External Assessment Report 2011

Subject	**Physics**
Level	**Higher**

The statistics used in this report are pre-appeal.

This report provides information on the performance of candidates which it is hoped will be useful to teachers/lecturers in their preparation of candidates for future examinations. It is intended to be constructive and informative and to promote better understanding. It would be helpful to read this report in conjunction with the published question papers and marking instructions for the Examination.

Comments on candidate performance

General comments

It is pleasing to report that there was again a significant rise in the number of candidates sitting the Higher Physics examination, bringing this year's total to over 9,500.

Markers believe that this year's paper provided good accessibility for 'C' grade candidates and at the same time had appropriate questions to provide good discrimination for those performing at 'A' and 'B' grades.

Markers have commented that some candidates were extremely well prepared for the 2011 examination and gained very high marks. They also say that only a small percentage of candidates were very poorly prepared for the examination.

It remains the case that although questions requiring candidates to perform calculations are generally answered very well, most candidates continue to perform much less well in questions requiring written descriptions and explanations. Centres and candidates should note that the ability to write descriptive answers and explanations is likely to receive at least as much, if not more, emphasis in future assessment under Curriculum for Excellence.

Areas in which candidates performed well

The multiple-choice section of the paper was found to be straightforward by most candidates, with questions 1, 6, 8, 9, 12, 16, 19 and 20 being answered particularly well.

Question 21 — In parts (a)(i) and (ii), it was pleasing to see a high proportion of candidates substituting into the equations of motion correctly. This required them to take care not to confuse the values of '*u*' and '*v*' and to ensure positive and negative signs were used consistently ('*a*' being in the opposite direction to '*u*').

Question 23 — Part (a)(i) required candidates to calculate the density of air from the given measurements and data. Most did this very well.

Question 24 — In part (b)(ii), where candidates had to analyse a parallel combination of resistors connected to a supply with an internal resistance, it was good to see a high percentage of candidates working through to the correct final answer for the unknown resistance '*R*'. It should be noted, however, that many candidates produced a very unstructured answer. Their analysis was unclear and would have gained few, if any, marks had their final answer been incorrect.

Question 25 — The calculations in parts (b)(i) and (ii) (to find the current in the circuit and the change in energy stored in a capacitor) were generally very well done.

Question 26 — In part (a)(i), most candidates were able to identify that the circuit diagram showed the op-amp connected in inverting mode. In part (b), most candidates sketched the correct graph for the output voltage of the op-amp circuit in differential mode.

Question 27 — Parts (a)(i) and (a)(ii)(A) were well done. Most candidates were able to substitute the given data into Snell's law to find the angle of refraction and the critical angle without difficulty.

Question 28 — For part (a), most candidates were able to state that the demonstration of interference is a 'proof' for the wave nature of light. In part (b)(i) the majority of candidates correctly applied the grating relationship to calculate the wavelength of light.

Question 29 — In parts (a)(i), (a)(ii) and (b)(ii), the calculations related to the photoelectric effect were generally well done.

Question 30 — This whole question was generally well done. In part (a)(i), most candidates were able to identify that the statement represented a fusion reaction. In part (a)(ii), most candidates correctly found the loss in mass and then used Einstein's formula, $E = mc^2$, to calculate the energy released in the reaction. Similarly, in part (b)(i), a high proportion of candidates were able to calculate the energy gap and use it correctly to calculate the wavelength of the absorbed light.

Areas which candidates found demanding

In the multiple-choice section of the examination, the only really poorly answered question was Question 7, where only 40% of candidates chose the correct option (A).

Question 21 — Candidates showed some strengths in using equations of motion, but their understanding of projectile motion was weak. Specific areas of weakness were:

- Part (a)(i):

  Substituting the values for ‘*u*’ and ‘*v*’ the ‘wrong way round’. This is wrong physics and allows only the formula mark to be awarded.

  Failing to have opposite signs for ‘*u*’ and ‘*a*’. This is wrong physics and allows only the formula mark to be awarded.

- Part (a)(ii):

  This is a ‘Show’ question and a candidate must start by writing a relevant formula and then substituting given data. It is not acceptable to start with just numbers in an answer to this type of question.

  As in part (a)(i), ‘*u*’ and ‘*v*’ must be substituted the ‘correct way round’; ‘*u*’ and ‘*a*’ must have opposite signs.

