External Assessment Report 2014

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 third year of the examination for the revised Higher Physics course.

In the first year, 20 early adopter centres presented 457 candidates for the Higher Physics (revised) examination. Last year there were 844 candidates presented by 35 centres. This year 1118 candidates were presented for the examination by 40 centres. The total number of candidates sitting Higher Physics this year (revised plus traditional) is approximately 10 300 candidates.

This examination included some questions that were also in the traditional paper. There were 44 marks (out of 90) in this examination which were common to both papers. In most of the common questions, candidates sitting the revised examination performed slightly better than those sitting the traditional paper. There were, however, also many common errors and weaknesses.

This is the third national examination to include open-ended questions (Q24 and Q31). These questions permit candidates to answer the question in their own chosen way. Although there were examples of weak answers to these questions (especially for Q31), 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 provided good accessibility for 'C' grade candidates and, at the same time, included appropriate questions to provide good discrimination for those performing at 'A' and 'B'. However, the examination was found to be a little more demanding overall than last year. The grade boundaries have been reduced this year to reflect this increased difficulty and to ensure that this year's candidates are not disadvantaged.

Areas in which candidates performed well

The multiple choice section of the examination was found to be quite straightforward by most candidates, with questions 2, 6, 7, 10, 11, 13, 14, and 20 being answered particularly well (at least 80% of candidates choosing the correct answers).

Question 23: in part (a)(i) many candidates were able to select and use the appropriate information to calculate the force between the spheres.

Part (a)(ii) was also well answered, a high proportion of candidates being able to use the universal law of gravitation and appropriately selected data to calculate a value for *G*.

Question 25: in part (a) the majority of candidates were able to carry out a correct calculation to identify the appropriate transition between the given atomic energy levels.

In part (b)(i) most candidates were able to use the graph of *wavelength* vs. *time* to determine the period of the star's orbit.

Question 26: part (a) required candidates to use their knowledge of fundamental particles along with handling information skills. All four parts in part (a) were answered well.

Question 27: in part (a)(i) candidates were asked to calculate the maximum kinetic energy of an emitted photoelectron. In part (a)(ii) candidates were asked to calculate the maximum velocity of an emitted photoelectron.

Both of these calculations were well done.

Question 28: in part (a) candidates had to select and use the grating formula and appropriate data provided in the question in order to calculate the angle to the third maximum. This was done very well.

In part (b)(i) many candidates were able to use the given data appropriately to justify their conclusion that destructive interference occurs at point J.

Question 29: as in the traditional paper, part (a) required candidates to use Snell's law to calculate the critical angle. This calculation was done very well. Some candidates were unable to get the required value of refractive index from the given graph. This appeared to be due to them making errors reading the scale(s).

Question 30: part (a)(i), determining the *e.m.f.* of the battery from the intercept on the voltage axis of the given graph, was very well done.

Part (a)(ii), determining the internal resistance of the battery from the given voltage/current graph, was well done.

Part (a)(iii), determining the short circuit current of the battery, was quite well done.

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 was only one question that was answered correctly by less than half of the candidates (question 5 [39%]). This question is about the energy emitted per second from hot objects and how it varies depending on wavelength and surface temperature.

Question 21 – This question uses the context of a parascender being pulled by a powerboat in order to probe candidates' understanding of vectors and the relationship between force and motion.

Candidates did not answer this question well. Part (b), which required candidates to explain the motion of the parascender in terms of the forces acting was particularly poorly answered.

Specific areas of weakness in the answers from candidates were:

Part (a)(i):

- Very few candidates could define the *resultant of a number of forces* as the single, overall force which causes the same effect (eg acceleration) as when all the forces are acting.
- Many candidates 'talked' about getting the resultant by adding the forces, but did not make it clear that this must be carried out as a vector sum.
- A significant number of candidates thought they were being asked to explain what a resultant force of 0 N means.

