External Assessment Report 2015

Subject(s)	Physics
Level(s)	Higher (Revised)

The statistics used in this report are prior to the outcome of any Post Results Services requests

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

This is the fourth and last year of the examination for the Revised Higher Physics course.

In 2012, 20 early adopter centres presented 457 candidates for the Higher Physics (Revised) examination. In 2013, there were 844 candidates presented by 35 centres. Last year 1118 candidates were presented for the examination by 40 centres. This year 722 candidates were presented for the examination by 27 centres. This decrease in the number of candidates sitting this year's examination paper is not surprising as centres have been moving to the new Higher course under Curriculum for Excellence.

This examination included some questions that were also in the traditional paper. There were 48 marks (out of 90) in this examination that were common to both papers. In most of the common questions, candidates sitting the revised examination performed very slightly better than those sitting the traditional paper. There were, however, also many common errors and weaknesses!

There is also overlap with the new Higher examination.

This is the fourth national examination to include open-ended questions (Q24 and Q28). These questions permit candidates to answer the question in their own chosen way. Although there were examples of weak answers to these questions, markers generally found that candidates made good attempts to demonstrate their understanding of relevant Physics facts and principles.

Markers continue to comment that candidates generally perform better in questions that required calculations than in questions that required written descriptions and explanations.

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

Areas in which candidates performed well

The multiple choice section of the examination was found to be quite straightforward by most candidates, with questions 10, 11, 12, 13, 17 and 18 being answered particularly well (at least 80% of candidates choosing the correct answers).

Question 21

This question was designed to provide a straightforward start to Section B and, in general, candidates answered it well.

Part (a)(i) required candidates to use the given graph to state the release speed of a shot put for a 40^o 'throw' and then to calculate both the horizontal and vertical values of its initial velocity. Most candidates were able to carry out these tasks correctly. There were a few who failed to read the graph correctly, but this did not prevent them from gaining marks for the calculations of the components. Only a small percentage of candidates failed to give correct units for velocity for one or all three of their answers (in this case ‘m s^{-1}’). The most common error was to write ‘m/s^{-1}’. It is worth noting that although the units for speed and velocity are given as m s^{-1} in SQA examination papers, it is perfectly acceptable for candidates to use m/s in their answers.

Question 23

In part (a)(i), the vast majority of candidates were able to use an impulse relationship to carry out a correct calculation to find the average force on the ball when struck by the hockey stick.

Question 25

In part (b)(ii) the majority of candidates were able to demonstrate a correct calculation to show that the redshift is 0·098.

In part (b)(iii) most candidates were able to carry out appropriate calculations to find the approximate distance to the distant galaxy.

Question 29

In part (a)(ii), a high proportion of candidates were able to use the relationship between refractive index and velocity to calculate the speed of the red light in the prism.

In part (b)(i), most candidates were able to use the grating formula to calculate the distance between the slits on the grating.

Question 30

Part (a)(i), where candidates were asked to show that the resistance of the lamp is 12 Ω, was very well done.

Similarly part (a)(ii), calculating the power output of the lamp at the given current, was well done.

Question 31

This question used the context of a defibrillator to ask about the charge and energy stored by a capacitor. A very high proportion of candidates answered the whole question very well.

However, some candidates showed a lack of knowledge of the prefixes ‘kilo’ and ‘micro’ and some failed to realise that maximum current occurs when the resistance is at its minimum.

It is worth repeating here that the majority of questions in which candidates performed well were ones that involved selecting appropriate relationships and carrying out calculations.

Areas which candidates found demanding

In the multiple-choice section of the examination, there were only two questions that were answered correctly by less than half of the candidates (question 8 [36%] and question 20 [38%]).

Question 8 required candidates to decide which of the terms ‘fermion’, ‘baryon’ and ‘meson’ can be used for classifying a proton. Most candidates thought that the only appropriate term was a ‘baryon’, failing to select ‘fermion’ as also being applicable.

Question 20 asked candidates to consider statements made by students about a given distance/time graph. A significant number of candidates chose each of the distractors. This means that 62% of candidates believed that the graph proved that the two quantities were directly proportional to each other – despite the fact that the given graph line did not pass through the origin.

Question 21

This question uses the context of putting the shot in order to test candidates’ understanding of projectile motion.

Specific areas of weakness in answers from candidates were:

Part (a)(ii)(A): (‘Calculate the total time between the shot being released and hitting the ground’)

- Very few candidates used a correct method to find the time taken for the shot to fall from its maximum height. The time for the shot to reach maximum height from the thrower’s hand was given as 0·76 s. Many candidates simply doubled this time, showing a lack of understanding that the time to fall to the ground would be longer than 0·76 s.
- Some started correctly with a relevant relationship (such as $s = ut + \frac{1}{2}at^2$) but then made an error during substitution - for example, giving opposite signs to *s* and *a*.

Part (a)(ii)(B): (‘Calculate the range of the shot for this throw’)

- It was disappointing that so few candidates realised that this part is answered by putting the constant horizontal component of velocity into the relationship between *distance*, *speed* and *time*. Some started by quoting $s = ut + \frac{1}{2}at^2$ and then substituted a non-zero value for *a*. Others started with $s = \frac{1}{2}(u + v) \times t$ and then substituted values for *u* and *v* that were different from each other.

Part (b): (‘Explain the effect of … on the kinetic energy’)

- Although this part was answered well by many, some candidates failed to gain any marks as they made no statement about what happens to the kinetic energy for an increased angle of projection. Re-reading the question after writing their answer might have made them realise this critical omission.

