External Assessment Report 2013

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

The statistics used in this report are pre-appeal.

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

Comments on candidate performance

General comments

This is the second examination for the revised Higher Physics course.

Last year, early adopter schools presented 457 candidates for the Higher Physics (revised) examination. This year there were 844 candidates, 35 centres presenting candidates for the revised paper compared to 20 centres last year.

On the whole, markers were impressed by the quality of the answers produced by these 844 candidates. This examination included some questions that were also in the traditional paper. There were 40 marks (out of 90) in this examination which were common to both papers. In nearly all of these common questions, candidates sitting the revised examination performed slightly better than those sitting the traditional paper.

This is the second national examination to include open-ended questions {Q25(b) and Q27}. 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.

This is the first revised paper to include an 'estimate' question (Q23). In most cases this was answered very well.

Candidates generally performed 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 more demanding overall than last year. The grade boundaries have been reduced by a few marks 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 paper was found to be reasonably straightforward by most candidates, with questions 1, 2, 6, 8, 9 and 10 being answered particularly well (at least 80% of candidates choosing the correct answers).

Question 21: This was designed to provide a straightforward start to Section B and, in general, candidates answered this question well. Part (a) required candidates to 'show' that the initial acceleration of the motorcycle was $5{\cdot}0\ \text{m s}^{-2}$. Most candidates demonstrated that they knew that, when answering a 'show' question, they must start with a relevant formula, substitute numbers without having performed any 'mental arithmetic' and then finish by writing down the required value.
Parts (b) and (c)(i) were also well answered, showing that a high proportion of candidates can select and use appropriate relationships in relation to force and motion.

Question 23: This is the first 'estimate' question in a revised paper. In order to 'Estimate the gravitational force of attraction between two students sitting beside each other', candidates had to make estimates of masses for the students and the distance between their 'centres' before substituting into Newton's universal law of gravitation. Although there were a few values given by candidates that were well outside a 'reasonable' range, most were realistic. The vast majority of candidates completed this question very well.

Question 24(b): The calculation of the Lorentz factor for 'v/c = 0·80', given the definition of the Lorentz factor, was very well done.

Question 26(a): The two calculations in (i) and (ii) of part (a) were both very well done.

Question 28(a)(ii) The calculation of the distance from the second source to the third maximum of the interference pattern was very well done.

Question 29(b): Part (b) required candidates to use Snell's law to calculate the critical angle. This calculation was done very well.

Question 30(a)(i): Candidates were given a graph of potential difference against current and asked to find the e.m.f. of the source. This was done well.

Question 31(b): Candidates were given a table of 'switch on' voltages for various colours of LED and asked to predict the switch on voltage of an LED emitting blue light. This was done very well.

Question 32(b): The graph drawing from the given data was done well.

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 18 [49%]). This question is about charge and potential difference for a capacitor. It is worth noting that the same question appeared in the traditional paper (as question 10) – there it was answered correctly by 43% of candidates.

Question 21 – The context of this question is a car and a motorcycle travelling in a straight line – the car moving at constant speed and the motorcycle initially accelerating uniformly. Part (d) asks candidates to analyse the effects that a decreasing unbalanced force has on the velocity/time graph.
On the whole, candidates showed reasonable ability in using equations of motion and $F = ma$ to answer parts (a), (b) and (c)(i). Part (c)(ii), which required candidates to explain force and motion relationships was poorly answered. Part (d), which required candidates to sketch a velocity/time graph for a decreasing unbalanced force, was poorly answered.

Specific areas of weakness in the answers from candidates were:

Part (a):

- Failing to include a relevant formula in an answer to a 'show' question.
- Substituting 'u' and 'v' the 'wrong way round' in an equation of motion.
- Giving the wrong units for acceleration.

Part (b):

- Working out the distance travelled by the motorcycle by taking its speed as being constant at 20 m s^{-1}, when part (a) had clearly stated that it was accelerating at 5·0 m s^{-2}.

Part (c)(i):

- This question asked for the value of the force of friction acting on the motorcycle. Candidates needed to use $F = ma$ to calculate the unbalanced force and then subtract this value from the driving force. However, some candidates stopped after finding the unbalanced force.

Part (c)(ii):

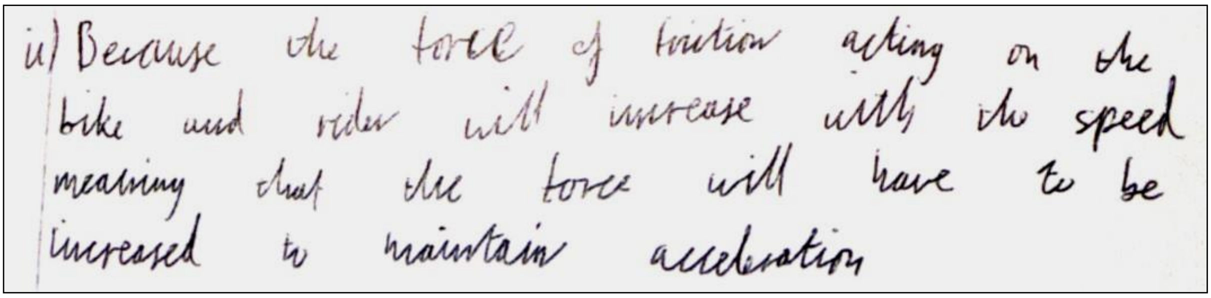
- This question asked candidates to ‘explain why the driving force must be increased with time to maintain a constant acceleration’. An acceptable answer should explain that, as the motorcycle’s speed increases, frictional forces also increase. The driving force must therefore be made greater in order to keep a constant unbalanced force (and hence constant acceleration). Candidates’ answers frequently showed little understanding of combination of forces and the relationship with acceleration. Many showed confusion in their understanding of the quantities *velocity* and *acceleration*.