  Some candidates lost marks by making a unit error by writing ‘secs’ — this is not an SI unit. The abbreviation for ‘seconds’ is ‘s’.

- Part (b)(i):

  As the question asks for ‘the **velocity** of the ball after 0·71 s’, a **direction must be given** as well as a value.

  It is not sufficient to state both the horizontal velocity and the vertical velocity. The candidate must show the result of the **combination** of these components.

- Part (b)(ii):

  This is a ‘must justify’ question. If no attempt is made at providing a justification, no marks can be awarded.

  It is essential that an answer makes clear whether the candidate is referring to the vertical component of velocity or the horizontal component of velocity. Answers which vaguely refer to ‘velocity’ or ‘speed’ cannot be expected to receive the justification mark.

Question 22 — Overall, this question was not answered well. Many candidates showed significant weaknesses in their understanding of the relationship between impulse and momentum and of the vector nature of these quantities.

- Part (a)(i):

  Rather than finding the area under the force–time graph, some candidates tried to calculate impulse from 'force x time'. However, when substituting for '*F*' they used '6·4 N'. This is wrong as it is the value of the maximum force.

  Many candidates wrongly wrote the units for impulse as 'N s^{-1}' or 'N/s' instead of 'N s'.

- Part (a)(iii):

  Many errors were made by candidates when attempting to use the relationship 'impulse = change in momentum'. The graph given in the examination paper shows the initial velocity of the cart to be 0·48 m s^{-1} and the final velocity '-0·45 m s^{-1}'. Many candidates failed to use opposite signs in their substitutions or they substituted '*u*' and '*v*' the 'wrong way round'. Of those who substituted '*u*' and '*v*' correctly, many made a different error by substituting the 'change in momentum' as positive rather than negative.

  Again there were many examples of candidates using the maximum value of the force rather than its average value.

- Part (b):

  Candidates were told to 'Copy the force–time graph shown and, on the same axes, draw another graph to show how the magnitude of the force varies with time in this (second) collision. … you must label each graph clearly'. Despite this instruction, a significant number of candidates gave so little information on their graphs that it was impossible for the Marker to identify which graph was 'new' and so no marks could be awarded.

Question 23 — Specific areas of weakness were:

- Part (a)(i):

  A small proportion of candidates failed to convert the units of their answer correctly into kilograms per cubic metre. There was even an example of a candidate saying that the examination paper was wrong in giving the information,
  'Volume of bell jar = 200 ml = $2{\cdot}0 \times 10^{-4}$ m^3'!

- Part (a)(ii):

  The 'expected' answer to the reason for the calculated value in part (a)(i) being too low was that not all of the air had been evacuated from the bell jar. However, many candidates suggested a reason which would have made the answer even worse. For example, some said that 'some air has leaked out of the bell jar' — this shows a basic lack of understanding of the physics of the situation.

- Part (b)(i):

  Despite the availability of the data booklet, a small number of candidates started by writing a wrong relationship, eg $P_1/V_1 = P_2/V_2$.

  The majority of candidates failed to realise that a constant mass of air has changed from occupying an initial volume of 200 ml to a new volume of 250 ml. They displayed poor understanding of physics by using a final volume value of 150 ml.

- Part (b)(ii): This part asked for an explanation of the change in pressure in terms of the kinetic model.

  The essential starting point in an answer requires a description of the **gas molecules colliding with the walls of the container**. Too many candidates failed to supply this. They provided only vague references to 'collisions' which did not say what was doing the colliding or what they were colliding with.

  The decrease in the **frequency** of the collisions (between the molecules and the walls) has to be given as part of the explanation. Again, too many candidates provided only vague answers such as 'less collisions' rather than 'fewer collisions per second' or 'less frequent collisions'.

  Candidates also made reference to the 'force' of collisions without making it clear whether they were referring to the force of individual collisions or an overall average force.

  Despite the question specifically saying that 'The temperature of the air remains constant', many candidates gave answers in which they described the kinetic energy of the molecules changing.

Question 24 — Although this question was answered quite well overall, areas of weakness were:

- Part (a)(i):

  A significant number of candidates did not know the meaning of e.m.f. — content statement 2.1.7.

  Of those who had learned the general definition of e.m.f., many failed to provide the **specific value** required in this example, ie '**ten joules** of (electrical potential) energy are given to **each coulomb** of charge **passing though the source/supply'**.