Example of a candidate's answer to question 21:

21.) (a)(i)(A) $11 \cdot 6\,ms^{-1}$

(B) $11 \cdot 6 \sin 40 = \underline{\underline{7 \cdot 5\,ms^{-1}}}$

(C) $11 \cdot 6 \cos 40 = \underline{\underline{8 \cdot 9\,ms^{-1}}}$

(ii)(A) $s = 4 \cdot 7\,m$
$u = 0\,ms^{-1}$
$t = ?$
$a = -9 \cdot 8\,ms^{-2}$

$s = ut + \frac{1}{2}at^2$
$4 \cdot 7 = (0 \times t) + \frac{1}{2} \times (-9 \cdot 8) \times t^2$
$4 \cdot 7 = -4 \cdot 9t^2$
$t = \sqrt{\frac{4 \cdot 7}{4 \cdot 9}}$
$t = 0 \cdot 98\,s$

total time $= 0 \cdot 98 + 0 \cdot 76 = \underline{\underline{1 \cdot 74\,s}}$

(B) $d = ?$
$v = 7 \cdot 5\,ms^{-1}$
$t = 1 \cdot 74\,s$

$d = vt$
$= 7 \cdot 5 \times 1 \cdot 74$
$= \underline{\underline{13 \cdot 05\,m}}$

(b) If the angle of projection is increased, the release speed would smaller. The max height would be reached sooner as well.

Comment: Part (a)(i)(A) is the correct answer (from reading the graph). **(1) mark.**

Parts (a)(i)(B) and (C) are the wrong way round – (B) should be the horizontal component, not the vertical component and (C) should be the vertical component, not the horizontal component. **No marks.**

Part (a)(ii)(A) starts with the correct equation but goes wrong at the substitution stage (*s* and *a* should have the same sign). The candidate has then conveniently deleted the unwanted negative sign and achieved the 'correct' answer. **(½) mark**.

Part (a)(ii)(B) correctly uses previous wrong answer(s). **(2) marks**.

Part (b) does not answer the question as there is no mention of the effect on the kinetic energy. **No marks.**

Question 22

This question uses the context of a spacecraft and rover vehicle descending towards the surface of a moon in order to probe candidates' understanding of the relationship between force and motion as well as their ability to handle components of forces.

Candidates did not answer either part of this question well.

Specific areas of weakness in the answers from candidates were:

Part (a):

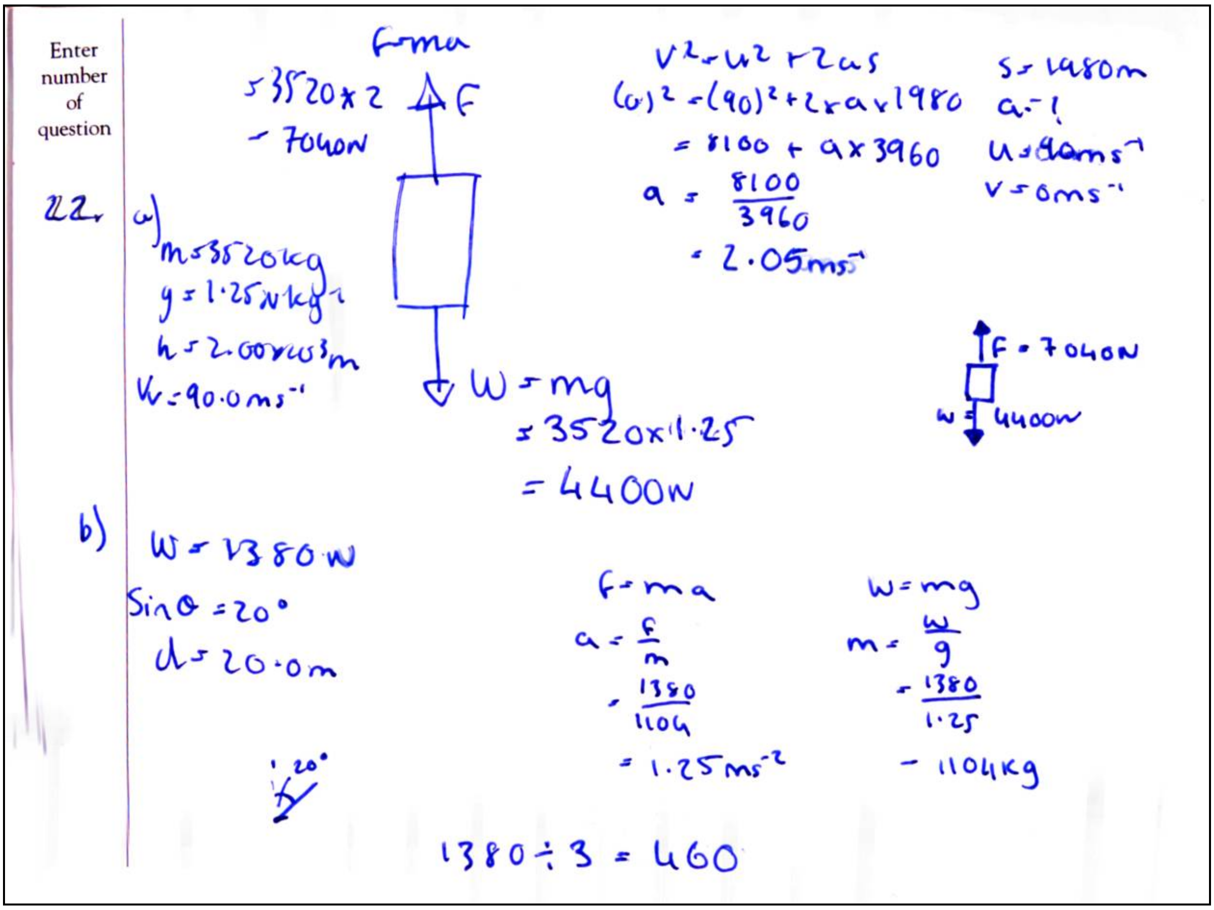
- Many candidates used $v^2 = u^2 + 2as$ to calculate the deceleration of the spacecraft for subsequent use in $F = ma$, but rounded their value for *a* too much, meaning that their answer for *F* was inaccurate.
- The rocket engines provide sufficient upward force to produce the deceleration and also balance the weight of the spacecraft. Many candidates forgot to include the weight of the spacecraft in their analysis.
- Of those who realised that they needed to include the weight, many did not know whether to add or subtract it from their value for *F*.
- Very few candidates sketched a free body diagram of the spacecraft. Drawing such a diagram to show the forces acting on the spacecraft, would probably have prevented many from making the mistakes mentioned in the above two bullet points.
- Some candidates attempted to answer by using $F \text{ x } d = \Delta E$. This is perfectly acceptable, but few realised that ΔE is the total energy change – found by adding both the loss in kinetic energy and the loss in gravitational potential energy.