Part (d):

- Candidates should have sketched a velocity/time graph which *gradually* curves over (starting at a time of 5·0 s) and then tends to ‘flatten off’ at a terminal velocity. Many graphs showed a ‘sudden’ change from an acceleration of 5·0 m s^{-2} to constant velocity. Others were wrong because they curved down again. Many candidates’ graph lines were drawn in ink – changes were untidy and unclear. The use of pencil for drawing the graph line is recommended.

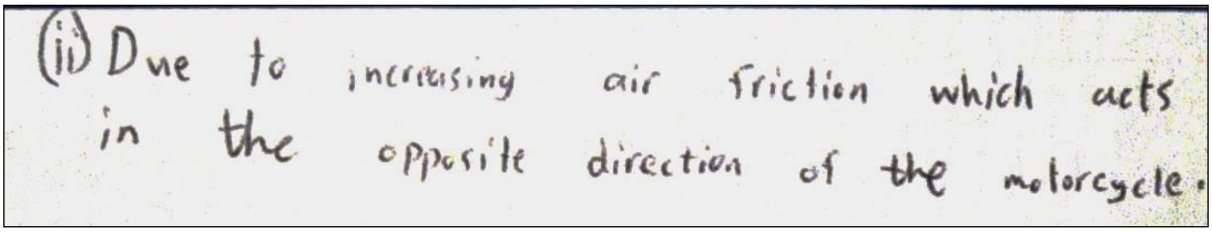
Examples of candidates’ answers to question 21(c)(ii):

1.


ii) Because the force of friction acting on the bike and rider will increase with the speed meaning that the force will have to be increased to maintain acceleration

Comment: This candidate has correctly identified that frictional forces increase as the speed of the motorcycle increase. However, the answer becomes weak at ‘*meaning that …*’. This is where the candidate should have provided some useful Physics such as ‘*the unbalanced force must be kept constant to produce a constant acceleration*’.

2.


(ii) Due to increasing air friction which acts in the opposite direction of the motorcycle.

Comment: There is nothing wrong stated here, but neither is there an explanation.
The candidate has failed to link together various facts, eg that the speed of the motorcycle increases and that this is why air resistance increases.
This candidate possibly has a correct idea in his/her head about the frictional forces being in the opposite direction to the driving force (‘*in the opposite direction of the motorcycle*’), but he/she needed to go much further and say that the driving force needs to be increased to keep the net forward force constant in order for the acceleration to remain constant.

Question 22 – The context of this question is a crash test dummy inside a car which collides with a wall. It provides opportunities for candidates to show their understanding of momentum conservation and their ability to carry out numerical analysis using the relationships for momentum and impulse.
Part (a) was very poorly done. Part (b) was answered quite poorly – surprisingly less well than the same question in the traditional paper. The answers to parts (c) and (d) were weak.

Specific areas of weakness in the answers from candidates were:
Part (a):

- The law of conservation of linear momentum states that '*the total momentum before a collision (or interaction) is equal to the total momentum after the collision, in the absence of external forces*'. Many candidates missed out vital words like 'total' and 'collision'. Many also did not refer to the condition of 'no external forces'. A common answer given by candidates was '*momentum before equals momentum after*' – this is obviously inadequate. Many candidates do not seem to realise that the momentum of each sub-part of a system *does* change in the course of a collision.
- A small but significant number of candidates gave completely wrong answers – these being about energy conservation or one of Newton's laws of motion. It was very disappointing to see such answers to a question that was simply about recall of knowledge.

Part (b):

- The change in momentum in an interaction is defined as 'final momentum – initial momentum' (ie $\Delta p = mv - mu$). Many candidates performed the subtraction the wrong way round. This is equivalent to substituting '*u*' and '*v*' round the wrong way in the relationship and is regarded as wrong Physics.
- Acceptable units in a candidate's answer were kg m s^{-1} (or kg m/s) or N s. Some candidates lost marks by wrongly writing N s^{-1}.

Part (c):

- This part of the question has 3 marks allocated. Candidates should have realised that this means that more was required than a single, simple calculation. Alternative methods of answering were possible but all required at least two separate calculations (eg an equation of motion to find acceleration followed by use of Newton's second law, or a calculation of kinetic energy followed by use of the 'work done' formula).
- Some of those who used an equation of motion went wrong at the substitution stage when they mixed up '*u*' and '*v*'.
- Many candidates demonstrated a lack of awareness of appropriate significant figures. It was not unusual for a marker to see the final answer written as 'F = 14028·125 N'. In the question, there is a mixture of two and three significant figures in the provided data. It is therefore appropriate to round the answer to the smaller number of significant figures, giving F = 14 000 N (or $1{\cdot}4 \times 10^4$ N), although F = 14 030 N (or $1{\cdot}403 \times 10^4$ N) is within the acceptable range for significant figures.

Part (d):

- Candidates should have explained that, for a given change in momentum (= $F\,t$), a greater time of collision means a smaller (average) force on the driver. Some thought that there was a change in the value of the impulse. Most answers were incomplete rather than wrong.

Examples of candidates' answers to question 22(d):

1.

