend upon the temperatures.

Q16

Anything that radiates outwards from a point source will obey the inverse square law, whether it be gravity, magnetism from a monopole, warmth or light. But there are situations when an electromagnetic wave does not radiate equally in all directions – as, for example, with a laser. So C is the correct response.

Q17

It would seem that many candidates were not familiar with reflection of a wave from a free boundary.

Q18

Current involves the flow of charge – just like the flow of water in a river or cars along a road. The statistics of this question showed that many candidates clearly had no concept of what current is all about. Here, when the charge (cars/water) arrive at the junction and their flow is distributed between the I_z and I_y stream then the current in the left hand resistor will be one third the value of the current in the right hand resistor (since the left hand resistor is three times more difficult to get through). So B is the only possible correct response.

Q23

The conventional current is opposite in direction to the electron flow. So here we have essentially anti-parallel currents and the candidates should know that such currents keep well away from each other, ie they repel, leaving D as the correct response.

Q30

Think units.

We want time, so the power must be on the bottom of the fraction ($W = Js^{-1}$). So A and D must be incorrect. As surface heat capacity involves a m^{-2} term we have to multiply by area to have any hope of getting seconds. Hence C.

Recommendations and guidance for the teaching of future candidates

Multiple choice items are an excellent, motivating and highly time-efficient way of testing and promoting learning while a course is being taught. They can be used as warmers to stimulate discussion as well as for quick tests and should never be regarded as add-ons to be practised, a paper at a time, solely for the final examination session.

Multiple choice questions test a different skill to structured questions. In paper 2 candidates are expected to display their knowledge in a logical and communicative fashion. But multiple choice questions test conceptual thinking, estimation (without a calculator), insight and problem solving.

Teachers frequently comment on unfair “tricky” questions, but the physical world has a history of tricking scientists into false conclusions. In order not to be “tricked”, candidates must read the question very carefully to visualise the situation. If necessary they should make a quick sketch as they read the question. Very often, once the question is fully understood, the answer will be obvious without copious calculations or application of equations.

The questions are peer-reviewed before publication and extreme care is taken to avoid superfluous or distracting statements. Candidates should therefore assume that every word in the question will be relevant to the selection of the correct response.

There is no single most successful strategy with MCQs, so flexibility of thinking is needed. Candidates should be encouraged to develop strategies for spotting the correct answer – rather than working it out as they would in a paper 2. Among the strategies leading to successful completion of multiple choice questions are:

- Eliminate the clearly incorrect responses.
- Consider the units. There is much evidence that candidates are not being taught the power and necessity of units. They are there to help the candidate, not to burden them, and will often lead to the identification of the correct response.
- If two responses are logically equivalent then they must both be incorrect.
- Exaggerate a variable – this will often point the candidate in the correct direction, especially if a variable is in the denominator in one response and the numerator in another.
- Distinguish between cos and sin functions – mentally making the angle 90˚ will show which is correct.
- Use proportion: new quantity = old quantity × a fraction, where the fraction depends upon the variables that have changed.
- Notice the axes on graphs and use units to attach meaning to the gradient and the area.
- If all else fails, make an intelligent guess.

The idea of the questions is to assess the candidate's thinking skills. Although they have access to the data booklet they should avoid reaching for it automatically.

Candidates should make an attempt at every item. It should be emphasised that an incorrect response does not give rise to a mark deduction.

Graphs, force diagrams and other means of illustration are a fundamental way in which physicists seek to model and understand the world. Candidates should be encouraged to sketch their answers to problems before they plunge into calculations. There is evidence also, from the written papers and extended essays, that this is not a skill shared by many candidates.

Multiple choice items are kept as short as is possible. Consequently, all wording is significant and important. Candidates should also bear in mind that they are asked to find the **best** response. Sometimes it may not be strictly 100% correct, but Physics candidates should be used to identifying and ignoring quantities that have negligible impact.

Candidates should consult the current Physics guide (first assessment 2016) during preparation for the examination, in order to clarify the requirements for examination success. Teachers should be aware that questions are constructed from the requirements of the syllabus – not from previous papers.

This guide does invite the candidates to recall certain simple facts, although most of physics is process orientated. Such facts lend themselves to multiple choice questioning, so the teachers should not be afraid to require their candidates to occasionally memorize information. Definitions (which are universally poorly given in written papers) are perhaps best learned and tested with simple multiple choice questions.

Candidates can expect the proportion of questions covering a particular topic to be the same as the proportion of time allocated for teaching that topic, as specified in the Physics guide. The common knowledge that most people have about certain areas of the guide is not always sufficient to answer questions, which are not trivial.