Part (b):

- This question asks candidates to 'show' that the tension in each cord is 490 N. The word 'show' means that candidates should provide some justification for the number 'juggling' they are about to perform. In this case, it would have been appropriate to say 'constant (or zero) speed means that the vertical forces are balanced and so the upward force = weight'. Very few candidates started their answer by stating a physics principle such as that. Most only showed formulae and numbers without providing a reason why they were relevant.

Example of a candidate's answer to question 22:

For part (a):



Enter number of question

22. a)
m = 3520 kg
g = 1·25 N kg⁻¹
h = 2·00 × 10³ m
v = 90·0 m s⁻¹

F = ma
= 3520 × 2
= 7040 N

W = mg
= 3520 × 1·25
= 4400 N

v² = u² + 2as
(0)² = (90)² + 2 × a × 1980
= 8100 + a × 3960
a = 8100 / 3960
= 2·05 m s⁻²

s = 1980 m
a = ?
u = 90 m s⁻¹
v = 0 m s⁻¹

F = 7040 N
W = 4400 N

b) W = 1380 N
Sin θ = 20°
d = 20·0 m

F = ma
a = F/m
= 1380/1104
= 1·25 m s⁻²

W = mg
m = W/g
= 1380/1·25
= 1104 kg

20°

1380 ÷ 3 = 460

Comment: For part (a), the candidate has used $v^2 = u^2 + 2as$ in order to calculate the deceleration. This is fine. However, an arithmetic mistake has been made after the substitution – the acceleration should be negative. The value of the acceleration has then been rounded inappropriately from 2·05 to 2 when multiplying by the mass of the spacecraft to find the unbalanced force {the value of the unbalanced force is then inaccurate because of this 'aggressive' rounding}. Although the weight has been calculated, there is no combining of the weight and the unbalanced force to give the force exerted by the rocket engines.

It is not easy to follow the layout of this candidate's answer.

For part (b), the candidate has used $F = ma$ (unnecessarily) to find the acceleration due to gravity on this moon. She/He has also used $W = mg$ (also unnecessarily) to calculate the mass of the rover vehicle. Neither of these calculations is helpful in answering this question. The only useful bit of the answer is the division of 1380 by 3 to find the vertical component of the rover's weight being supported by each cord. This answer is obviously incomplete.

Question 23

This question uses the context of a penalty shot in hockey to allow candidates to show their knowledge about impulse and change in momentum. It also tests their abilities to sketch force/time graphs and to consider any changes resulting from using a softer ball (for the same change in momentum).

Part (a)(i) was well done, but the rest of this question was more poorly answered than had been expected.

It should be noted here that the quality of presentation of sketched graphs has improved over the last few years after repeated criticism of candidates efforts in previous external assessment reports. Although the quality of presentation of some graphs was still poor, the greater problem this year was with physics errors in the answers.

Specific areas of weakness in the answers from candidates were:

Part (a)(ii): (Sketch a graph of how the force on the ball varies with time during the impact)

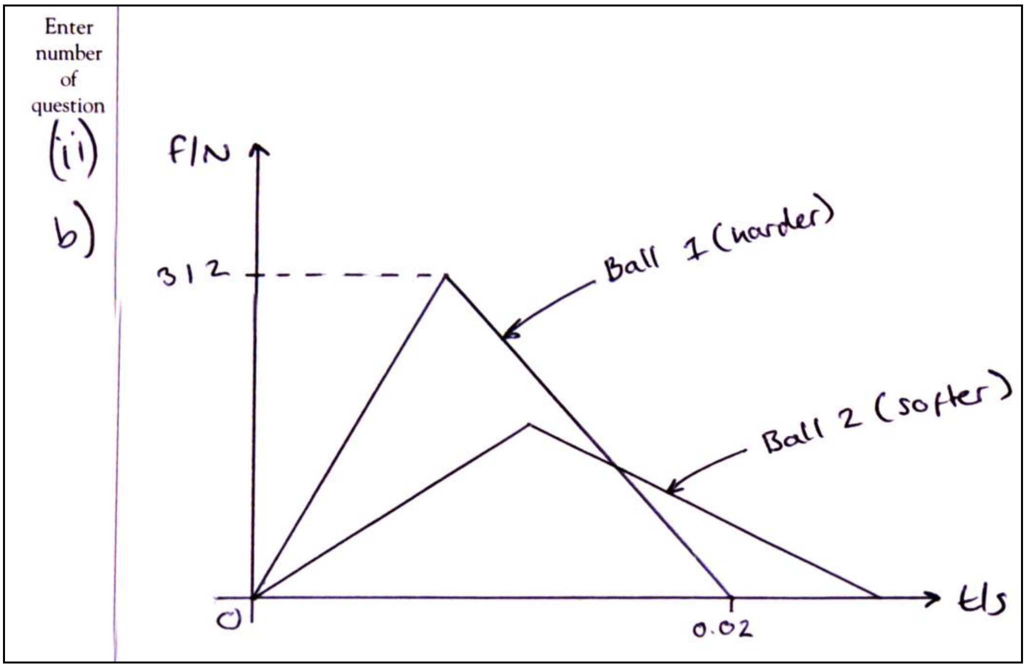
- Unlabelled axes
- Unlabelled origin
- The peak force being given the value of the average force from part (a)(i)
- The peak force being labelled as occurring at the total time of contact (0·02 s)
- Most candidates drew a triangular shape for the graph. Although this was not wrong, it was surprising to see very few ‘bell’ shaped curves, which would be nearer the ‘real’ shape of the variation of force with time.
- There were frequent examples of wrong graph shapes, eg exponential decay curves, lines ‘stopping’ at a non-zero force value, lines starting at the average force value and then continuing as a square wave shape etc.

Part (b): (Sketch a second graph for a softer ball to show the comparison with (a)(ii))

- Despite the question making it clear that each graph had to be clearly labelled, a significant number of candidates did not do so and so could not be awarded marks.
- The second graph should have shown a force with a lower peak value and acting for a longer time. Many candidates did not realise that there were two points being looked for by markers (the 2 mark allocation should have been a ‘clue’).
- Other errors by candidates included those that showed the peak force to be higher and the time of contact to be shorter.