If the seatbelt stretches it increases the time of impact which reduces the ~~Force~~ opposing Force.

Comment: This candidate has identified some correct Physics (increased contact time), but he/she has not provided the full argument about why the force is reduced – the fact that the change in momentum is the same and that it equals '*force* x *time*' should also have been mentioned.

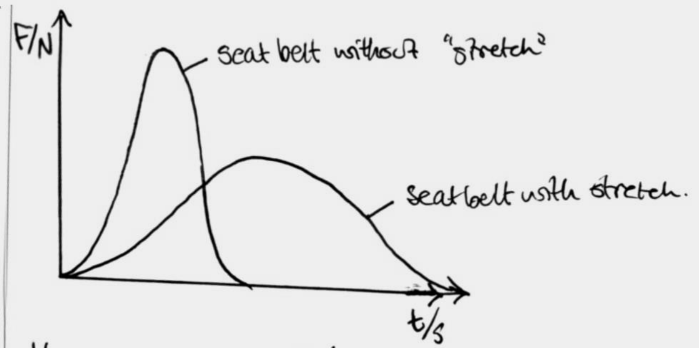
2.

(d) If the seatbelt stretches it means the ~~impulse~~ ~~still~~ force applied will be for a greater amount of time. This means that the force can be lower and still have the same change of momentum. ∴ it will be less dangerous to the driver.

Comment: This candidate has identified much of the necessary Physics. The answer would have been improved by stating the link between momentum and impulse, ie 'change in momentum equals force x time'.

3.

d)



If an object ~~collides~~ exerts a force upon an inelastic object, the force is applied over a very brief time so will be more damaging. With an ~~in~~ elastic object, like a stretchy seatbelt, the force is exerted over a longer period of time, making it less damaging.

Comment: The candidate has used both words and a diagram to present their argument. A marker can see that the candidate knows that the maximum force will be less and the time of impact greater. The answer could have been improved by saying that the change in momentum is constant (area under the force/time graphs are equal). It might have been better not to use the words 'elastic' and inelastic' as these are used specifically in Physics to refer to collisions where total kinetic energy is conserved or not conserved.

Question 23 – Candidates were asked to ‘Estimate the gravitational force of attraction between two students sitting beside each other’. They needed to make an estimate of mass for each of the students and an estimate of the distance between the students before substituting into Newton’s universal law of gravitation.

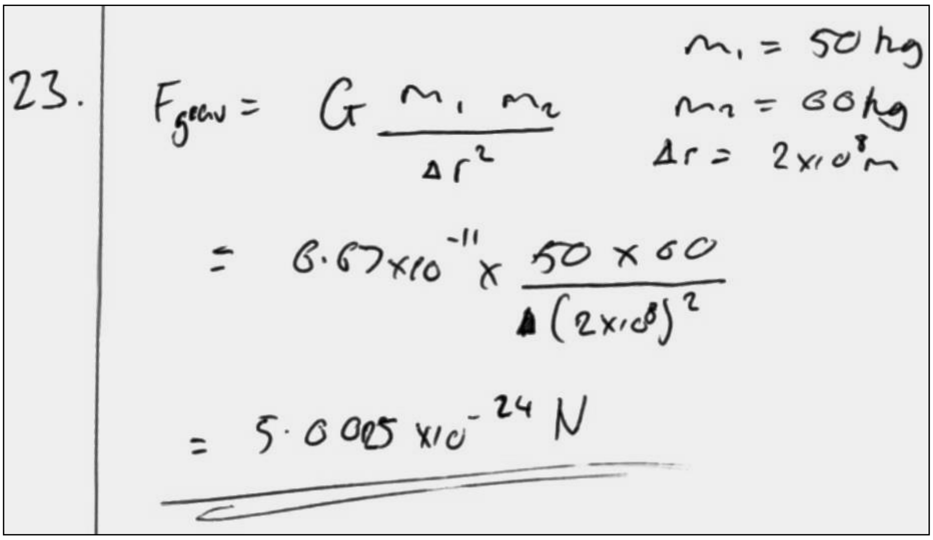
The vast majority of candidates completed this question very well.

Specific areas of weakness in the answers from candidates were:

- Some estimates of mass were outside an acceptable ‘normal’ range. Markers were told to accept any value of mass in the range from 20 kg to 200 kg. It was felt that these limits were quite ‘generous’.
- Some estimates of distance were outside an acceptable range. Markers were told to accept any value of distance in the range from 0·10 m to 2·0 m. It was felt that these limits were also quite ‘generous’.
- Some candidates stated an acceptable value for distance, but then went on to substitute *half* of this value in the equation. Some sketched diagrams showed that they thought they should use a value of ‘radius’ from a point that was mid-way between the two masses.
- There were some candidates who substituted a value of ‘9·8’ for ‘G’.
- Some candidates did not state their estimates. Their answers started with the formula and moved straight into the substitution stage. Candidates should know that, in any future ‘estimate’ questions, all estimated values should be clearly stated (eg in a list) before any attempt is made to use them in a formula.

Examples of candidates’ answers to question 23:

1.


23.