Higher and standard level paper two

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 11	12 – 22	23 – 31	32 – 40	41 – 50	51 – 59	60 – 95

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 6	7 – 12	13 – 16	17 – 21	22 – 25	26 – 30	31 – 50

General comments

Very few G2 comments were received from schools, no more than 10% of centres sent in replies. This is disappointing and can only be interpreted by the senior examiners as meaning that 90% of schools were entirely content with the paper. If this is not the case, we encourage teaching colleagues to tell us. On balance, those who contributed felt that the HL paper was a little harder than usual. This was however not confirmed by the statistics of the cohort. At SL teachers regarded the paper as being equivalent to that set twelve months before. Respondents described the examination papers as being clear and well presented. Access issues were felt to be well handled.

The poor presentation displayed by candidates in writing their answers continues to give concern. There is no doubt that a lack of clarity in the explanation of a calculation loses marks. This is a matter that needs to be addressed with candidates throughout the course, not just when they are in the final weeks of preparation for the examination. The rationale for each step of a solution should be apparent in an answer.

Candidates need to be clear about the meanings of the command terms used in the examinations. The differences between “Outline” and “Explain”, between “Calculate”, “Show that” and “Deduce” are subtle but reflected in the mark schemes and the intentions of the examiners.

Diagrams were poorly executed. In particular the diagrams for the electric and magnetic field patterns both showed a very poor level of technical skill. Candidates should be encouraged to use drawing instruments. The overwhelming impression given by these diagrams (and scripts as a whole) is that candidates have little pride in their work.

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

Areas that appeared difficult included:

- Photo-electricity
- Calculations involving charge-coupled devices
- Transformer theory
- Circuit electricity calculations and descriptions
- Magnetism theory

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

- Radioactivity topics
- Calculations of experimental uncertainty
- Simple harmonic motion
- Energy resources
- Mechanics topics

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

Question 1 HL and SL except where noted

(a) Many candidates were able to draw acceptably smooth curves but sometimes these failed to stay within the region of the error bar “box”. Only a handful attempted to draw a straight line through the points. On the whole, the technical drawing of the lines was better than in previous years but there are still too many thick, doubled or kinked lines.

(b)(i) **HL only** Many read two points correctly from the line, but too often examiners saw lines that missed a data point with the printed point still being used for the read-off. These derived data then generally led to a correct evaluation of $\frac{h}{T^2}$ (or it’s reciprocal). However, for full marks, the examiners needed to see some consideration of the (sometimes considerable) error represented by the error bars and this was only rarely present.

(b)(ii) **HL only** There were a number of alternative statements that could gain credit here. The most frequently seen suggestion was that, because two points can define a line of any curvature, therefore a third (or more) data point is required to establish the proportionality.

(b) **SL only** Many candidates stated that the line did not go through the origin. Although this answer was counted as neutral it showed that candidates were repeating by rote rather than applying their knowledge to the graph in question.

(c)(i) This was usually correct. The main error was to quote the answer to 2 or more significant figures.

(c)(ii) **HL only** About one-third of candidates were able to give some explanation – almost always in terms of the thermometer and its use for every reading.

(c)(ii) **SL only** This was poorly done. The question asks about a physical characteristic of the thermometer and proportionality. Answers often just repeated the question in other words.

(d) There were many correct and well explained evaluations of the uncertainty in *K*. However many candidates failed to link the magnitude of the percentage uncertainty with a sensible significant figure for the final answer. Only 1 significant figure was accepted by examiners following the large final percentage error in the answer. A unit for the answer was also required and this too was frequently omitted.

Question 2 HL and SL

(a) Candidates were asked to outline the real meaning of “uniform circular motion”. They were required to link the gravitational force acting on Phobos due to Mars (and the constancy of this force) to the dynamics of the force direction associated with the orbit and its consequences for the change in velocity (and lack of change in speed). Few managed to score all points with the majority managing to score 2 out of the 3 available.

(b) This was a particularly simple “show that” question. Once again, examiners saw considerable numbers of answers that gave little information about the origin of the solution. As in past examinations, examiners saw much pure substitution without any explanation of its origin. This does not score well. It is best practice for candidates to present a full argument in calculations, and in “show that” and “deduce” questions it is essential.

(c) Candidates were on surer ground with the deduction of the mass of Mars. An algebraic starting point was allowed and many scored all 3 marks. However, a very large number failed to arrive at the correct numerical answer due to errors in powers of ten from the data provided.