Part (a)(ii):

- Very few candidates made a good attempt at drawing a scale diagram of the forces acting on the parascender.
- Many did not seem to realise that the three forces acting (1200 N, weight and the parasail's force) should be added as vectors to give the resultant of zero given in the question, ie having drawn the 1200 N and weight to scale and in the correct relative directions, the third force should be drawn back to the origin to complete the triangle.
- Of those who remembered to give a direction, many tried to quote it as a three-figure bearing. This is not appropriate in this question, as the force exerted by the parasail should be quoted relative to the horizontal (or vertical). North is neither defined nor relevant in this question.
- Many attempted to use the cosine rule. This is a perfectly valid and acceptable way to answer this question, but candidates must realise that the cosine and sine formulas are not provided. There were many examples of candidates writing down a wrong formula – no marks can be awarded when the starting relationship is incorrect. Candidates who wish to use this method must memorise the relevant formulas before sitting the examination.

Part (b):

- This part of the question told candidates that the parascender releases the rope and initially rises higher. They were asked to 'explain, in terms of forces, why the parascender rises'. An acceptable answer should explain that, as there is no longer a downward component of force from the rope, the upward vertical component of the force from the parasail is greater than the weight of the parascender. This causes a (brief) resultant upward force and consequent upward acceleration. Candidates' answers frequently showed little understanding of the combination of forces and the relationship with acceleration. Few showed that they understood the need to consider just the vertical components of forces in order to explain behaviour in the vertical direction.

Examples of candidates' answers to question 21(b):

1.

b) As there will be an unbalanced force pulling the parascender upwards as the weight of the parascender will not have changed ~~to~~ and there will be no longer be a force from the boat ~~force~~ pulling the parascender down ~~from the boat~~.

Comment: This candidate has correctly identified that there is now an unbalanced force upwards. The answer is vague in its reference to 'no longer a force from the boat'. It would have been improved by stating that the upward vertical component of the force exerted by the parasail is greater than the weight and so there is now an unbalanced force upwards.

2.

21 b) When he is holding the rope, the forces are balanced and he is therefore not accelerating ~~up~~ in any direction. However, when he releases the rope, the only forces acting on him are ~~wgt~~ his weight and the force exerted by the parasail. The resultant force of these two unbalanced forces is exerted in an upwards direction, so the parascender will rise.

Comment: This is one of the few answers seen by markers that indicate the candidate has good understanding of what is happening. The answer could have been improved slightly by being more precise about relevant components of forces, for example, by saying 'the vertical component of the force exerted by the parasail' rather than 'the force exerted by the parasail'.

3.

question	
b)	When he releases the rope, the ~~[illegible]~~ vertical component of force of the powerboat that is pulling him closer to the water ~~[illegible]~~ is lost. ~~[illegible]~~ Only ~~[illegible]~~ the force of gravity is ~~[illegible]~~ acting downwards, while the vertical component of the force of the parasail is pulling him upwards, and the forces are unbalanced since this is a larger ~~[illegible]~~ force, so he initially rises.

Comment: This candidate has given a good answer. It is pleasing to see correct references to relevant components of forces.

Nit-picking points: it would have been better to name the 'force of gravity' as 'weight'; it would have been a slight improvement to say that the unbalanced force upwards causes an upward acceleration, not just that 'he … rises'.

Question 22 – This question aims to provide candidates with opportunities to show their knowledge and understanding of the conservation of linear momentum. It also tests their abilities to use the conservation of energy and momentum in the analysis of interactions between objects.

This question was more poorly answered than had been expected.

Specific areas of weakness in the answers from candidates were:

Part (a):

- Few candidates set out their answer to show the total momentum before, the total momentum after and then to equate these two quantities.
- Many candidates wrongly thought that by showing that the magnitude of the momentum of X after the explosion was equal to the magnitude of the momentum of Y after the explosion they had then proved the conservation of momentum.
- Some candidates did not appear to appreciate the vector nature of velocity (and consequently the vector nature of momentum).
- Some candidates did not show that they had multiplied the mass (of X) by its velocity to get the momentum (of X). This is a 'show' question and the value of the momentum should not just 'appear'.

Part (b)(i):

- This is a ‘Show’ question and the candidate must start by writing the relevant formulas ($E_k = ½ mv^2$ and $E_p = mgh$ in this case) and then substitute the relevant given data. It is not acceptable to start with just numbers in the answer to this type of question.
- The final line of the candidate’s answer must state the value that they were asked to show – in this case 1·7 m s^{-1} (not 1·72 m s^{-1}).

Part (b)(ii):

- It was disappointing that many candidates attempted to use an energy calculation (rather than conservation of momentum) to work out the velocity of the dart before its collision with the wooden block.