$m_1 = 50$ kg

$m_2 = 60$ kg

$\Delta r = 2 \times 10^8$ m

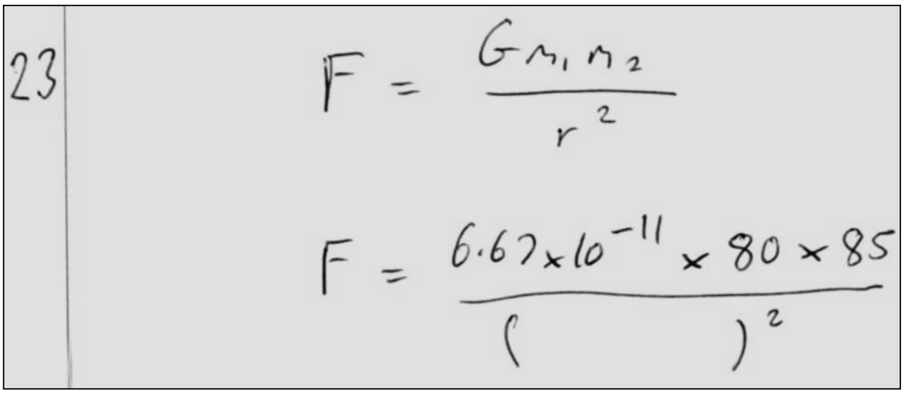
$$F_{grav} = G\frac{m_1 m_2}{\Delta r^2}$$

$$= 6.67 \times 10^{-11} \times \frac{50 \times 60}{(2 \times 10^8)^2}$$

$$= 5.0025 \times 10^{-24} \text{ N}$$

Comment: This candidate has selected the appropriate relationship for the calculation. The estimates for the masses are clearly shown and are within the acceptable range. However, the distance between the students cannot be correct for them to be ‘*sitting beside each other*’! The candidate (unaware of their error with the distance) should have given fewer significant figures in their final answer for the data used.

2.



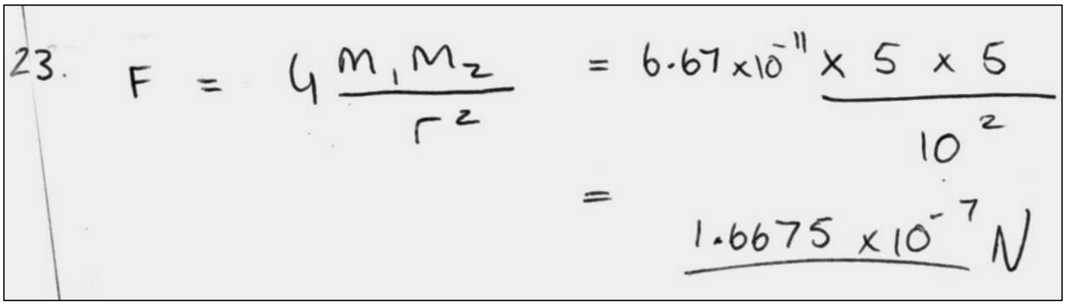
23

$F = \frac{Gm_1m_2}{r^2}$

$F = \frac{6.67 \times 10^{-11} \times 80 \times 85}{(\quad)^2}$

Comment: No list of estimates has been provided. A marker should not have to look to the substitution stage to find these estimates. For some unknown reason the candidate has not been able to make any estimate for distance and has abandoned their answer at the substitution stage. This answer can still be awarded partial marks for the correct formula and the mass estimates.

3.

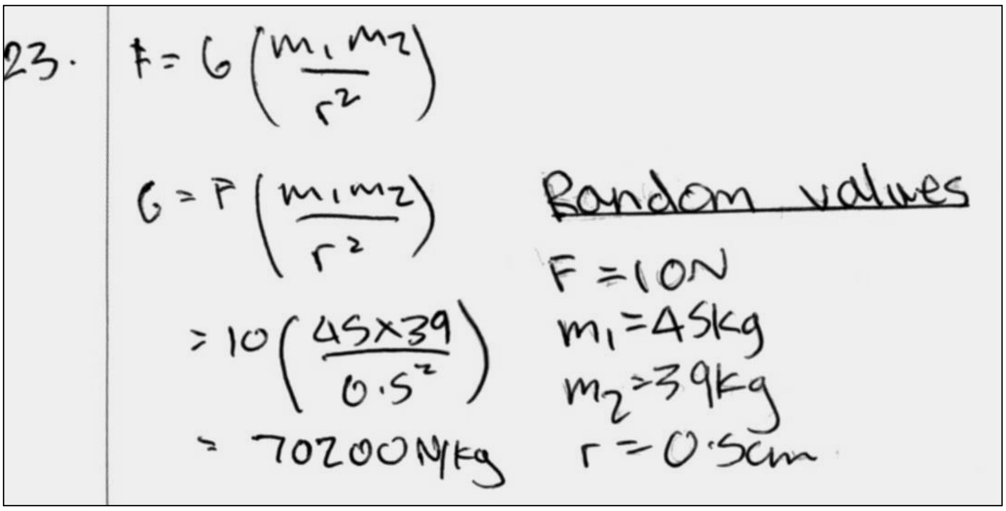


23. $F = G\frac{m_1M_2}{r^2} = 6.67 \times 10^{-11} \times \frac{5 \times 5}{10^2}$

$= \underline{1.6675 \times 10^{-7}}\ N$

Comment: No list of estimates has been provided. The substitution stage shows that the candidate has chosen 5 kg for each of the masses – these values are too small. The substitution stage also shows that the candidate has chosen 10 m for the distance – this is too large. This answer can only be awarded partial marks for the correct formula.

4.