Examples of candidates' answers to question 23:

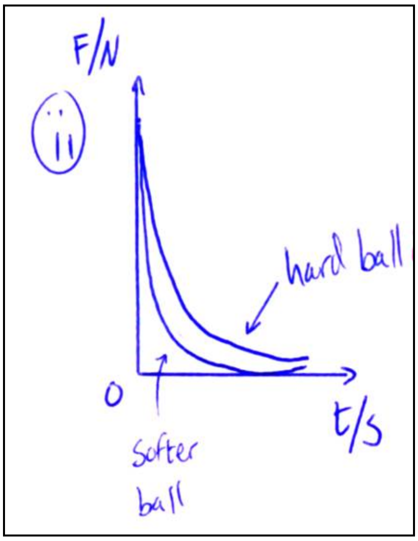
1. For parts (a)(ii) and (b):



Comment: For part (a)(ii), the graph for the harder material shows a wrong value for the peak force. The time value of 0·02 s is correctly positioned.

The softer ball is clearly labelled – this correctly shows both of the points being looked for by markers.

2. For part (a)(ii) and (b):



Comment: This is an example of a completely wrong answer. No marks can be awarded (eg for labelled axes) when the physics is so wrong.

Question 24

This is the first of two open-ended questions in this year's paper. It uses the context of a slow-running clock in a car to provide opportunities for candidates to demonstrate their knowledge about time dilation.

An open-ended question allows candidates to answer the question in their own chosen way. Candidates should use the opportunity to show to the marker that they know which areas of Physics are relevant. They should also provide some discussion and/or analysis to demonstrate the depth of their understanding of that knowledge.

There is no 'checklist' that is used by markers to allocate marks to a particular answer. Each candidate's answer is considered as a 'whole' and is awarded a mark depending on the level of understanding demonstrated. Zero marks are awarded if the answer demonstrates 'no understanding' of relevant Physics. The answer receives one mark if it shows 'limited understanding', two marks for 'reasonable understanding' and three marks for 'good understanding'.

Specific areas of weakness in the answers from candidates were:

- The core of the question is whether time dilation could be the reason why the clock in a car is running slow. It was therefore surprising that some candidates did not include the formula for time dilation in their answer. Some did, but did not attempt any calculation or make any estimates of values. While it was not essential to perform a time dilation calculation (using estimated values) in order to gain marks, doing so greatly increased the likelihood of a candidate being awarded higher marks.
- Many candidates repeated the same point several times over. This was not gaining them any marks and was potentially wasting time that they could have used for other answers.

Examples of candidates' answers to question 24:

1.

24) This is most likely untrue, unless the car has been approaching speeds close to 3×10^8 ms. This is because ~~[crossed out]~~ the car would not be travelling fast enough to cause a noticeable time dilation ~~#~~ shown through equation:

Assume fastest speed of car is 150km/h

$v = 150km/h$
$= 150000 m/h$
$= 2500 m/min$
$= 417 m/s$ (3sf)

$$\gamma = \frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$$

$$= \frac{1}{\sqrt{1-\left(\frac{41.7}{3\times10^8}\right)^2}}$$

$$= \frac{1}{\sqrt{1-(1.39\times10^{-7})^2}}$$

$$= \frac{1}{\sqrt{1-1.9321\times10^{-14}}}$$

As this number is so small it has negligible effect to the 1. This means the lorentz factor comes out as ~~one~~ 1.

$$= \frac{1}{\sqrt{1}}$$

$$= 1$$

$$\therefore t' = t\gamma$$
$$= 1\times t$$
$$= t$$
$$t' = t$$ Hence shown.

The change in time is most likely due to an inaccuracy in the clock.

Comment: This answer contains some good physics. Although there is always scope for criticism, this candidate appears to have a good understanding of the issue.

2.

24. The observed time is much longer for the observer than the proper time.
If someone was in space and another was on Earth. The time for the person in space would be much shorter than for the person in space.

Comment: What is '*the proper time*'? '*The time for the person in space would be much shorter than for the person in space*'? – this error might have been caught by the candidate re-reading their answer.

This answer does not convince a marker that the candidate has any understanding of time dilation.

3.

24. This is wrong as the clocks would not change in time that is noticeable to a human. This is because the car will have been travelling at a miniscule fraction to the speed of light and this will have an almost non existent impact on the clock in the car

Comment: This candidate has made some correct statements, showing some understanding. The answer would have been improved by including the time dilation relationship and relevant calculations (using estimated values).

4.

number of question

(24)

The effects of time dilation and length contraction would not be experienced by the family whilst travelling as they would be travelling in the same frame of reference as the clock. They would also be travelling far less than 0·1c – so no real relativistic effects would be observed by a stationary observer looking at the clock either.

Assuming the car is driven at motorway speeds:

velocity of car

70 mph

$70 \div 3600 = 0{\cdot}0194$ mps

$0{\cdot}0194 \times 1600 = 31 \ ms^{-1}$

time of 6 months

6 months × average of 30 days per month

180 days × 24 hours

4320 hours × 60 minutes

259200 minutes × 60 seconds

15552000 seconds in 6 months

$$t' = \frac{t}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$$

$$t' = \frac{15552000}{\sqrt{1 - \left(\frac{31}{3 \times 10^8}\right)^2}}$$

$t' = 15552000$ is the time recorded by a stationary observer so there would be no noticeable time change.

Therefore: Because the family are travelling in the same frame of reference as the digital clock, they observe the same laws of physics and therefore record the exact same time as the digital clock, however a stationary observer records the exact same time as well, which means that the change in time is NOT due to time dilation, it is due to the systematic failure of the car to accurately record the time. It demonstrates that the car cannot fully accurately record the time. So the physics student is not correct.

Comment: There can be little doubt from this answer that the candidate has a good understanding of time dilation.

Question 25

This question provides information about the absorption spectra of light from the Sun, a nearby galaxy and a distant galaxy in order to test candidates' knowledge of redshift, Hubble's law and the expanding universe.