- Part (a)(ii):

  This is a 'Show' question and the candidate must start by writing a relevant formula and then substitute the relevant given data. It is not acceptable to start with just numbers in the answer to this type of question. For example, those who decide to answer by analysing the 'lost volts' should state,

  'lost volts = e.m.f. – terminal p.d. = 10 – 7·5 = 2·5 V' and not just say 'lost volts = 2·5 V'.

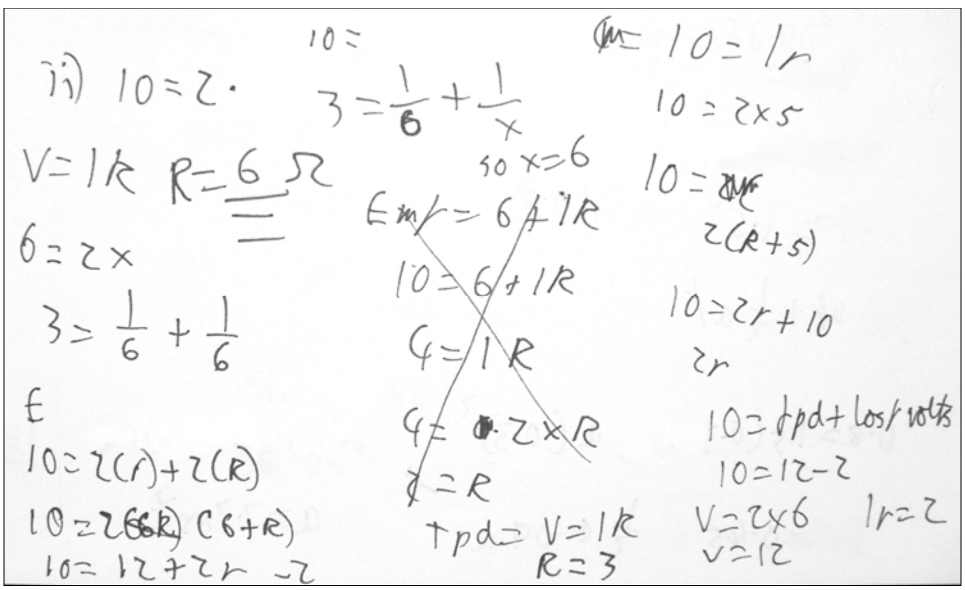
- Part (b)(i):

  Candidates were asked to ‘Explain why the reading on the voltmeter has decreased’.

  Markers reported an increase in the number of candidates using up (↑) and down (↓) arrows rather than using words. Whilst this may be acceptable ‘shorthand’ for use while making their own notes during lessons, candidates should not use this symbolism for communicating physics to others — as in examination answers.

- Part (b)(ii):

  The structure of the answers given by many candidates was often poor. Markers had difficulty following the logic or reasoning in these answers. Many candidates wrote various numbers and formulae in an apparently random arrangement. For example, the following is a candidate’s response to Q24 (b)(ii):



  Candidates must realise that it is in their own best interests to make the order and logic of their analyses clear to the Marker. They could clarify what they are attempting to calculate by using subscripts. For example, they could state ‘R_{total} = e.m.f./current’ or ‘$R_{external}$ = (terminal p.d.)/current’, rather than repeatedly stating ‘$R = V/I$’.

  A significant number of candidates calculated that the combined parallel resistance is 3 ohms, but then wrote ‘$3 = 1/R_1 + 1/R_2$’, rather than ‘$⅓ = 1/R_1 + 1/R_2$’.

Question 25 — Areas of weakness were:

- Part (a):

  A significant number of candidates did not know the meaning of capacitance — content statement 2.3.3.

  Of those who had learned the general definition of capacitance, many failed to provide the **specific value** required in this example, ie '**200 microcoulombs** of charge are stored for **every volt** across the plates'.

- Part (b)(i):

  The resistance value was given as '1·4 kΩ' — a small number of candidates did not know the meaning/value of the prefix 'kilo'.

  A significant number of candidates did not round their final answer correctly. Rounding the answer of $8{\cdot}571428571 \times 10^{-3}$ amperes to two significant figures gives $8{\cdot}6 \times 10^{-3}$ A. Markers often saw the final answer given as '$8{\cdot}5 \times 10^{-3}$ A'.