23. $F = G\left(\frac{m_1m_2}{r^2}\right)$

$G = F\left(\frac{m_1m_2}{r^2}\right)$

$= 10\left(\frac{45 \times 39}{0.5^2}\right)$

$= 70200\ N/kg$

<u>Random values</u>

F = 10N

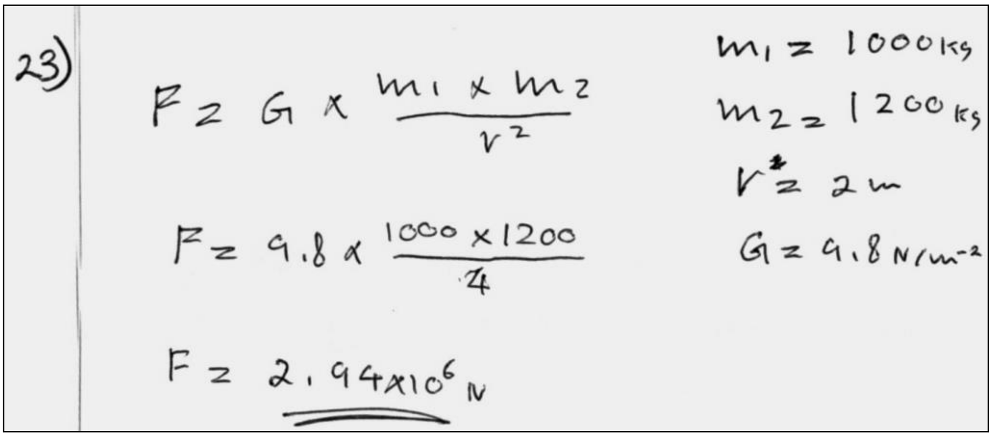
$m_1 = 45kg$

$m_2 = 39kg$

r = 0·5cm

Comment: A list of estimates has been provided, although it is unclear why the candidate thinks these are ‘*random*’! There should not have been an estimate for ‘F’ – this is what the answer is meant to be calculating. The estimate for distance is too small – it is difficult to imagine students being so close that there is only 0·5 cm between their centres of mass! The relationship has been rearranged wrongly. This answer can be awarded partial marks for the initially correct formula and the mass estimates.

5.


23)

$F = G \times \frac{m_1 \times m_2}{r^2}$

$F = 9.8 \times \frac{1000 \times 1200}{4}$

$F = 2.94 \times 10^6$ N

$m_1 = 1000$ kg

$m_2 = 1200$ kg

$r = 2$ m

$G = 9.8$ N/m^{-2}

Comment: The chosen relationship is correct. A list of estimates has been provided. The estimate for the distance is acceptable (just!). The estimates for the masses of the students are too large. The candidate has wrongly used ‘9·8’ for ‘G’. This answer can be awarded partial marks for the correct formula and the distance estimate.

Question 24 – The context of this question is a fictitious web page giving information on the Lorentz factor in special relativity. This provides opportunities for questions on the candidates’ knowledge of special relativity and their skills of handling information provided in the web page.

Part (b) was well done, but parts (a), (c) and (d) were quite poorly answered.

Specific areas of weakness in the answers from candidates were:

Part (a): (‘Explain what is meant by the term *length contraction*’)

Most candidates showed a poor understanding of the term *length contraction*.

- Many implied that it is an absolute change in length for all observers.
- Many thought it was a change in length of an object for an observer in the same frame of reference.
- Many talked of a change of length but did not say which frame of reference the observer was in.

Part (b): (‘Calculate the Lorentz factor when v/c = 0·80.’)

- Most candidates seemed to be well practised in this type of calculation. However, a few failed to carry out all the stages of squaring, subtracting, then finding the square root and the reciprocal. Perhaps this was due to lack of experience in using their calculators?

Part (c): (‘State this relationship in terms of l', l and γ’)

- This was an opportunity for candidates to demonstrate their skills in selecting information from the web page and then rearranging a formula appropriately. It was surprising that fewer than half of the candidates were able to complete this correctly.
- A significant number of candidates worked through to the correct answer but then gave a contradictory answer and so lost the mark. For example, saying $l' = l/\gamma$ which means that $\gamma = l' \times l$.

Part (d): (‘Explain, in terms of the Lorentz factor, why an observer can ignore relativistic effects for an object which is moving with a velocity much less than *c*.’

- Many candidates failed to refer to the Lorentz factor in their answer. These candidates therefore did not answer the question and so could not be awarded any marks.
- Many just repeated the expression ‘relativistic effects’ in their answer without explaining what these effects could be.

Examples of candidates’ answers to question 24:

1.

> (24) (a) "Leangth Contraction" is when the length of a fast moving object, appears shorter by the observer.

Comment: This answer does not tell us where the observer is. The answer cannot be awarded any marks until the marker knows that the observer is in an appropriate frame of reference relative to the moving object.

2.

> 24(a) The ~~contr~~ shortening of observed length between them that an object experiences when it nears the speed of light

Comment: This answer does not say anything about the observer. It could be that the candidate thinks the observer is moving with the object (which would make the answer definitely wrong).

3.

> 24. a) When an object is moving close to the speed of light, the length of it apears to be altered. An Person moving with the object measures its length to be l and an observer will measure it as l'.

Comment: This answer is very nearly correct. The critical omission is a failure to state that the observer who ‘sees’ the length to be *l*’ must be stationary relative to the moving object.

4.

> c) $l' = l\sqrt{1-\frac{v^2}{c^2}}$
>
> $l = \frac{l'}{\sqrt{1-\frac{v^2}{c^2}}}$
>
> $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

Comment: This candidate has correctly written out expressions for ‘*l*’ and ‘γ’ but has failed at the last step to put them together (which is needed to actually answer this part of question 24). He/She should also have added ‘so *l* = γ *l*’ ‘.