Parts (b)(ii) and (b)(iii) were done well {these were calculations}, but (a) and (c) were answered poorly.

Specific areas of weakness in the answers from candidates were:

Part (a): (Explain how the dark lines in the spectrum of sunlight are produced.)

- Few candidates appeared to know why dark lines appear in the visible spectrum of sunlight.
- Those who knew about absorption of the energy did not say that it only occurs for certain frequencies – their answers simply said that 'the dark lines are because light is absorbed'
- Many who did refer to certain frequencies of light being absorbed were vague about where and how this absorption occurs – some answers wrongly said 'elements in the Sun's core absorb the light'.
- Some candidates said that the absorption occurs in space between the Sun and the Earth; others thought it occurs in the Earth's atmosphere.

Part (c): (Explain why the spectra support the theory of the expanding Universe.)

- Many candidates simply referred to redshift occurring. They should have gone on to explain that because the redshift is greater for the distant galaxy, the distant galaxy must also be moving further away from the nearby galaxy.
- Markers frequently saw answers that said 'galaxies are redshifted' rather than 'the **light** from the galaxies is redshifted'.

Examples of candidates' answers to question 25(a):

The following answers show a variety of weaknesses in candidates' answers. Some show lack of knowledge, some demonstrate confused knowledge and some indicate difficulties in candidates being able to express themselves in words.

25.	a) when the light is observed, specific wavelengths of light are absorbed by corresponding wavelengths on the ~~absorption~~ spectrum, causing dark lines to appear.

Q25·a) Because different wavelengths of light come from the sun and these wavelengths of light are shown with the black lines. I.e the black lines are produced when light of different wavelengths in shone ~~on the spectrum~~ on the collector.

25.
a) They are wavelengths of light which have been absorbed by elements when entering /travelling through our atomosphere. (absorption spectra)

25) a) Elements within the suns' light interfere with the wavelengths given out.

25a The dark lines in the spectrum are produced as the electrons have absorbed the photons of light which have the same energy.

question
25a) These wavelengths of light are absorbed by particles.

Question 26

This question is about the Standard Model and the Higgs boson.

Parts (a) and (b)(i) were well done but part (b)(ii) was answered poorly.

Specific areas of weakness in the answers from candidates were:

Part (b)(ii): (Candidates were asked to compare the mass of the Higgs boson with the mass of the proton in terms of orders of magnitude.)

The expected answer was that because the mass of the Higgs is just over 100 times that of the proton, it is **two orders of magnitude bigger**.)

- Many candidates demonstrated that they did not understand the terminology *orders of magnitude*. There were many answers that simply said ‘the mass of the Higgs boson is greater than the mass of a proton’.

Question 27

This asks a few questions around an example of alpha decay and an example of beta decay.

Specific areas of weakness in the answers from candidates were:

Part (a)(i): (Explain why energy is released in the given decay.)

- There were surprisingly few candidates who gave the correct answer by saying ‘some mass is lost and changed into energy according to $E = mc^2$’.
- Many answers tended to be vague, for example saying that ‘the masses before and after are not the same’ – this could mean that the candidate believes that the mass increases.

Part (a)(ii): (Explain why the kinetic energy of the alpha particle is less than the energy released in the decay.)

There were surprisingly few candidates who gave the correct answer by saying ‘some of the energy is shared with the Thorium nucleus’.

Markers read many examples of wrong physics such as ‘some energy is lost to the surroundings as heat and sound’.

Part (b)(ii): (In the given beta decay, the total energy is not accounted for by the products shown. What conclusion have particle physicists drawn from this?

The expected answer was a description of the discovery of the (anti)neutrino.)

- Few candidates seemed to be aware of this experimental evidence being the background to the discovery of the (anti)neutrino.

Examples of candidates' answers to question 27:

For part (a)(i):

> question
> 27ai there is energy given out due to the mass before dosn't equal the mass after the reaction

> (27) a) i) When a nuclear decay takes place there is a change in mass. This change is given off as energy.

Comment: These are examples of answers which do not specifically say that there is a **loss** in mass which is changed into energy.

For part (b)(ii):

1.

> ii) They have concluded that during beta decay aswell as an electron being released, its anti matter particle is also released, to conserve momentum. Physicist called it the positron

Comment: This candidate has 'partially remembered' that this was evidence of another particle being emitted. However, it is not the positron.

2.

> ii) That there is another particle that carries away the missing kinetic energy and momentum, called a neutrino. It is neutral and highly penatrating.

Comment: This candidate has clearly and concisely described the meaning of the experimental evidence.

Question 28

This is the second of the two open-ended questions in this year's paper. It uses the context of a coconut shy to provide opportunities for candidates to demonstrate their knowledge about the photoelectric effect.

An open-ended question allows candidates to answer the question in their own chosen way. Candidates should use the opportunity to show to the marker that they know which areas of Physics are relevant. They should also provide some discussion and/or analysis to demonstrate the depth of their understanding of that knowledge.

There is no 'checklist' that is used by markers to allocate marks to a particular answer. Each candidate's answer is considered as a 'whole' and is awarded a mark depending on the level of understanding demonstrated. Zero marks are awarded if the answer demonstrates 'no understanding' of relevant Physics. The answer receives one mark if it shows 'limited understanding', two marks for 'reasonable understanding' and three marks for 'good understanding'.

Specific areas of weakness in the answers from candidates were:

- A significant proportion of candidates wrote a lot about the photoelectric effect but did not make many comments on the coconut shy analogy as the question had asked them to do. This was obviously a weakness in their answers.
- Again, some candidates repeated the same point several times over.
- Some candidates wrote a full A4 page to answer this question. Even when the resulting answer was awarded the full three marks, this is not an efficient use of examination time. Other candidates were able to produce much shorter, succinct answers that were also awarded three marks.

Example of a candidate's answer to question 28:

28) This analogy is suitable as the changing balls is equivalent to the frequency of photons contacting the metal. The higher frequency of the photon, the higher mass of the ball. The threshold frequency is represented by the smallest ball that can knock down a coconut showing the photons must be of sufficient frequency to knock off an electron from the metal. This also represents the idea of increasing light intensity, as if you throw more balls per amount of time, if they are sufficiently massive more coconuts will be knocked down. However throwing many balls of insufficient weight will not knock over a coconut. The same happens with light intensity; an increase causes more photons to hit the metal per second. If they are over the threshold frequency, more electrons are released per second. However if the photons are not above the threshold frequency there will be no electrons released, regardless of light intensity.