Question 3 HL and SL

(a) A good definition of simple harmonic motion must focus on the proportionality between acceleration and displacement *from some fixed point* and on the directional relationship between acceleration and displacement. Many failed to emphasise the fixed-point aspect of the definition. Attempts made to define simple harmonic motion in algebraic terms normally omitted a clear statement of the symbols and the meaning of the negative sign.

(b) This was almost universally well done.

(c) Similarly, this was well done. Most appreciated the need to truncate the final answer to a sensible number of significant digits (two in this case).

(d) A large number of candidates could not translate a $\frac{\pi}{4}$ phase change into the correct time lead or lag. Most used the answer for $\frac{\pi}{2}$ and lost a mark in consequence. Most free-hand sketches of sine curves were acceptable.

Question 4 HL only

(a) It is sad that many young physicists at this level cannot negotiate their way correctly through a straightforward gas-law calculation. As usual, many failed to convert from degree Celsius to Kelvin before carrying out the numerical manipulation. This was an excellent way to lose marks.

(b) A good number were able to give answers to parts of this question but few could pull all the strands together convincingly. Frequent omissions were: to show that the internal energy changes are identical because the endpoint temperatures are the same, and to use the first law to confirm the final linking statement.

Question 4 SL only

(a) This was generally well done, but too many candidates focused upon a description of the experiment rather than the evidence it provided.

(b) Very poorly done.

(c)(i) The word nuclide refers to a nucleus with a specific number of protons and neutrons. Very few candidates understood this. They were, however, mostly able to show a clear understanding of what an isotope was.

(c)(ii) No problem for the majority of candidates.

(c)(iii) Most candidates were able to give the correct answer.

Question 5 HL only

(a) A number of alternative arguments can be used in this question. The most frequent one was the approach via the instantaneous appearance of the electron when radiation of even the lowest intensities is incident. Too many candidates simply quoted some random observations supposing that the examiner would be happy to join up the thinking. However, one route was allowed with arguments that linked the observation quoted with the predictions that would follow from a consideration of the wave model.

(b)(i) Many candidates can now carry out this and similar calculations fluently and confidently.

(b)(ii) Again, a large number of correct solutions were seen with many more deficient in one or two aspects of the solution.

Question 5 part 2 SL only

(e) The essential difference between specific heat capacity and specific latent heat is that the former refers to a change of temperature without changing state; whereas the latter refers to a change of state without changing temperature. Most candidates just wrote definitions which they had learnt by rote – and omitted the constant temperature for a substance changing state.

(f)(i) This is a question specifically about energy changes so candidates are expected to use accurate language and spell out the changes one by one. Common mistakes were omitting the "gravitational" in gravitational potential energy; referring to "heat" rather than thermal energy; and saying that gravitational potential energy changed to thermal and kinetic energy as if it were a single process.

(f)(ii) This was generally well done. There were four marks and the question asks the candidates to "deduce" so it is essential that the argument is transparent. The examiner cannot be expected to search through a mass of numbers in order to carry forward an error.

Section B

Question 6 Part 1 HL only

(a) Field patterns were often negligently drawn. Lines did not meet both plates, edge effects were ignored, and the (vital) equality of spacing between drawn lines was not considered. Candidates continue to show their inadequacy in responding to questions that demand a careful and accurate diagram.

(b) This sequence of calculations was often undertaken well with appropriate figures carried through from part to part. The only common error was the omission of a consideration of the gain or loss of the energy change in part (iii).

(c)(i) Too many candidates repeated the question back to the examiner in this part. A simple "photon has no mass or no charge" was all that was required.

(c)(ii) As one of the easiest questions on the paper this was predictably well done.

(c)(iii) In the past candidates have found calculation involving exponential change difficult. On this occasion, however examiners saw a large number of correct and well explained solutions from candidates.

Question 6 Part 1 HL and Question 4 part 2 SL

(d) This was well done – an omission of the vital unit (so that the examiner can confirm the reading) was not too common.

(e)(i) and (ii) Both parts were well done.

(f)(i) Many candidates described the meeting or interference of two waves, however, a considerable number went on to confuse amplitude with displacement in their answer and lost marks.

(f)(ii) This was a demanding drawing requiring candidates to show the complex superposition of two waves. Some candidates rose well to this challenge, took their time, and drew very good attempts. Many however produced rather half-hearted and rushed diagrams that lost one or more marks for lack of quality. Teachers would be advised to study the mark scheme as it gives a sensible route for the construction of the final answer.

Question 7 Part 1 HL and Question 5 Part 1 SL

(a) Many obtained the correct answer but failed to give coherent reasons as to why it was correct.