5.

> d. $\gamma = \frac{1}{\sqrt{1-(v/c)^2}}$
>
> If v is much less than C, then $(v/c)^2$ is a tiny amount that when taken away from 1, is calculated to still be one. this means that the Lorentz factor is seen to be 1 here, and so there is no need to use relativistic effects on small velocity's, as the answer is merely one.

Comment: A good answer to this question must state that for small velocities the Lorentz factor is very nearly one and that this means there is negligible change to length or time (eg *l* and *l*’ are almost identical). The answer above is correct in stating that the Lorentz factor is approximately one but has not given enough detail about why this means that relativistic effects can be ignored.

6.

> d) as the velocity is much lower than c, v/c is likely to be close to 0. Therefore,
>
> $\gamma = \frac{1}{\sqrt{1-0}}$
>
> $= \frac{1}{\sqrt{1}}$
>
> $= \frac{1}{1}$
>
> $= 1$
>
> Hence, there seems to be no change.

Comment: This answer also identifies that the Lorentz factor is very nearly one for low values of velocity, but also fails to give an explanation of why this causes relativistic effects to be negligible.

7.

> d) For speeds much less than c, the Lorentz factor will be very close to 1, and thus for a given object moving at speeds much less than c, it will be modified by relativistic effects by a negligible amount and can be ignored

Comment: This answer also identifies that the Lorentz factor is very nearly one for low values of velocity, but like examples 5 and 6 it fails to specifically explain that the length contraction is negligible or that the time dilation is negligible.

Question 25 – This question is in two parts. Part (a) gives candidates the opportunity to show their knowledge of the *Big Bang Theory* and the evidence which supports it. Part (b) is an open-ended question about why '*Looking through a telescope is like looking back in time*'.

Neither part of this question was particularly well done. This was disappointing, particularly for part (a) which should have been little more than recall of knowledge.

Part (a):

Specific areas of weakness in the answers from candidates were:

- A significant number of candidates referred to the Big Bang as being a 'collision'.
- Many candidates used the word 'explosion' to describe the Big Bang.

Part (b): This is the first of two open-ended questions in this year's paper. It gained a mean mark of 43%.

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:

- Some candidates mistakenly discussed this as being about time dilation.
- 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 part (a):

1.

25a)	The big bang theory is that the universe used to be a singularity until it expanded rapidly and it became large very quickly. background radiation is a piece of evidence to prove this because it is uniform throughout the universe

Comment: The first part of this answer provides a reasonable description of the Big Bang. As evidence of the Big Bang Theory being correct, the answer then refers to '*background radiation*'. This might be the candidate's attempt to refer to Cosmic Microwave Background Radiation, but without 'Cosmic Microwave', the term '*background radiation*' is referring to radioactivity.

Examples of candidates' answers to part (b):

1.

b) Stars and planets from distant galaxies radiate electromagnetic radiation.
One form of this radiation is ~~oth~~ visible light – which can be seen through a telescope.
This light travels at a speed approximately $3 \times 10^8 ms^{-1}$.
~~Looking at distant~~ As light travelling from distant ~~ga~~ celestial bodies has taken time to travel such great distances – on observance of such bodies one is looking at light emitted from the past.
Therefore it seems as if we are then looking back in time.

Comment: We would normally consider that it is only stars, and not planets, which are significant radiators of electromagnetic radiation. However, this does not detract from this being a good answer. It is worth repeating that markers are not seeking full and perfect answers before awarding full marks.

2.

b) by looking through a telescope you may be able to see the centre of the universe where every thing is move away from.
• there fore by looking at these points we see places that earth once was in time.
• you may also see supernovas that elements of the earth have once come frome in previous time.

Comment: There does not seem to be much evidence, if any, that this candidate has an understanding of the issue.

3.

b) When we look through a telescope at night, we see the ~~a~~ sky and stars and space as it was millions of years ago. This is because of time dilation, whereby ~~time~~ clocks in space slow down and objects contract in order to keep the speed of light constant for all observers. Time dilation means time is longer in space than on Earth, and we are therefore looking back in time when we look into space.

Comment: This is an example of a candidate showing that they have not understood that the relevant Physics is light taking significant time to travel the vast distances across the universe. Instead, they have wrongly discussed time dilation which is to do with differing values of elapsed time for different frames of reference.

4.

> b) Since the speed of light is ~~limit~~ limited at the constant $3\times10^8 ms^{-1}$. Light cannot therefore not go faster than this speed. Since cosmic distances are vast it would take time to reach here. For Instance our nearest star is 4 light years away. Therefore we are are looking at light that came of the star 4 year ago. i.e 4 years in the past.

Comment: This candidate has demonstrated a reasonable understanding of the appropriate Physics. The 'double negative' in the second sentence has been ignored!

5.

> b) When you look at the stars in the night sky you are seeing the light reflected off the star. As the stars are so far away the light takes a long time (e.g light years) to travel to our eyes so therefore we are seeing reflected from a few minutes or years ago. even when we look at a clock we are seeing the time it was a few seconds ago.

Comment: There are a number of things wrong in this answer; light is radiated from stars, not reflected by them; a 'light year' is a distance, not a time; unless your clock is in a distant orbit, there are not 'a few seconds' of delay! This candidate has shown little, or no, understanding of correct Physics.

6.