Comment: This candidate has explained the analogy; comparing the action of different balls hitting coconuts with different photons interacting with electrons. Appropriate reference has also been made to irradiance and the rate of throwing balls. There can be little doubt that this candidate has a good understanding.

Question 29

This question presents candidates with two experimental setups in which visible light spectra are produced. This provides a context to test their understanding of refraction, gratings and spectra.

Parts (a)(ii) and (b)(i) were well done [they were both calculations], but the responses to parts (a)(i) and (b(ii) were poor.

Specific areas of weakness in the answers from candidates were:

Part (a)(i): (Explain why a spectrum is produced when a ray of white light enters a glass prism.)

- Very few candidates were able to give learning outcome 3·2·4 in their own words (*State that the refractive index depends on the frequency of the incident light*.)
- A significant number of candidates tried to explain the spectrum by saying that it is due to diffraction occurring in the prism.

Part (a)(ii): (Calculation of the speed of red light in the glass prism.)

- Some candidates carried out a double stage calculation, but inappropriately rounded their intermediate answer, giving an inaccurate final answer.

Part (b)(i): (Calculate the distance between the slits on the grating.)

- This was generally answered very well, but markers did see a few examples of inappropriate intermediate rounding.
- A few candidates, having worked out an answer for d, then went further and calculated $1/d$.

Part (b)(ii): (Explain why the angle to the second order maximum is different for blue light than for red light.)

- Some candidates' answers said that this is due to differing amounts of refraction for red and blue light — this is obviously incorrect physics.
- Very many candidates said that this is due to '*red light diffracting more than blue light*'. This is not a correct physics explanation. At the slits on the grating red and blue light are both diffracted so much that they are then effectively semicircular waves which overlap and interfere on the right hand side of the grating. The different colours have different wavelengths and so they meet in phase at different positions (because path difference must equal $n\lambda$ for constructive interference). Hence the blue and red maxima are seen at different places on the screen.

Examples of candidates' answers to question 29:

For part (a)(i):

> 2a) a) i) White light is made up of lots of different wavelengths. Due to $n = \frac{\lambda_a}{\lambda_g}$, the wavelengths will be effected by the glass (because the refractive index is constant) differently and so they become seperated.

Comment: This answer shows some errors and confusion in the candidate's knowledge. Refractive index is not constant. He/she is also confusing the different wavelengths in visible light with the change in wavelength that occurs on refraction. That is one reason why it is wise to say that the refractive index depends on **frequency** (frequency does not change on refraction).

For part (a)(ii):

> (ii) $n = \frac{V_1}{V_2}$
>
> $1.54 = \frac{3 \times 10^8}{V_2}$
>
> $V_2 = \frac{3 \times 10^8}{1.54}$
>
> $= 1.95 \times 10^8 \, ms^{-2}$

Comment: This answer goes wrong at the last line. The candidate has given the wrong units for speed.

For part (b)(ii):

> Enter number of question
>
> ii). Because Blue light through a grating refracts less and So the Angle it produces to the Second Maximum would be less.
> The wavelength for Blue is less than is for red and So thats why it refracts less in a grating.

Comment: This is a completely wrong answer. The production of a spectrum using a grating has nothing to do with ‘refraction’. [Note that this answer would also be wrong as an explanation for the production of a spectrum in a triangular prism, where blue refracts more than red.]

Question 30

This question is about a technician investigating the use of a lamp and an LED as light sources for a torch. It uses this context to probe candidates’ understanding of *e.m.f.*, *internal resistance*, *power* and the operation of LEDs.

Parts (a)(i), (a)(ii), and (b)(i) were well done.

Parts (b)(ii) and (c) were answered quite poorly.

Specific areas of weakness in the answers from candidates were:

Part (b)(ii): (Candidates were asked to calculate the potential difference across the variable resistor.)

Candidates are usually good at carrying out straightforward calculations. However, there was a slightly more complex situation for them to analyse in this part. They needed to allow for the lost volts across the internal resistance as well as the potential difference across the LED in order to calculate the p.d. across R_v. This more complex situation proved to be too difficult for many.

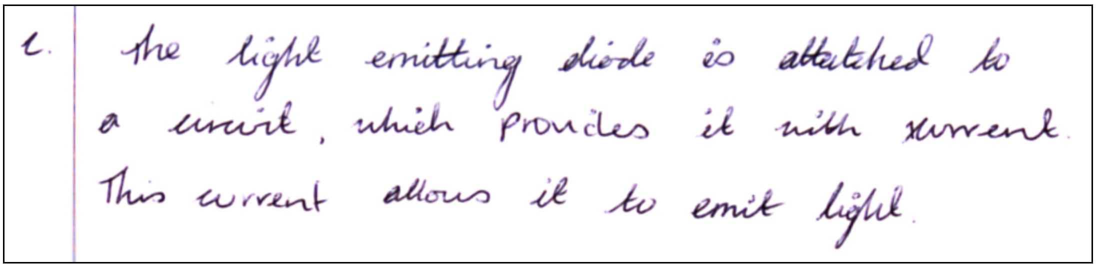
- Many candidates thought that it was correct to use ‘$V = IR$’ with values for *I* and *R* taken from part (a). This is despite part (b) making it clear that there is now a different value of current.
- Many candidates neglected to include the effect of the lost volts.
- Despite there being various resistances to be considered, markers often saw ‘$V = IR$’ being written down a number of times without any subscripts (or other descriptions) to clarify what the candidate was working out.

Part (c): (Describe how an LED operates.)

Markers were looking for candidates to state that ‘photons are emitted when there is a current through a p-n junction’.

- A significant proportion of candidates showed confusion between what happens in an LED and what happens in a photodiode.
- Some candidates stated that an LED produces light when it is reverse biased.

Example of a candidate's answer to question 30(c):


c. the light emitting diode is attached to a circuit, which provides it with current. This current allows it to emit light.