One candidate’s answer to question 22:

1. For part (a):

22a) $m_1V_1 + m_2V_2 = m_3V_3 + m_4V_4$

$(0{\cdot}7\times0)+(0{\cdot}3\times0)=(0{\cdot}7\times0{\cdot}5)+(0{\cdot}3\times1{\cdot}19)$

$0 \quad = -0{\cdot}35+0{\cdot}35$

$=0$

As momentum is the same, before and after the collision, therefore momentum is conserved

Comment: When you are attempting to prove a relationship it is not ideal to set out an answer this way, as the first line is actually stating what you wish to prove. It is better to consider the left hand side separately from the right hand side. It can then be shown that the two sides (ie before and after) are equal to each other and so the desired relationship has been proved.

It should be noted, however, that candidates were not penalised for setting out their answers as above.

The strengths within the above answer are:

- the total momentum before has been shown to be zero
- the individual momenta of X and Y after the explosion are clearly shown
- the total momentum after has been shown to be zero
- the conservation of momentum has been established and stated

Question 23 – This question uses the context of the Cavendish-Boys experiment to probe candidates' knowledge of the universal law of gravitation and experimental uncertainties as well as issues of experimental design.

Both parts of (a) were well done. Part (b) was quite well done, but answers to part (c) were generally poor.

Specific areas of weakness in the answers from candidates were:

Part (c): (The pointer is replaced with a mirror and a beam of light from a laser now reflects from the mirror on to the scale. Candidates were asked to explain how this modification improves the accuracy of the experiment.

An ideal answer would state that when the mirror turns through an angle θ, the reflected ray of light turns through an angle 2θ. This increases/doubles the reading on the scale and so produces a smaller percentage uncertainty in the result.)

- Few candidates realised that the reading on the scale is increased/doubled.
- Some candidates said that a spot of laser light on the scale means that the reading could be measured more precisely than when there is a gap between the pointer and the scale. They were awarded a mark for saying this.
- Few candidates mentioned percentage (or fractional) uncertainties in their answer. Discussion of why the percentage uncertainty has been reduced should be fundamental to any answer that is attempting to explain why the accuracy of an experiment has been improved.

Examples of candidates' answers to question 23(c):

1.

Enter number of question	
c)	There will be no gap between the pointer and scale, Which will make the reading more accurate. The laser will also be thinner than the pointer, giving a more accurate result.

Comment: The candidate should give an explanation for why this 'will make the reading more accurate'. A beam of laser light is not necessarily 'thinner' than a pointer.

2.

> c) The laser beam points exactly at the scale, as opposed to the pointer which didn't actually touch the scale.

Comment: This answer consists of a statement without giving any explanation about the effect it has on accuracy. There is no reference to how the percentage uncertainty in a reading is affected.

Question 24 – This is the first of two open-ended questions in this year's paper. It uses the context of Monty Python's *Galaxy Song* to provide opportunities for candidates to demonstrate their knowledge about the expanding universe.

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 allocated 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 did not 'comment on these lyrics' as instructed. They used the opportunity to, for example, discuss the speed of light but did not then return to the lyrics to say whether or not those lyrics were correct in the eyes of a Physicist.
- 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.
- A significant proportion of candidates wrote a full A4 page (or more) 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.

Examples of candidates' answers to question 24:

1.

24 Although the universe is forever expanding in every way nothing can travel faster than the speed of light, 3×10^8.
Also although the whole universe is expanding, every object is coming closer together, because of the gravitational pull of every object on this earth.

Comment: This answer contains contradictions – how can it be that 'the whole universe is expanding' as well as 'every object is coming closer together'? The speed of light is quoted as ‘3 x 10^8’, but no units are given. The answer does not demonstrate any real understanding and is awarded 0 marks.

2.

Q24)	The first part is almost true as the ~~you~~ universe is still expanding but expands forwards not backwards, and expands at the speed of light. Can use red light-shift of galaxies to work out that the universe is still expanding. The second part is also true as nothing can travel faster than $3 \times 10^8\ ms^{-1}$

Comment: This candidate shows some awareness of the expansion of the universe, but not about differences in the expansion rate.

This answer demonstrates some limited understanding and is awarded 1 mark.

3.