- Part (b)(ii):

  This part required two energy calculations to be performed. Once the initial energy and the final energy values have been found (at 12 V and 4 V respectively), a subtraction gives the required decrease in energy in the capacitor. A significant number of candidates, however, thought that this could be done with a single calculation using $E = ½CV^2$ and the voltage **difference** of 8 V. This is wrong physics and only the mark for the relationship can be awarded.

  Some candidates rounded the initial energy value (an intermediate calculation). This led to an inaccurate final answer (and to the loss of marks).

  The capacitance value was given as '200 μF' — a significant number of candidates did not know the meaning/value of the prefix 'micro'.

- Part (c)(ii):

  Despite being told in the question that the ball 'is travelling at 1·5 m s^{-1} when it reaches foil A', some candidates substituted a value of zero for '*u*' in their chosen equation of motion.

- Part (c)(iii):

  Candidates' answers as to why the new experimental arrangement gives a more accurate result were nearly always vague and imprecise. Markers often saw responses such as 'measurements are more accurate' and 'uncertainties are less'. Most candidates did not show an appreciation of the difference between absolute uncertainty and percentage uncertainty. In this experiment, the absolute uncertainties in the measurements of both the time and the distance will be the same as before, but the percentage uncertainties in both measurements will be reduced as a result of the distance (and the time) being increased.

Question 26 — Overall, this question was answered quite well. However, some areas of weakness were still evident:

- Part (a)(i):

  A small, but not insignificant, proportion of candidates could not identify that the op-amp is connected in inverting mode. Markers saw answers such as ‘inverted’, ‘non-inverting’ and ‘differential’.

- Part (a)(ii):

  Despite answering part (a)(i) correctly, many candidates missed out the negative sign in the inverting mode relationship. This is regarded as wrong physics as the answer starts with an incorrect relationship — no marks can be awarded.

- Part (a)(iii):

  Many candidates said that ‘the output voltage saturates’ instead of explaining that because the **op-amp saturates**, the output voltage cannot exceed the supply voltage.

  Some candidates were careless about the difference between ‘input’ and ‘supply’. They gave wrong answers such as ‘the output voltage cannot exceed the input voltage’.

- Part (b):

  Marks were lost by some candidates because they failed to fully label both axes of their graph. Each axis should be labelled with both the name of the quantity and its units.

  Some candidates’ graphs were carelessly drawn and so lost marks. For example, the output voltage **remains constant at +2·0 V** for the whole of the first second — a ‘freehand’ graph line which shows V_o varying in value during this time cannot gain the marks.

  Some candidates produced two **conflicting** answers to this question — one in their booklet and another on separate graph paper. Markers need to be clear which version the candidate wishes to be marked. Candidates should delete any draft answer(s).

Question 27 — The calculations in this question were answered well. However, the parts requiring deeper analysis and explanations were not answered well. Areas of weakness were:

- Part (a)(ii)(A):

  Some candidates rounded the value of 1/1·66 too much before finding the inverse sine (ie rounding 0·6024096386 to 0·6). This led to an inaccurate final answer for the angle of refraction.

- Part (a)(ii)(B):

  In this part of the question, the refracted ray is emerging along the face of the prism. This, therefore, means that the angle of incidence is equal to the critical angle. Angle ‘X’ is therefore equal to twice the value of the critical angle. Very few candidates realised that this was the case and many tried to answer using incorrect geometrical analysis.

- Part (b): Many candidates' errors and misunderstandings were shown up, eg:

  - confusion between 'reflection' and 'refraction'
  - lack of understanding of the difference between 'internal reflection' and '**total** internal reflection'
  - stating the wrong relationship between wavelength and frequency
  - wrongly stating that a higher frequency corresponds to a smaller refractive index
  - wrongly thinking that the ratio of frequencies equals the ratio of refractive indices
  - inappropriate terminology, eg 'blue light **bends more** than red'

Question 28 — In general, this question was poorly answered.

- Part (a):

  Although most candidates were able to state that the demonstration of interference is a 'proof' for the wave nature of light, a few seemed confused and gave answers like 'It shows that light behaves as a stream of particles' or 'It proves that light behaves as a wave and particles'.

- Part (b)(i):

  Although the majority of candidates correctly applied the grating relationship to calculate the wavelength of light, a few candidates failed to divide the given angle of 22° by 2. Some failed to realise that the given data only allows a calculation to be carried out for '*n*' = 2.

- Part (b)(ii):

  Very few candidates realised that the decreasing refractive index causes the wavelength to increase which, in turn, causes the interference maxima to spread further apart. It was common for candidates to make the mistake of trying to explain a pattern change in terms of light **refracting** differently compared with before the temperature was increased.