> b) This statement is essentially true. Due to the vast size of the universe even light, which travels at 3×10^8 m/s, [redacted] takes a noticeable length of time to travel from distant galaxies to earth. [redacted] Humans observe events by taking in the visible wavelengths of electromagnetic radiation through our eyes and it is therefore true in some cases that the events we observe [redacted] already occurred [redacted] a significant time ago but we only see them now because the electromagnetic radiation has had to travel huge distances.

Comment: This writing is not easy to read. However, the candidate is showing good understanding of the correct Physics.

Question 26 – This question uses the context of a cyclotron. In part (a), candidates are required to carry out a calculation on the energy involved in moving a charged particle in an electric field. Candidates then have to equate this answer to the formula for kinetic energy in order to work out the final speed of the charged particle. In part (b), candidates need to determine the direction of the magnetic field given the direction of deflection of the charged particles. Part (c) provides an opportunity for candidates to show their understanding of how a cyclotron operates.

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

Specific areas of weakness in the answers from candidates were:

Part (a)(ii):

- Although this question was generally well done, some candidates failed to round their answer to an appropriate number of significant figures. The display on their calculators was likely to be 3243458·634. The value of the energy had been provided to two significant figures. It was therefore appropriate to give the same number of significant figures in the final answer for the velocity. The final value for the velocity should have been stated as $3{\cdot}2 \times 10^6$ m s^{-1}.

Part (b):

- Less than half of the candidates were able to give the direction of the magnetic field correctly. This may have been due to lack of experience of using an appropriate tool (such as the right hand motor rule {for electron flow}).

Part (c):

Very few candidates seemed to understand the operation of the cyclotron. They did not appreciate that protons are only being accelerated (increasing velocity) by the electric field as they pass across the gap between the dees. The magnetic field is then causing the semicircular path (and change of direction) and so the accelerating voltage has to be changed in polarity to 'match' the new direction of the protons as they cross the gap again. This regular change of direction of the protons is why the accelerating voltage needs to be alternating.

Question 27 – This is the second of two open-ended questions in this year's paper. It gained a mean mark of 52%.

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'.

This question provides a textbook's diagram of an atom and asks candidates to '*use* (their) *knowledge of physics to comment on this diagram*'.

Many candidates concentrated on ‘*an atom*’ and in their answers gave detailed descriptions of parts of the Standard Model. Markers often saw long paragraphs on quarks combining to form protons and neutrons, strong and weak forces etc., etc. While this is not irrelevant, it does not get to the heart of this question as they did **not** *comment on this diagram*, (not even saying ‘*the ‘blob’ in the middle represents the nucleus which is actually made up of ……*’)

Their answers might have been improved by referring to:

- the lack of labels on the diagram (and what those labels should have been)
- the lack of any shown charges on the particles in the diagram (and what those charges should have been)
- the scale of the particles shown on the diagram (and how that does not represent ‘reality’)
- the scale of the gaps shown in the diagram (and how that does not represent ‘reality’)
- electron shells (and energy levels), rather than the ‘balls’ shown
- the structure and charges in the nucleus (some reference to the Standard Model could be relevant here)

This is not an exhaustive list!

Examples of candidates’ answers to question 27:

1.

> 27 The diagram shows a typical structure of an atom – there is a large centre and then a cloud of smaller objects on the outside. Although there are no labels it can be assured that the centre is the nucleus and the outside objects are electrons. The diagram is clearly not a scale drawing as if it was the electrons would be many kilometres away. Aswell as that the diagram shows the nucleus as 1 uniform mass where infact is is actually made of neutrons and protons.

Comment: This candidate has followed the instruction in the question to ‘comment on this diagram’. He/She has discussed issues of labelling, scale and detail of structure. There may be some concerns about ‘*large centre*’ and ‘*Many kilometres away*’. It can be argued that this answer shows reasonable understanding.

2.

27. This is quite a simple diagram of an atom,
which appears to be based on the Rutherford model.
Firstly, it is not to scale as the electrons
should be much smaller compared to the nucleus
and much further away
Secondly, it doesn't show the protons and
neutrons which makes up the nucleus, instead
it shows a solid sphere for the nucleus, which
is fine for a simple model but is
technically incorrect,
Finally, it could be given the title 'lithium'
(as an atom with 3 electrons probably is)
as have a label the electrons/nucleus which
isn't crucial, just bad form

Comment: This candidate has followed the instruction in the question to ‘comment on this diagram’. He/She has correctly discussed various relevant issues. It can be argued that this answer shows good understanding.

3.

27. The "ball" in the middle of the diagram is the nucleus of an atom. Inside the nucleus, there are protons, neutrons, gluons and bosons. The gluons are force carriers which carry the strong nuclear force. The bosons are the force carriers which carry weak nuclear force. The neutrons and protons are composed of quarks. Normally, the positively charged protons in the nucleus would repel each other, but the strong force overcomes this and allows more than 1 proton to be beside each other in the nucleus. The orbits around the nucleus are energy shells where electrons are positioned. An electron usually moves very fast around these energy shells and can move from one electron shell to another if they receive or emit energy. The small circles on these orbits are electrons.

Comment: The majority of this answer is not directly commenting on the diagram as had been instructed. A large proportion is about the Standard Model. The candidate's discussion then returns to the diagram in the last three sentences. Some might argue that only limited understanding has been demonstrated but, overall, reasonable understanding has been shown.

4.