24.	The Universe does keep expanding as it came from a single point, then rapidly expanded outwards and continues to do so. Evidence of this is the presence of Cosmic Microwave Background Radiation which is pervasive throught the Universe and has a temperature of approximately 2·7K due to cooling ~~on~~ expansion. We can calculate the speed of distant galaxies using Hubble's Law and we find that they are all moving away as the Universe expands outwards. So far as we know, nothing can travel faster than the speed of light which is $3 \times 10^8\ ms^{-1}$ and so will approximately be 12 million miles per minute.

Comment: This candidate is demonstrating knowledge of the expansion of the universe and the evidence for it. Although there is a reference to Hubble’s law, the candidate has not taken the opportunity to comment on the different speeds of galaxies at different distances (and compared these speeds of expansion with the speed of light).

This answer demonstrates reasonable understanding and is awarded 2 marks.

4.

24 The ~~th~~ first line of the lyric is correct because there is evidence to support the expanding of the universe in all different directions, such as redshift which shows ~~[illegible]~~ the apparant change of frequency (and wavelength) of light from a star as it travels away from the observer. Also Olber's paradox asks why the night sky is dark and this shows that the universe is not fixed and we are only seeing the observational universe, or the light from stars that died millions of years ago, not from all the stars that are there today. However the second part of the lyric that states that it is travelling at the speed of light is incorrect because although the speed of light is "the fastest speed there is," the universe expands ~~[illegible]~~ at a speed that is directly protional to the distance of the observer according to hubble's law showing it is not expanding at a fixed speed.

Comment: This candidate shows significant knowledge about the expanding universe and the evidence for it. Also provided is an appropriate discussion about the rate of expansion compared to the speed of light. The discussions also suitably refer back to the lyrics of the song.

This answer demonstrates good understanding and is awarded 3 marks.

Question 25 – This question provides information about a binary star system and uses this context to test data handling skills as well as to ask questions about atomic energy levels and recessional velocity.

Parts (a) and (b)(i) were done well, but (b)(ii) and (b)(iii) were answered poorly.

Specific areas of weakness in the answers from candidates were:

Part (a):

- There were some examples of candidates performing inappropriate intermediate rounding during the required double calculation – this produced inaccurate final answers for the value of the energy gap.

Part (b)(ii):

- Candidates needed to use the given data along with two relationships involving *red shift* *z*, ie $z = (\lambda_{observed} - \lambda_{rest})/ \lambda_{rest}$ and $z = v/c$. This was poorly recognised by many candidates.
- There were a few candidates who used the wrong value of wavelength. They should have found that the maximum observed wavelength is 656·41 nm. The wrong values appeared to be due to candidates making mistakes in reading the vertical scale of the graph.
- Again, intermediate rounding was carried out by some candidates during the required double calculation – this sometimes produced inaccurate final answers for the value of the recessional velocity

Part (b)(iii):

- Although the question asks candidates to 'explain', many answers were simply statements that compared the velocities.

Question 26 – This question is about fundamental particles and particle accelerators.

Part (a) was well done but part (b) was answered poorly.

Specific areas of weakness in the answers from candidates were:

Part (b): (Candidates were asked how particle accelerators are able to (i) accelerate and (ii) deflect charged particles.

The expected answers were that acceleration is achieved using electric fields and deflection is caused by magnetic fields.)

- Despite the expected answers being little more than the simple recall of knowledge, very few candidates gained many marks.

Question 27 – This question is based on an experimental arrangement to investigate the photoelectric effect.

Parts (a)(i) and (a)(ii) were well done but the responses to part (b) were poor.

Specific areas of weakness in the answers from candidates were:

Part (a)(i): (Calculation of the maximum kinetic energy of a photoelectron.)

- Many candidates correctly started their answer with $E_k = hf - hf_o$. However, some then substituted the work function of sodium in place of 'f_o' rather than for 'hf_o'. This error meant that they could only be awarded the partial marks for selecting the correct formula.

Part (a)(ii): (Calculation of the maximum velocity of a photoelectron.)