(b)(i) Although many understood the purpose of the heat exchanger in a nuclear reactor they did not express the answer well and did not convey the sense of transfer of thermal energy.

(b)(ii) A very high number now realise that the purpose of the moderator is to slow down (or remove kinetic energy from) the neutrons. Too many however believed that this was achieved by absorption of the neutrons. Only about one-third of candidates were able to go on to say that the effect of energy removal was to increase the chance of further fissions by the neutrons.

(c)(i) Where candidates wrote down what they were doing, they usually succeeded in working towards a correct answer – and even if they did not then it was possible to award partial credit for a partially correct solution. However there were far too many solutions where candidates did not give anywhere near enough explanation for the examiners to begin to give some of the marks.

(c)(ii) Many failed to remember that the answer they had given in (c)(i) was the amount of energy for one gramme and then went on to confuse the units in this part.

(d)(i) An essential rationale for a pumped storage plant is its ability to pump water back to the upper reservoir at times when the energy is cheap or off-peak. Although candidates could explain the principle of a hydroelectric plant, they usually omitted this essential part of the argument.

(d)(ii) Very many candidates were able to take this straightforward calculation through to a conclusion. Common errors were to omit the efficiency and to perpetrate power of ten errors.

Question 7 Part 2 HL

(e) In calculations involving a comparison between two quantities it is vital that the examiner knows which value is referred to by the candidate. Fortunately, the accounts of this calculation were generally very good with clear descriptions of the method and neat layouts of the solution. Where candidates failed to do this they fell into error. Candidates were allowed either to assume a resolution criterion that features a clear two-pixel separation between images or a single pixel gap. Whichever case was used, the answer (that the images were not resolved) was the same. Many candidates scored well on this question.

(f)(i) Most knew the meaning of quantum efficiency.

(f)(ii) This calculation on the other hand was not well done. Candidates became confused about the various conversions and it was common to see the simple equation $C = \frac{Q}{V}$ mis-quoted or inverted during the manipulation. Few scored full marks.

Question 8 Part 1 HL and Question 6 Part 1 SL

(a)(i) Another "show that" question and it was common to see candidates writing down strings of letters and numbers with no clear description of what was going on. Candidates need much more practice in satisfying their teachers as to the meaning of calculations. In these problems it is not sufficient to arrive at the same answer, examiners expect to see well-presented solutions with the answers taken to at least one more significant figure than quoted in the question. These reports have made this point for a number of years and the quality of these answers does not improve.

(a)(ii) This was accurately done by many.

(b) Responses were not clearly focussed; the references to a suitable law of motion were often confused. There was usually no clear comparison between the magnitudes of the two tensions. Another issue with answers (although condoned by examiners) was that candidates often talked in terms of zero tension in the belt for car I. There is of course always tension in the belt, the point at issue being whether the magnitude of this tension increases or decreases during times of deceleration.

(c)(i) Most were able to apply momentum conservation principles to arrive at a correct answer for the speed of O.

(c)(ii) Equally, although there were sometimes errors to be carried forward, many were able to offer persuasive and complete solutions to this problem.

(d) In the second part of this question, candidates showed themselves to be much less confident with ideas of electromagnetic induction. Discussion of induction of the secondary emf in the transformer ought to be well rehearsed and confident from a candidate at this level. Instead, examiners were treated to incomplete and often non-physical descriptions. Standard and expected terminology was rare. Terms such as magnetic flux, linking, emf and induction were either omitted or misused. This is clearly an area where there is much misunderstanding.

(e) On the other hand, candidates were well able to cope with the (straightforward) calculation of the induced emf across the secondary coil. However, a frequent omission was the final conversion to a peak value.

(f) This whole sequence of calculations was poorly done. Candidates appear never to have considered the problem of energy loss in the cabling between energy generator and consumer. This ought to be straightforward work for the candidates, but it proved not to be. Solutions as a whole were confused with little clear explanation of what was going on. Candidates were evaluating the wrong quantities without realising it and then misapplying them later in the question. As an example, simply labelling a quantity as "*Power* =…" is unhelpful. What power is being referred to by the candidate? The argument *must* be clear in order that an examiner can award error carried forward.

(g) Many had rote learnt the first point about laminations in a transformer core: that the eddy currents are reduced. However, a good candidate will realise that the nature of the core must mean that they are never entirely eliminated – complete elimination of the currents was a common and incorrect answer.

Question 9 Part 1 HL and Question 6 Part 2 SL

(a) **HL and** (e) **SL** In this “show that” question the working was again obscure, read-offs from the graph (essential) were not flagged up, and presentation was negligent. There was a common failure to read the correct line on the graph.