Comment: This answer is not wrong – it just has some weaknesses. It would have been improved by saying that current in the p-n junction causes photons to be produced.

Question 31

This question uses the context of a defibrillator to ask about the charge and energy stored by a capacitor. The last part then asks for a calculation and conclusion using Ohm's law.

A very high proportion of candidates answered the whole question very well.

Specific areas of weakness in the answers from candidates were:

Part (a):

- Some candidates showed a lack of knowledge of the prefixes 'μ' and 'k'.

Part (b):

- Some candidates chose to use the relationship $E = ½ CV^2$, but then used the value of the charge when substituting for *C*.

Part (c):

- Some candidates seemed to believe that the maximum current would occur for the maximum resistance.
- Some candidates carried out two calculations, one for the smallest resistance and another for the largest resistance, but did not then state a conclusion about the maximum current.

Question 32

This question tests skills related to experimental design and evaluation using the context of an investigation about the deflection of a beam of electrons in a region of uniform magnetic field. It also provides opportunity for candidates to demonstrate their abilities of graph drawing and data analysis.

Part (a) was quite well done. Most answers to parts (b)(i) and (b)(ii) were mediocre and part (c) was poorly answered.

Specific areas of weakness in the answers from candidates were:

Part (a): (Determine the direction of the magnetic field.)

Candidates were provided with a diagram which showed the initial direction of the electron beam and the subsequent deflection.

- A higher proportion of candidates than expected were unable to give the direction of the magnetic field (into the page).
- Some candidates gave unclear or ambiguous answers such as ‘down’ {this might mean down the page from top to bottom}.

Part (b)(i): (Drawing a graph of the given data.)

Candidates were asked to use square ruled paper and plot a graph of r against $1/B$.

Issues and errors noted by markers include:

- Points were plotted correctly but no graph line was drawn through them.
- Poor attempts were made at drawing the best fit line (ie a ‘hairy’ line or multiple lines rather than a single, best fit line). Candidates should note that a drawn line cannot be the line of best fit if all the points that are not on the line are **all to one side** of that line.
- A series of straight lines were drawn from dot-to-dot through the plotted points.
- The graph line was drawn in ink rather than pencil, thus preventing easy correction.
- Axes were not labelled with both the name of the quantity and its units.

Part (b)(ii): (Calculate the gradient of your graph.)

- Candidates sometimes had difficulty using their own chosen scale to take correct readings from their graph.
- Some candidates failed to take into account the power of 10 on the axis label when calculating the gradient
- Part (b)(iii): (Use the gradient of your graph and the given relationship to calculate the electron speed v.)
- Many candidates did not use the value of their gradient as instructed. They simply selected values of r and B from the table and substituted them into the given relationship. As well as not following the instructions in the question, this also showed that these candidates did not appreciate one of the basic reasons for taking a series of readings, drawing a graph and using its gradient, ie this process helps reduce the effects of experimental uncertainty in any subsequent analysis.

Part (c): (Describing how the student could use the apparatus to investigate the relationship between the speed v of an electron and the radius r of its path in the magnetic field.)

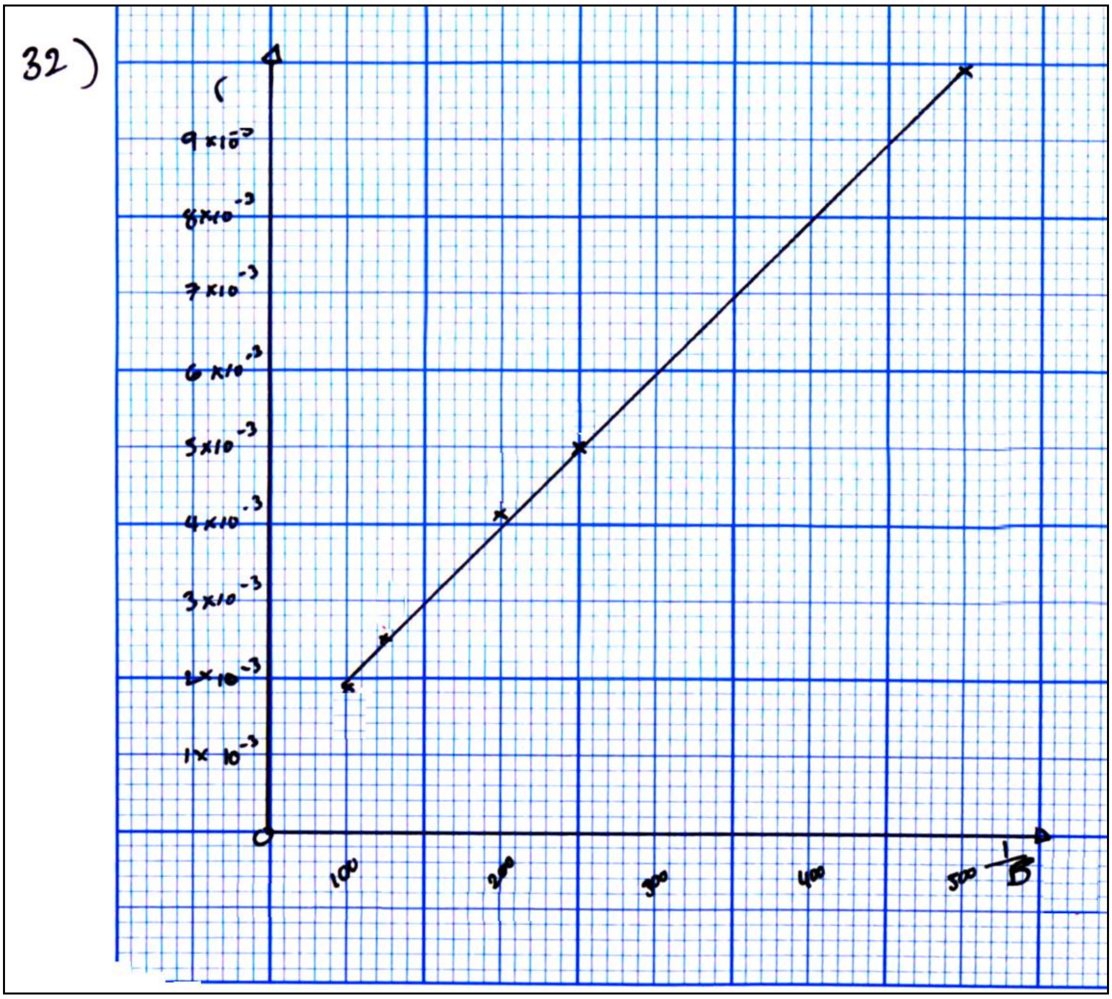
Markers were looking for the following points:

- Set (or measure) the speed v of the electrons
- Measure the radius of the path they follow in the magnetic field
- Keep the magnetic field strength constant
- Repeat the experiment for different values of v

The answers from many candidates were too vague and lacked sufficient detail or technical rigour. (For example '*change the speed and see how this affects the radius*'.)