- Many candidates quoted too many significant figures in their final answer. The mass of an electron is given on the data sheet (page two of the examination paper) as $9{\cdot}11 \times 10^{-31}$ kg. This value (along with the other data provided in the question) has been given to three significant figures and so the appropriate number of sig. figs. in a candidate's answer should ideally be no greater than three also. However, markers frequently saw answers such as, '$v = 388817{\cdot}34$ m s^{-1}' (ie to eight sig.figs.). It appears that some candidates are confused about the difference between quoting an answer to, say, three significant figures and quoting an answer to three decimal places. It is recommended that candidates practise using scientific notation and giving the same number of significant figures in their final answer as the data in the question.
- There were also examples of rounding errors in the final answer. Ideally the answer of 388817·34 m s^{-1} should be given as $3{\cdot}89 \times 10^5$ m s^{-1}, but some gave it as $3{\cdot}88 \times 10^5$ m s^{-1} – this is incorrect rounding.

Part (b): (Candidates were asked to explain how decreasing the irradiance of the radiation affects the maximum velocity of a photoelectron.

An ideal answer would be: 'The reduction in the irradiance means that fewer photons are incident on the sodium plate every second. However, each photon has the same energy as before and, as one photon gives all its energy to one electron, each photoelectron has the same maximum velocity as before.' It is important to include this concept of one photon interacting with and releasing one electron as this is the basis of the quantum theory.)

- Although candidates were asked to 'explain', many failed to provide any attempt at an explanation.
- Some attempts at an explanation were simply statements and not explanations. For example 'the velocity of the photoelectrons is the same because irradiance does not affect velocity'. Markers were looking for the candidate to explain **why** changing the irradiance does not affect the maximum velocity of a photoelectron.

Examples of candidates' answers to question 27:

1. For part (a)(i):

27 (a) (i)

$$E = hf$$

$$3.78 \times 10^{-19} = 6.63 \times 10^{-34} \times f$$

$$f_o = 5.7 \times 10^{14} \text{ Hz}$$

$$E_k = hf - hf_o$$

$$= \left((6.63 \times 10^{-34}) \times (6.74 \times 10^{14}) \right) - \left((6.63 \times 10^{-34} \times 5.7 \times 10^{14}) \right)$$

$$E_k = 4.4682 \times 10^{-19} - 3.7791 \times 10^{-19}$$

$$= 6.891 \times 10^{-20} \text{ J}$$

Comment: This candidate has 'gone round in circles' by unnecessarily calculating the threshold frequency from the work function, only to use it again to calculate the work function! (hf_o). In the process, they have quoted the threshold frequency to two significant figures. With different figures, this process could have introduced an inaccuracy in the final answer. Also, time has been wasted that might have been important to the candidate for a later question.

2. For part (a)(ii):

ii)

$$E_K = \tfrac{1}{2} m v^2$$

$$6.9 \times 10^{-20} = \tfrac{1}{2} \times 9.11 \times 10^{-31} \times v^2$$

$$v^2 = \frac{6.9 \times 10^{-20}}{\tfrac{1}{2}\, 9.11 \times 10^{-31}}$$

$$= 1.51\ldots \times 10^{11}$$

$$v = \sqrt{1.51\ldots \times 10^{11}}$$

$$= 389,206.7 \text{ ms}^{-1}$$

$$= 389,207 \text{ ms}^{-1}$$

Comment: This candidate has used their value of kinetic energy (from the previous part) given to two significant figures. However, they appear to believe it is then appropriate to quote their final answer for the velocity to six significant figures.

3. For part (a)(ii):

$$= 6.89 \times 10^{-20}\ J$$

ii

$$E = \frac{1}{2}mv^2$$

$$6.89 \times 10^{-20} = \frac{1}{2} \times 9.11 \times 10^{-31} \times v^2$$

$$v^2 = \frac{6.89 \times 10^{-20}}{0.5 \times 9.11 \times 10^{-31}}$$

$$v^2 = 1.51 \times 10^{11}$$

$$v = \sqrt{1.51 \times 10^{11}}$$

$$= 388924.61\ ms^{-1}$$

Comment: This candidate has used their value of kinetic energy (from the previous part) given to three significant figures. However, they appear to believe it is appropriate to quote their final answer for the velocity to eight significant figures.

4.. For part (b):

b) the maximum velocity of a photoelectron would stay the same as irradiance only affects the number of photoelectrons produced and not the amount of energy they have.