(d) **SL only** Examiners expected to see some superlatives in the answer. The statement that the resistance of an ammeter must be less than R was not sufficient. It needs to be very much less, almost negligible. Similarly, saying that it is zero does not answer the question (and cannot strictly be true).

(b)(i) **HL and** (f)(i) **SL** Discussions of the internal resistance of a cell were woolly and failed to get to the heart of the matter: that the resistance arises from the material inside the cell and that these lose energy from the complete circuit (except when an open circuit – see later).

(b)(ii) **HL and** (f)(ii) **SL** The first of two poorly answered calculations. As in previous series, candidates reveal that even relatively simple electrical calculations are beyond them. This is a topic that needs considerable attention in schools as it is disturbing to find that only a handful of physicists, some on the brink of a university career, cannot perform these calculations with confidence and accuracy.

(b)(iii) **HL only** This was somewhat better than the previous question and all that candidates had to do was to insert derived values into an equation. However, as in question 8 Part 2, the wrong quantities were sometimes used.

(c) **HL and** (g) **SL** The emf was only calculated correctly (allowing for errors carried forward) by about half the candidates.

(d) **HL only** A considerable lack of thought was in evidence in this part. The correct answer can be stated baldly: *a short circuit means that R is zero and therefore the emf of the cell acts on the circuit and the power acting can be read directly from the graph as about 1.5 W. It is greater than 1.2 W and will therefore damage the cell*. Few managed to answer in such a direct or convincing way. Most used weasel words that simply repeated the first sentence of the question back to the examiner in an alternative way.

Question 9 Part 2 HL only

(e) While very many candidates scored a maximum 2 out of 2 marks for this part, this was only because there were 3 marks available. Circles were rarely circular – most were freehand sketches (do modern candidates not possess drawing instruments?). It was rare to see accurate drawings that showed a clear greater line spacing as the distance from the wire increased.

(f) Many scored 2 out to 3 in this part through failing to give the direction rule (first alternative in the mark scheme) by which they assigned the force on the bottom wire. The second alternative attracted maximum marks for many.

(g)(i) This simple calculation was well done. The unit, however, was frequently incorrect (not a marking point).

(g)(ii) Only a handful of candidates were able to work this problem through. Significant hurdles for many included: failure to calculate the volume of the wire (not just a radius/diameter confusion, a genuine inability to operate $l\pi r^2$ convincingly), inability to include the charge on the electron correctly, and an apparent misunderstanding of the operating equation with trigonometric functions appearing out of the blue.

(h) Many simply stated the answer without any rigorous explanation of the causal links and therefore scored a generous one mark for what might have been close to a guess (had the option of "no change" not been available).

Recommendations and guidance for the teaching of future candidates

It is recommended that candidates should be taught:

- to structure their calculations giving full explanation of the steps undertaken
- the meanings of the command words in the papers
- a better understanding of electrical theory with full weight to the concepts of the topic
- to structure answers where a standard description of a topic is required, eg the induction of an electromotive force across the secondary coil of a transformer
- to avoid simple slips in calculations, e.g. in powers of ten
- the importance of including units in an answer.

Higher and standard level paper three

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 7	8 – 15	16 – 22	23 – 27	28 – 33	34 – 38	39 – 60

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 4	5 – 9	10 – 13	14 – 17	18 – 20	21 – 24	25 – 40

General comments

Only a small percentage of the total number of teachers or the total number of centres taking the examination returned G2 forms. For SL there were 28 responses from 230 centres and for HL there were 23 responses from 286 centres. While we thank those who took the trouble to provide G2 feedback, we would continue to urge all centres to contribute; comments from teachers are carefully considered and inform the process of setting realistic and fair grade boundaries given the nature of the paper.

The replies received indicated that the November 2015 papers were generally well received, with many of the G2 forms received containing favourable comments. 96% of the HL respondents and 100% of the SL respondents felt that the paper was of an appropriate difficulty. Compared with last year's paper it was deemed to of a similar standard by around 70% of HL and SL respondents, around 10% rated it a little easier and the remaining 20% rated it a little more difficult.

All respondents were satisfied with the clarity of wording and presentation of the paper.

The paper was prepared well; each of the options contained questions with a broad variety of knowledge and skills to be presented and applied. The difficulty of each of the options was almost the same. The candidates proved that they had enough time to complete the paper. Discrimination of the paper was at the proper level. Among answers we can see many examples of good understanding in each of the questions. Almost all candidates answered all questions from two options selected; it seems that no candidate forgot to answer a part of a question from the options selected. The vast majority of candidates kept responses in the answer boxes provided and if they used extension sheets they referred to this within the answer box. Handwriting seems to be at the same level as other sessions, generally, the answers were legible and no rescan was necessary. There was no problem with marking in black-and-white.