  Some candidates thought that the '*n*' in the grating formula stands for the refractive index of the medium.

Question 29 — Areas of weakness were:

- Part (a)(i):

  This is a 'Show' question and required candidates to write down the relevant formula(s), substitute correctly and write down that this calculation gives the required answer. Some candidates rounded their intermediate answer for frequency, making it impossible for the energy value to be exactly as required — full marks could not be awarded for this.

- Part (b)(i):

  Candidates were asked why the kinetic energy of electrons is zero below the (threshold) frequency, f_o. Very few gave a full explanation in terms of the energy of a photon being less than the work function of the metal. Some referred to the 'energy of the radiation' being insufficient, but this does not get to the heart of the reason — ie one photon interacts with (and gives all its energy to) one electron.

- Part (b)(ii):

  Many candidates rounded their calculated value of the threshold frequency ($3{\cdot}3785822 \times 10^{14}$ Hz) wrongly to $3{\cdot}37 \times 10^{-3}$ 10^{14} Hz instead of to $3{\cdot}38 \times 10^{-3}$ 10^{14} Hz.

Question 30 — Overall, this question was answered well. Areas of weakness were:

- Part (a)(i):

  A disappointingly high number of candidates were unable to identify the given reaction as being '(nuclear) fusion'.

  A worryingly large number of candidates gave 'fussion' as their answer. Markers reported that this response was seen more frequently than ever before. This is not awarded any marks. It cannot be accepted as poor spelling of 'fusion' as it could also be poor spelling of 'fission'.

- Part (a)(ii):

  Despite advice in previous external assessment reports, there were still a large number of candidates who rounded mass values before finding the loss in mass in the reaction. The loss in mass during a fusion reaction is so small that the effects of early rounding make the answer very inaccurate. Carrying out such inappropriate rounding is wrong physics.

- Part (b)(i):

  When attempting to find the energy gap between the given levels, a significant minority of candidates performed the subtraction the 'wrong way round' and so ended up with a negative energy. This is another mistake which means few marks can be awarded, as it is wrong physics. Whilst it is acceptable to have a negative value for an energy **level** (as this depends on where 'zero' is defined), it is not acceptable to have a negative energy **value** for a photon.

- Part (b)(ii):

  There were candidates whose answer for the wavelength in part (b)(i) was correct but who could not match this with an appropriate colour in the visible spectrum. It is disappointing that they did not refer to the data sheet (on page two of the examination paper) to find helpful information.

Other general issues:

- Some candidates were careless in transferring data from the question paper to their answer script. For example, in 24(a), substituting the number ‘1·2’ for current (instead of the given ‘1·25’).
- A number of Markers complained about the difficulty they had in reading the answers of candidates who used a pencil and wrote their answers very faintly.
- Markers reported that some candidates were poor at labelling their answers to match the given parts of questions.

Advice to centres for preparation of future candidates

General

Candidates must read each question very carefully and ensure that their response really does answer what has been asked. Candidates should be encouraged to re-read a question immediately after writing their answer. This procedure could reduce the frequency of inappropriate or incomplete answers.

Candidates should be strongly encouraged to present their numerical analyses in a clear and structured way — Markers need to be able to follow the logic in their answers.

Candidates would benefit from re-reading their answers in the examination, asking themselves the question 'Will a Marker follow/understand the structure and reasoning of my answer?'

If the answer to this question is 'No' or even 'Possibly not', they should aim to improve their attempt.

When a candidate makes two (or more) attempts for the same part of a question, they must score through the part(s) which they do not wish to be considered by the Marker — they must not leave alternative answers for the Marker.

Candidates must take great care to transfer data accurately from the examination paper to their answers. Developing a habit of double-checking that figures have not been transposed or omitted could reduce the number of such costly errors.

Candidates must remember to quote direction as well as magnitude when giving vector quantities as answers.

Candidates must take great care to substitute the initial velocity value for u and the final velocity value for v in the equations of motion and in the relationship for calculating change in momentum.

Candidates must be careful to take into account the vector nature of u, v and a in the equations of motion, and other relationships such as change in momentum, to ensure that they substitute the values as being positive or negative as appropriate.

Candidates must start their answers to 'show' questions by quoting an appropriate formula before any numbers/values are used. The substitution of numbers should then use the data given in the question without further guidance and 'mental arithmetic' having been performed.