Comment: This answer does not state wrong physics. However, it is merely a statement, not an explanation. An explanation should include a reference to one photon releasing one electron when it gives all its energy to that photoelectron. It should also clarify that a reduction in irradiance only decreases the number of photons **per second** and not the energy that each photon carries.

Question 28 – This question asks candidates about the interference patterns produced by two different experimental setups. The first uses monochromatic light incident on a grating and the second uses a source of microwaves in front of a double gap in metal plates.

Parts (a) and (b)(i) were well done, but the answers to part (b)(ii) were poorer.

Specific areas of weakness in the answers from candidates were:

Part (a):

- The wavelength of the light was given as '589 nm' – some candidates did not know the meaning/value of the prefix 'nano'.

Part (b)(i): (Candidates were given the path lengths from each gap and asked whether constructive or destructive interference occurs at point **J**. They were also told that they must justify their answer by calculation.

The most straightforward way to answer this part is to show that the path difference is 75 mm and that 2·5 wavelengths 'fit into' this path difference. The odd half wavelength in the path difference means that destructive interference occurs at **J**.)

- Some candidates made no attempt at a calculation. Showing an appropriate calculation was essential in order to gain any marks.
- A significant number of candidates worked out the path difference in millimetres but then divided this by the wavelength in metres (despite having been given this too in millimetres).
- A significant number of candidates did not answer as instructed by choosing 'constructive' or 'destructive'. Markers quite frequently saw 'minimum' and even 'deconstructive'.

Part (b)(ii): (Candidates were told that point **K** is initially a point of destructive interference. They were asked what happens to the strength of the signal detected at **K** when one of the gaps is covered with a sheet of metal. Again they were told that they must justify their answer.

An appropriate answer should have said that, because there is now only one set of waves reaching point **K**, destructive interference no longer occurs and so the strength of the signal increases.)

- Some candidates made no attempt at a justification. Providing a justification was essential in order to gain any marks.
- Some candidates said that the signal strength increases because constructive interference now occurs at **K**, apparently being unaware that interference can only occur when two (or more) sets of waves meet and combine. This justification is wrong physics and prevents any marks being awarded.

Question 29 – This is a short question on the refraction of light in a triangular glass prism. It also involves data handling skills, candidates being given a graph of refractive index versus wavelength for the glass prism.

Part (a) was quite well done, but the answers to part (b) were poorer.

Specific areas of weakness in the answers from candidates were:

Part (a): (Candidates were asked to calculate the angle of refraction for the ray of light as it leaves the prism.)

- There were a few candidates who used the wrong value of refractive index. They should have found that the refractive index for a wavelength of 660 nm is exactly 1·615. The wrong values for 'n' appeared to be due to candidates making mistakes in reading the vertical scale of the graph.
- Although most candidates were able to select the Snell's law relationship, a significant number made errors at the substitution stage. The fact that the refraction is occurring as light travels from **glass into air** meant that candidates often substituted the angles the 'wrong way round'. [It is worth noting that candidates who used '$n_1 \sin\theta_1 = n_2 \sin\theta_2$', usually substituted correctly, worked out the correct answer and received full marks. Although that relationship is not provided in the data booklet, there is no problem with candidates using it in their answers.]
- There were a few candidates who performed inappropriate intermediate rounding when evaluating 'sin 38' and who therefore ended up with an inaccurate final answer. They should have kept the 'full' answer in their calculators in order to find $\sin^{-1}\{1{\cdot}615 \times \sin 38\}$.
- Some candidates failed to give the units for their final answer (ie degrees).

Part (b): (Candidates were told that light of shorter wavelength is now shone through the prism and asked whether its speed is less than, the same as or greater than the speed of the original ray. They were asked to justify their answer.

The correct answer required candidates to refer to the graph to realise that this shorter wavelength has a greater refractive index. As $n = v_1/v_2$, there is a greater change of speed and so the speed is less than before.)

- Many candidates quoted the wave formula ($v = f\lambda$) and stated that, because frequency remains constant on refraction, a shorter wavelength means a smaller velocity. This showed a lack of appreciation of the situation being presented in the question, where a different wavelength (and so a different frequency) was being used.

Question 30 – This question is about *e.m.f.*, internal resistance and the combination of resistances in the context of a technician testing a car battery.

Part (a) was moderately well done, but part (b) was answered very poorly.