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

Each of the questions was accessible to well or average prepared candidates. Some average prepared candidates failed in explaining concepts in clarity and writing definitions of physical quantities. Generally, phrases such as define, show that, compare, discuss, calculate, and outline were better addressed by candidates than in previous sessions. Some weaker candidates demonstrated difficulty in explaining well-known phenomena or well-known relations, while some of them only rewrote the question.

Other difficulties:

- Arithmetic and algebraic mistakes, calculator mistakes.
- Power of ten (POT) mistakes in calculations.
- Layout of working in numerical questions; bad layout and incorrect answer sometimes makes it difficult to award partial marks.
- Sequencing the presentation of facts to support an explanation and description.
- Analysing a real situation, where information is given in the form of sketch and/or graph, eg in questions 11, 14, 15, 16.
- Quite often average prepared candidates read questions superficially and, even if they wrote some correct sentences, did not answer the question.

Difficulties related to syllabus details:

Wien's law, meaning of λ_{MAX} (E2.6)

Parallax method, basic understanding (E3.2)

Hubble's law, its limitations (E6.5)

Modulation, communication of clear idea (F1.1, F1.2)

Amplifier, gain of the circuit, input/output voltage (F5.6)

Schmitt trigger, calculation (F5.5)

Virtual image, meaning of (G2.5)

X-ray spectrum and potential difference applied (G5.3)

Relativistic momentum and energy, calculation (H5)

Michelson–Morley experiment, expectation and observed evidence (H5.4)

Analysing intensity level vs frequency graph (I1.10)

Particle accelerators, structure and operation (J2.3, J2.4)

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

The best candidates have clearly seen the syllabus and also some of the previous examinations and presented good understanding. The well prepared candidates can analyse the situations, present working in logical manner and use proper terminology, physical quantities and units. The majority of candidates presented the ability to read and understand questions. They demonstrated understanding of facts and concepts and were able to use them with proper terminology. Most candidates proved ability to clearly present well known facts in words and sentences. In numerical answers this year we see that use of units and significant figures was much better than in previous years.

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

Option A – Sight and Wave Phenomena (SL only)

A popular option.

A1 The Eye Most candidates knew that rods were activated for low-light viewing and cones were activated for bright-light viewing. Spectral response characteristics of the different cells were not as well known. While the locations of the rods and cones were known, the explanation for the differences in perception were rarely given or apparently understood.

A2 Sound Waves Many candidates drew the 5^{th} harmonic, not realising that the harmonic number is related to the multiple of the frequency which is only odd in “closed” pipes. This was not penalised in ECF.

A3 Diffraction and resolution The majority could correctly sketch the diffraction pattern and only a few showed non-zero intensity at the minima. The definition of Rayleigh’s criterion was well known but candidates found it difficult to gain full marks explaining how the Rayleigh criterion applies to diffraction patterns, as asked. The calculation was well-attempted.

A4 Polarization A good majority misinterpreted the question, explaining how the LCD works rather than describing how it can be demonstrated to be polarized.

Option B – Quantum Physics and Nuclear Physics (SL only)

A very popular option.

B5 Photoelectric effect The general idea of the photon explanation of the photoelectric effect was well known, but only a few clearly referred to photon energy transfer. Very few could explain why monochromatic light gives varied electron energies, most referring to various frequencies of light as the reason. The common mistake was the electron gaining different amounts of energy from different frequencies (despite monochromatic being stated in the question). While threshold frequency was well understood the effect of intensity was usually overlooked. The calculation was usually well attempted.

B6 Energy level transitions The hydrogen atom energy diagram was generally well-answered. The energy of the maximum wavelength was usually confused with the maximum frequency. The description of the photons of different energies were usually answered incompletely, not referring to both the radiation and the hydrogen atoms. A number of candidates referred to hydrogen atoms jumping energy levels, rather than electrons.

B7 Radioactive decay This was generally well answered, although a significant minority insisted that nuclear half-life is defined by a loss of mass.

Option C – Digital Technology

An unpopular option.

C8 Data storage capacity This question was generally well answered, except that many candidates failed to estimate the number of characters in a word for the calculation.

C9 Charge-coupled devices The definition was generally well answered. The determination of potential difference was usually without annotation to allow the marker to follow the thinking. The output was often given only in decimal, rather than in binary as required.