Most candidates need more practice in writing descriptions and explanations. They need to be more careful in the detail and precision of the language used in their descriptions and explanations.

When writing a description or explanation in which a quantity such as wavelength varies, candidates should say ‘the wavelength increases’ rather than ‘the wavelength ↑’ or ‘the wavelength decreases’ rather than ‘the wavelength ↓’.

Many candidates would benefit from spending more time learning correct technical terminology (like ‘op-amps’ saturate, not ‘voltages’) and correct spelling (like ‘fusion’, not ‘fussion’). To help them do this, candidates should be encouraged to study carefully the content statements for the Course.

Candidates must understand that to ‘sketch’ a graph does not mean that the graph can be untidy or inaccurate. The instruction to ‘sketch’ a graph only means that ‘it does not have to be drawn to scale’. Care should still be taken to present these sketches as neatly as possible. For example, a ruler should be used to draw the axes and any straight sections of the graph line. The origin and axes on sketch graphs must be labelled and any important values carefully shown.

Some candidates would benefit from further advice and practice on presenting their final answers to an appropriate number of significant figures.

In numerical calculations, candidates should round off values only at their **final** answer for a part of a question. The answer(s) to any intermediate calculation(s) should not be rounded to the extent of causing inaccuracy in the final answer.

Candidates should memorise, and practise using, all the prefixes listed in the content statements.

Candidates would benefit from becoming more familiar with the variety of data provided on page two of the examination paper.

Centres could consider using this year’s examination paper, the published marking instructions (MIs) and this report for a variety of staff and student development activities such as:

- Answering question(s) under ‘exam conditions’, then self-marking the answers, making reference to both the MIs and this report to identify and improve any areas of weakness.
- Answering question(s) under ‘exam conditions’, then cross-marking the answers with a peer, making reference to the MIs and this report to identify areas of weakness. This should be followed up by one-to-one discussions or small-group discussions for further clarification and improvement opportunities.
- Attempting to identify questions/areas in the examination paper likely to cause difficulties and then comparing those ‘predictions’ with the information given in this report.
- Attempting to identify the errors in physics which lead to each of the wrong options being chosen in the multiple-choice questions.
- Repeatedly practising writing out answers to the ‘more difficult’ questions, especially those that require a definition, description, explanation or justification.

Statistical information: update on Courses

Higher

Number of resulted entries in 2010	9,014

Number of resulted entries in 2011	9,445

Statistical information: Performance of candidates

Distribution of Course awards including grade boundaries

Distribution of Course awards	%	Cum. %	Number of candidates	Lowest mark
Maximum Mark 90				
A	29·6%	29·6%	2,794	64
B	27·4%	57·0%	2,592	53
C	20·6%	77·7%	1,950	43
D	7·9%	85·6%	745	38
No award	14·4%	100·0%	1,364	-

General commentary on grade boundaries

While SQA aims to set examinations and create marking instructions which will allow a competent candidate to score a minimum of 50% of the available marks (the notional C boundary) and a well prepared, very competent candidate to score at least 70% of the available marks (the notional A boundary), it is very challenging to get the standard on target every year, in every subject at every level.

Each year, therefore, SQA holds a grade boundary meeting for each subject at each level where it brings together all the information available (statistical and judgemental). The Principal Assessor and SQA Qualifications Manager meet with the relevant SQA Head of Service and Statistician to discuss the evidence and make decisions. The meetings are chaired by members of the management team at SQA.

The grade boundaries can be adjusted downwards if there is evidence that the exam is more challenging than usual, allowing the pass rate to be unaffected by this circumstance.

The grade boundaries can be adjusted upwards if there is evidence that the exam is less challenging than usual, allowing the pass rate to be unaffected by this circumstance.

Where standards are comparable to previous years, similar grade boundaries are maintained.

An exam paper at a particular level in a subject in one year tends to have a marginally different set of grade boundaries from exam papers in that subject at that level in other years. This is because the particular questions, and the mix of questions are different. This is also the case for exams set in centres. If SQA has already altered a boundary in a particular year in say Higher Chemistry this does not mean that centres should necessarily alter boundaries in their prelim exam in Higher Chemistry. The two are not that closely related as they do not contain identical questions.

SQA's main aim is to be fair to candidates across all subjects and all levels and maintain comparable standards across the years, even as Arrangements evolve and change.