Specific areas of weakness in the answers from candidates were:

Part (a)(i):

- The *e.m.f.* is equal to the intercept on the vertical axis when the given graph line is extrapolated. This answer is 12·0 V, but some candidates gave an answer of 10·0 V, seemingly thinking that the *e.m.f.* is the value at the end of the graph line without extrapolating it to the voltage axis. Other candidates gave an answer of 14·0 V, which appears to have been chosen because it is the highest labelled value on the vertical axis.

Part (a)(ii):

- Some candidates calculated the internal resistance using $E = V + Ir$, using their value of *e.m.f.* from part (a)(i) and values for V and I taken from the graph. Those who used this method generally did very well.
- Other candidates attempted to use the gradient of the given graph. Those who used this method did not perform so well. A significant proportion of candidates did not realise that the internal resistance is equal to the **negative** of the gradient of the graph. Saying 'r = gradient of graph' is the same as starting an answer with a wrong formula.

Part (a)(iii):

- When a supply is short circuited, the resulting current can be calculated from E/r. Although this relationship is not provided, it is expected that candidates will be familiar with using Ohm's law and be able to substitute E for 'V' and r for 'R'.

Part (b): (Candidates were asked to explain why the headlamp becomes dimmer when the starter motor is operated. It was expected that this is an everyday context commonly used by teachers to illustrate the effects of internal resistance. Candidates' responses did not indicate that this is the case.)

- Many candidates thought that it was sufficient to state that, because the headlamp and starter motor are in parallel, the current splits. They appeared to believe that the total current was the same as before and seemed unaware that the supply provides a greater current when the motor is switched on.
- It was concerning to find many candidates stating that the parallel connection means that the supply voltage splits between the two components. This is a very basic error in the understanding of parallel circuitry.
- Markers saw numerous examples of the misuse of physics terminology, for example candidates saying 'voltage through' and/or 'current across'.

Question 31 – This is the second of two open-ended questions in this year's paper. It provided candidates with information about 'ultracapacitors' and AA rechargeable cells. Candidates were required to compare the advantages and/or disadvantages of using these components.

Being an open-ended question, there were many acceptable ways to answer. For example, candidates had the 'freedom' to use calculations (eg of charge or energy stored) as part of their answer. Markers were surprised to find that candidates did not respond well to this 'freedom' – perhaps because it was not the structured calculation that candidates are used to.

Specific areas of weakness in the answers from candidates were:

- Candidates often carried out calculations without making it clear to markers what exactly they were trying to do. Their answers would have been much clearer (and improved) by making an initial statement such as 'the charge stored in the AA cell = …', 'the charge stored on the capacitor = …', 'the energy stored in the capacitor = …' or 'the energy available from the AA cell = …' etc.

- Many candidates carried out calculations to find the charge or energy in the components but then failed to go on and discuss any comparison between them or the advantages or disadvantages of using either component.

Examples of candidates' answers to question 31:

1.

31, $C = \frac{Q}{V}$ $Q = C \times V$

$Q = 100 \times 2.7$

$Q = 2700\ C$

$E = \frac{1}{2}QV$

$E = \frac{1}{2} \times 2700 \times 2.7$

$E = 3645$

$P = IV$

$P = 1.5 \times 3600$

$P = 5.1$

Ultracapacitors are capable of holding a much larger amount of charge compared to the AA cells, they hold a much ~~grea~~ greater amount of energy and are capable of ~~being~~ being charged at a much greater rate than their rechargeable counter-parts.

Comment: This candidate has not made clear what any of the calculations are actually for. The marker is left to 'guess' that, for example, *Q* = *CV* is being used to find the charge stored in the capacitor (there is a demonstrated arithmetic error in that calculation).

It appears that the '*E*' calculation is to find the energy in the capacitor. However, no calculation for the AA cell has been shown. Calculations are needed in order to justify the statements made. It is incorrect that an ultracapacitor holds more charge (even allowing for the arithmetic error). It is incorrect that an ultracapacitor stores more energy. No information is provided that would allow the candidate to make a meaningful statement about the relative charging rates.

This answer demonstrates no understanding and is awarded 0 marks.

2.

31 Capacitors are built to release charge very quickly in short bursts which is better for a camera flash but rechargeable batteries are more [illegible] for long term as they discharge more slowly.