C10 (F6 HL) Amplifier circuit In general the gain was found correctly. Few candidates presented a fully correct sketch, though most made some attempt to add a scale and gave a generally correct shape. The calculation of the input value was often not attempted and very rarely answered correctly. (See section in Option F for HL comments on the same question).

Option D – Relativity and particle physics

Not a very popular option.

D12 (H12 HL) Relativistic kinematics Only HL Questions 12(a), (b)(i) and (c) were common with SL questions 12(a), (b)(i) and (c). Many did not address “frame of reference”, only explaining “inertial”. Most could identify the postulate relevant to Galilean transformations but few could earn full marks. The calculation was well done by those who attempted the question.

D13 (See section in Option J HL for comments).

Option E – Astrophysics

One of the most popular options.

E1 (E14 SL) Distance to a nearby star Well discriminating question, better candidates realized that the star is closer to Earth and drew the diagram. Many candidates made a mistake to present diameter and the angle, giving half of the proper values. The relationships were generally well explained. In the alternative pair of quantities many candidates stated only the quantity for distance, not for the angle. The HL question related to Hubble’s law was properly answered only by better candidates. The SL question was poorly answered with most confusing stellar and spectroscopic parallax.

E2 (E15 SL) HR diagram and the Sun SL candidates notably addressed absolute magnitude without referring to apparent magnitude as the question asked. Well-prepared candidates (both HL and SL) only had a problem with the part related to the use of a non-linear temperature scale. Average prepared candidates displayed difficulty in the experimental measurement of the temperature of the distant star and also with details of nuclear processes occurring in the Sun during transformation to a red giant.

E3 (E16 SL) CMB radiation Well done by candidates, weaker candidates did not write their ideas clearly enough in (a)(ii). Part (b) was also quite well done, but only better candidates mentioned uncertainty in measurement of distances to galaxies. At SL the calculation of the temperature of the CMB was successful for most candidates, however, relating it to Newton's static universe polarised candidates into non-answers or correct answers.

Option F – Communications

This option was not so popular, and only better candidates proved good knowledge in this option.

F4 (F17 SL) Modulation and satellite communication A high number of candidates failed to clearly define the basic concept of modulation and did not use clear terminology of carrier and signal waves. A quite common mistake was made in (b)(iii), where many candidates result was double the right value by misusing the carrier wave frequency. Discussions about advantages of geostationary and polar satellites were quite well presented for HL. In SL answers were very vague.

F5 (F18 SL) Sampling and fibre optics Time-division multiplexing was well presented by the majority of HL candidates, but calculations in sampling and attenuation proved difficult for average prepared candidates. SL candidates tended to give poorer, vaguer answers and frequently did not attempt the calculation.

F6 (C10 SL) Amplifier circuit While calculation of gain was well done by average candidates, other calculations were made only by better candidates, and correct Schmitt trigger calculations were made correctly by only the few best candidates. Presenting variation of input-output voltages in a graph was also difficult, with the proper values in the axes often missing, especially for weaker candidates. (See section in Option C for SL comments on the same question).

Option G – Electromagnetic waves

Relatively popular option for HL and very popular for SL

G7 (G19 SL) Light scattering HL candidates were able to discuss and outline common natural phenomena using proper physics terminology. SL candidates were less well-prepared, and a significant number expressed very unscientific views.

G8 (G20 SL) Convex lens As usual, geometrical optics is well managed by all candidates, but weaker candidates made some mistakes in calculation and in explanation of the virtual image.

G9 (G21 SL) Light interference For HL candidates quite an easy question on a topic which has proved difficult in past sessions, but generally well mastered this year. SL candidates could generally suggest a reasonable method to make sure the light was coherent, but rarely earned full marks in explaining why P was a dark fringe.

G10 X-rays Surprisingly a lot of mistakes were presented in the answers, with even better candidates shifting the peak intensities in the graph and only a few candidates explained changes in the graph well referring to energies and the target material.

G11 Thin-film interference Vast majority of candidates calculated the values well and also explained destructive interference properly.

Option H – Relativity (HL only)

Very popular option.

H12 Relativistic kinematics This question required quite high ability to apply relativistic kinematics in standard situations and also explain the twin paradox. Well done by average and better candidates. There was a slight change made to the wording of the question 12(b)(ii) in the published paper and published markscheme in comparison with the wording used in the exam.

H13 Relativistic mass and energy Discriminated well between the best and average candidates, in part (a)(ii). Many weaker candidates did not distinguish between energy and kinetic energy of the particle, and often also forgot to calculate the potential difference; part (b) proved difficulty for majority of candidates, even if some very clear and good answers are among the answers of better candidates.