Examples of candidates' answers to question 32:

For part (b)(i):



Comment: This candidate has:

- failed to give units on either axis
- not provided a linear scale on the horizontal axis (the first centimetre = '100', but subsequent centimetres = '50').

For part (c):

The following answers all illustrate the vagueness and lack of technical rigour often seen by markers.

> c) Instead of adjusting the size of the magnetic field, the student could alter the speed of the electron in order to asess how this changed with the radius ~~of the path~~ r of its path in a magnetic field.

> C. Repeat the experiment, but make the speed the independant variable, then edit it and record the effects on the radius.

> c) Increase and decrease the radius (r) to see if the speed is constant.

Other general issues

- Many markers complained about the difficulty they had in reading the answers from some candidates due to unclear handwriting.
- Markers reported that the structure of numerical calculations were sometimes of a poor standard and difficult to follow.
- Markers reported that candidates' diagrams were sometimes carelessly drawn and unclear or inaccurate.

Advice to centres for preparation of future candidates

General

Although this is the last year of the Revised Higher Physics examination paper, the new Higher examination requires candidates to have similar examination skills and techniques.

Many of the following points were made in the external assessment reports of the last three years. However, these points are being repeated as they cover areas which still require to be improved to ensure better success for candidates in the future.

- 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 practice could reduce the frequency of inappropriate or incomplete answers.

- Candidates should be encouraged to present their numerical analyses in a clear and structured way —– markers need to be able to follow the logic in candidates' answers.

- Candidates must attempt to write their answers legibly. If they wish to change an answer, it is usually better to rewrite the answer than to 'overwrite' the original answer.

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

- Candidates must be prepared to present their answers on blank paper. It should be ensured that they have had sufficient practice in presenting written paragraphs, clearly structured calculations and neat diagrams on unlined paper prior to sitting the examination paper.

- Candidates should consider using square-ruled paper for some of their answers. Answers which might be improved by using this paper include sketched graphs and other diagrams such as those showing the path(s) taken by rays of light.

- Candidates should use a ruler when drawing straight lines. For example, when drawing the axes of graphs and the path(s) taken by rays of light.

- Candidates must consider direction as well as magnitude when dealing with vector quantities.

- Candidates should use words such as 'increases' or 'decreases' in their answers rather than using up (↑) and down (↓) arrows. The use of arrows may be acceptable 'shorthand' when making their own notes, but candidates should not use this symbolism when attempting to communicate Physics to others — as in examination answers.

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

- Candidates must be aware that, in a 'must justify' question, no marks can be awarded if the candidate makes no attempt at a justification.

- Many 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.

- Many candidates would benefit from spending more time learning correct technical terminology (for example, '*redshift of the light from a galaxy*', not '*redshift of a galaxy*') and spelling (eg '*atmosphere*', not '*atomsphere*').

- 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. It is useful to link these important values to the relevant parts of the graph line using dotted reference lines. It is wise to use a pencil when attempting to draw the graph line — any wrong line(s) can then be erased to leave a neat, clear, single line as the final answer.

- Many candidates would benefit from more practice at reading data from graphs which have been drawn using a variety of scales.

- Candidates should try to avoid being repetitive in their answers to open-ended questions.

- 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. This could also involve advice being given about the efficient use of handling data on a calculator.

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

- Candidates must ensure that they know all the prefixes required for the course and that they practise using the correct power of ten for each prefix.

- When asked to draw a graph using square ruled paper, candidates should use suitable scales on the axes in order to produce a graph that is not too small. However, they should also ensure that their scale is ‘easy to work with’. Candidates should ensure that each axis is labelled with both the name of the quantity and its units. Points must be plotted clearly and accurately. A best-fitting line (straight or curved as appropriate) should be drawn through their plotted points. However, this graph line should not be ‘forced’ to touch each point. Again, it is wise to use a pencil when attempting to draw the graph line – any wrong line(s) can then be erased to leave a neat, clear, single line as the final answer. At the graph drawing stage, the line should not be extended beyond the limits of the data (ie it should not be extrapolated).

Statistical information: update on Courses

Number of resulted entries in 2014	1111

Number of resulted entries in 2015	717

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	36.8%	36.8%	264	59
B	24.3%	61.1%	174	50
C	16.9%	78.0%	121	42
D	6.7%	84.7%	48	38
No award	15.3%	-	110	-

For this course, the intention was to set an assessment with grade boundaries as close to the notional values of 50% for a Grade C and 70% for a Grade A. The starting point for discussion was the 2014 set grade boundaries as instructed by the panel in 2014. A 1 mark adjustment was made for Q20 of the multiple choice section for the A and the Upper A boundaries. A 1 mark adjustment was made to the Upper A, A and C boundaries for Q21(b). The MIs were changed for 21(b) to try to avoid this being a non-functioning question but this did not work as intended. A 1 mark adjustment was made at the Upper A, A and C boundaries to account for the adjustment made for a non-functioning open-ended question in 2014. There were no non-functioning open-ended questions in 2015. An action from 2014 was to ease the paper and this was felt successful, therefore a 3 mark adjustment was made at the C boundary, a 2 mark adjustment to the A boundary and a 1 mark adjustment to the upper A boundary to take account of this easing of the paper.

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, SQA therefore 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 Business Manager 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.