Comment: No use has been made of the data provided. However, this answer demonstrates some limited understanding of capacitors and cells and is awarded 1 mark.

3.

31.

Capacitor

2.7V 100F

$C = \frac{Q}{V}$

$Q = CV$

$Q = 100 \times 2.7$

$= 270\,C$

rechargable cell

1.5V 3400mAh

$Q = It \rightarrow 3400 \times 10^{-3} \times 60 \times 60$

$Q = 12240\,C$

by comparison, the rechargable batteries seem better in the long run but if your looking for high energy quickly then its the ultra capacitor.

Comment: This candidate has clearly shown which calculation is for the capacitor and which is for the cell. Both of these calculations for the charge are correct. A comparison has been made between the components on the basis of these calculations.

This answer demonstrates reasonable understanding and is awarded 2 marks.

4.

(31) One disadvantage of ultracapacitors is that, as they discharge, the voltage across them decreases, unlike rechargeable cells where it remains relatively constant. This means ultracapacitors couldn't be used for something requiring a specific voltage, even though the initial voltage can be higher (2.7 > 1.5) than AA rechargeable cells.

The charge an ultracapacitor can store is:

$Q = CV$

$= 100 \times 2.7$

$= \underline{\underline{270\ C}}$

An AA rechargeable cell can store 3400mAh of charge which is:

$Q = It$

$= 3400 \times 10^{-3} \times (60 \times 60)$ ← 60×60 seconds = 1 hour

$= \underline{\underline{12240\ C}}$

As such, AA rechargeable cells also store a greater amount of charge. This suggests the only advantage of ultracapacitors is the ~~initial~~ initial higher voltage they can supply.

Comment: This answer correctly contrasts the value and variability of the output voltage from the capacitor with the (approximately) constant output voltage from the cell. It also refers to these issues perhaps being more of less important for different applications.

There are two clearly identified calculations of the charge stored by each component. These calculations are both correct. A comparison has then been made between the components on the basis of these calculations.

This answer demonstrates good understanding and is awarded 3 marks.

Question 32 – This question is about skills related to experimental design and evaluation using the context of an investigation into the transmission of light through an optical fibre. 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) and (c) were mediocre and part (d) was very poorly answered.

Specific areas of weakness in the answers from candidates were:

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

Candidates were asked to use square ruled paper and plot a graph of the given results.

Issues and errors noted by markers include:

- Points were plotted correctly but no graph line 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).
- 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): (Estimating the required radius by taking a reading from the drawn graph.)

Candidates needed firstly to calculate 75% of 0·80 V and then use their graph to find the corresponding radius of loop.

- Candidates sometimes seemed to have difficulty using their own chosen scale to take a correct reading from their graph.

Part (c): (Suggesting two improvements to achieve a more precise determination of the radius for part (b).

The ideal answer should state that the measurements should be repeated {several times} to produce a better mean value of voltage at each value of radius **and** that measurements should be taken with smaller steps in the radius around the 75% value of voltage.)

- It is pleasing to report that vague, imprecise answers such as ‘use more accurate apparatus’ and ‘take measurements to more significant figures’ were seen less frequently by markers this year.
- Many candidates just stated ‘take more measurements’. Whilst this is not wrong, it is not clear whether they mean repeating the experiment to produce better average values or whether they mean new measurements with smaller steps in radius. Both of these ideas are important and they should each be stated clearly.

Part (d): (Describing further work to investigate another factor that may affect the transmission of light through the fibre.)

Many answers were vague and lacked detail.

It should be noted that an answer to this type of question should include something about each of the following:

- Identification of a suitable variable to investigate.

- Identification of variable(s) to be kept constant.
- Detail of how to change and measure the chosen independent variable.

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

Many of the following points were made in the external assessment reports of the last two 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 should not use up (↑) and down (↓) arrows in their answers rather than using words. This may be acceptable 'shorthand' for use 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 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, '*destructive interference*', not '*deconstructive interference*') and spelling (eg '*capacitor*', not '*capacitator*').

- 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 with a variety of scales.

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

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

- 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 2013	841

Number of resulted entries in 2014	1111

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	36.0%	36.0%	400	56
B	23.2%	59.2%	258	46
C	17.6%	76.8%	195	37
D	6.9%	83.7%	77	32
No award	16.3%	-	181	-

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.