H14 Michelson–Morley experiment Well done by majority of prepared candidates, but some, even if well prepared, demonstrated difficulty in giving essential details in discussion about expectations of the experiment.

H15 General relativity Part (a)(i) and (b) were done well. Discussion about the shift in frequency in (a)(ii) was difficult as many candidates did not mention potential energy or other equivalents in the discussion.

Option I – Medical physics (HL only)

Quite popular option, often well scored.

I16 Hearing loss Answers in part (a) contained general ideas not connected to the elderly person, whose audiogram was presented, but many candidates who read the question carefully gave nice correct comparisons. In part (b) the only not well scored issue was the frequency dependent threshold of normal hearing forgotten in majority of answers in (b)(i). Nice was, that majority of candidates properly read the value from the graph in (b)(ii) and suggested real social and economic implications in (c).

I17 Radioactive tracers Nice and not easy question, well discriminating through whole range of candidates. Some candidates proved difficulty in definitions and proper terminology in the topic of half-life, and continued in difficulty in ideal properties of a tracer in (c). Other candidates made mistakes in the calculation in (b).

I18 Use of ultrasound Often well answered with clear outlying of the frequency appropriateness in different depths of organs displayed.

I19 Attenuation Generally easy, well answered question well discriminating between weak and average candidates.

Option J – Particle physics

Not very popular option, but well answered by many candidates who selected this option.

J20 (D13 SL) Interactions and quarks Well answered question, often very clearly and straightforward; some, even better candidates made mistakes in calculation in (b)(iii). SL candidates showed more difficulty with (b)(iii), often using an incorrect approach.

J21 Particle accelerators Quite a hard question, but well answered by better candidates. Many candidates read part (a) superficially and did not focus their answer on the variation of the field and also many candidates made mistakes in (b).

J22 Particle interactions Generally well answered.

J23 Deep inelastic scattering Generally the answers were vague, without essential details, and so often partly scored.

J24 Nucleosynthesis in the universe Calculation in (a) was well done by vast majority of candidates and (b) was answered well only by few the best candidates.

Recommendations and guidance for the teaching of future candidates

Based on the evidence gathered from the responses this session, and considering the new Physics syllabus for the next sessions, we can offer the following recommendations:

Candidates score better in paper 3, if they:

- are informed about aims, objectives and syllabus details at an early stage of IBDP study and at the final stages of preparing they check understanding of basic terms and definitions mentioned in the Physics guide;
- are informed about standard command terms and the terms are often used in communication between teacher and candidate during the whole learning/teaching process; this seems to be equally important in teaching candidates who are working in their mother language or in a second language;
- study both options before revision of core physics, so at revision they can see the connections among topics;
- use the Data Booklet when solving multistep, complex problems;

- practice questions from past papers relevant to the new syllabus;
- try not only to understand and apply, but also to remember precise formulations of definitions, especially of physical quantities used only in options;
- try to connect knowledge specific to optional topics to core physics, take it as context to use of general physics quantities such as energy, power, force, pressure ... ;
- study an option together, with the teacher, not on their own;
- are trained to express their ideas in written form: in a logical manner, with a proper layout, showing each step, even if “fully clear”; sometimes candidates do not write such obvious information, such as that mass has gravity, or the speed of light is constant for each observer, and it is hard to see if such information is or is not implicit in their answers; if such information is necessary, especially in “show that” questions, it should be mentioned;
- are also encouraged to write some words explaining their working in calculations, derivations and other use of formulas; especially in not fully correct answers or alternative answers this can be helpful and candidates can reach some marks for partly correct working; also candidates might find their own mistakes in derivation, or calculation and can amend their answer;
- do not neglect units, sporadically we can see mistakes, eg well calculated distance and time unit used; or well calculated energy and unit of power used;
- are encouraged to be careful with the difference between “equal” and “proportional”;
- are performing a whole range of empirical learning as in core physics; activities such as simple laboratory demonstration of parallax, location of a star in the night sky, or working with computer interactive model of X-ray tube can significantly raise, amongst others, the self-confidence of the candidates;
- re-read the question, after answering or formulating their answer (to check they are answering what is asked);
- take into consideration the number of marks allocated to a question, as a general guide to the detail required and the time to be spent on the question.

Candidates must be reminded that every word must be readable, that the process is two ways – it is not enough to write the answer, somebody must be able to read and assess the answer. Answers must be in the box or on additional sheets.

Also candidates should be reminded that incorrect answers are not penalized, so the working and answer should be crossed out only if an alternative better answer is given. Sometimes a partly correct answer is crossed out and no other answer is offered by some candidates.