27

- The electrons occur on different valence bands so the inner valence band would be filled first so the diagram is not correct.
- The electrons are too big as they are much smaller than the nucleus
- There are no anti matter particles shown on the diagram.
- The nucleus is not a huge ball but also made up of protons and neutrons and their anti matter particles.

Comment: Although it is correct to say 'the electrons are too big', this point could be stated by many students in the earlier years of secondary school. The answer contains major errors, eg the term 'valence bands' is not relevant for an atom, the references to antimatter particles are inappropriate. This answer demonstrates no real understanding of the correct Physics for this level of study.

Question 28 – This question asks about interference patterns for two different experimental setups. The first uses two sources of microwaves and the second uses monochromatic light incident on a grating.

All parts of this question were reasonably well done.

Specific areas of weakness in the answers from candidates were:

Part (a)(i):

- The explanation of why destructive interference occurs (to cause the minimum readings) should have been answered even better than it was. Interference is due to waves from different sources meeting and combining. In this case, the combination of waves that are 180^o out-of-phase produces waves of reduced amplitude. There were many answers from candidates which just referred to waves 'being' out-of-phase without any reference to them meeting or combining. Some said the waves are 'not in phase', but this does not mean the same as '180^o (or completely) out-of-phase'. Wrong words and terminology were often seen by markers (eg '*deconstructive interference*').

Part (a)(ii):

- Although many candidates gave correct answers to this part, there were a significant number who, having correctly worked out that the path difference was 84 mm, then wrongly subtracted this from 620 mm. Perhaps re-reading the question would have reminded them that the distance to S_2 must be larger, not smaller, than 620 mm.

Part (b)(i):

- Many candidates were able to use the relationship '$m\lambda = d \sin\theta$' to calculate that the fifth maximum will just appear on the screen. However, many forgot that the symmetrical interference pattern will have the first to the fifth maxima appearing below the middle line also. Few realised that the central maximum should then be added to give a total of 11 maxima on the screen.
- The wavelength of the light was given as '420 nm' – some candidates did not know the meaning/value of the prefix 'nano'.

Part (b)(ii):

- Some candidates said that '*red light diffracts more than blue light*' in their attempts to answer this question. However, this shows a lack of understanding about how the patterns of the different colours are produced. All wavelengths of visible light are 'fully' diffracted by the grating, effectively into semicircular waves. These waves spread out on the right hand side of the grating and interfere. On the screen, the positions of constructive interference (the maxima) are further apart for red light than for blue light because the greater wavelength of red light requires there to be a greater path difference (and hence angle) before the waves meet in phase again.

Question 29 – This question uses the context of a paperweight full of air bubbles to ask about refraction, critical angle and the formation of a spectrum by dispersion.

Part (a) was moderately well done, part (b) was well done, but the responses to part (c) were poor.

Specific areas of weakness in the answers from candidates were:

Part (a):

- Although most candidates were able to select the Snell's law relationship, many made errors at the substitution stage. The fact that refraction is occurring as light travels from *glass into air* (ie into the bubble) 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.]

Part (b):

- This question was answered well. However, there were a few candidates who performed inappropriate intermediate rounding when evaluating '1/1·49' and who therefore ended up with an inaccurate final answer. They should have kept the 'full' answer in their calculators in order to find $\sin^{-1}(1/1{\cdot}49)$.

Part (c):

- Candidates were asked to explain why a spectrum is formed when a ray of white light enters the air bubble. Many seemed to think that it was sufficient to state that white light is a '*mixture of all the colours of light*'. They should have realised that the word 'explain' was requiring them to give a reason why the colours follow different paths. The ideal answer is based on content statement 3.2.4 which states that 'the refractive index depends on the frequency of the incident light'. This means that each frequency, which corresponds to each colour, refracts through a (slightly) different angle and so travels in a (slightly) different direction. It is not appropriate to give an answer in terms of different wavelengths since 'wavelength' is medium dependent - the wavelength of a particular frequency/colour changes during refraction.
- A significant number of candidates wrongly said that a spectrum was caused by diffraction.

Question 30 – This question is about e.m.f., internal resistance and the combination of resistances in the context of circuits which contain thermocouples.

Part (a) was moderately well done, but part (b) was answered 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 0·22 V, but some candidates gave an answer of 0·20 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.

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 do so well. Many did not realise that the internal resistance is equal to the *negative* of the gradient of the graph. Saying 'r = gradient of graph' is like starting an answer with a wrong formula.

Part (b):

- To answer this question candidates had to take readings from both graphs to find the values of e.m.f. and internal resistance at 800 ^{o}C. Many made scale reading errors.
- To find the current in the coil at 800 ^{o}C, it was necessary to find the total circuit resistance and then apply Ohm's law. Many candidates failed to add the resistance of the coil to the internal resistance in order to find this total resistance.
- Many weaknesses in the use of appropriate significant figures and in rounding were seen by markers. The circuit current, $I = e.m.f./R_{total}$ = 0.88/0·27 = 3·259259259…. This answer requires to be rounded to an appropriate number of significant figures (in this case two significant figures would be ideal). Rounding this answer to two significant figures gives I = 3·3 A. To three significant figures the answer is 3·26 A. Markers often saw final answers stated as 3·2 A or 3·25 A, where candidates had not rounded their answers correctly.

Question 31 – This question asks about how conduction occurs in a pure semiconductor and about the emission of light by LEDs.

Part (b) was well done, but the answers to parts (a) and (c) were poor.

Specific areas of weakness in the answers from candidates were:

Part (a):

- Many candidates did follow the instruction to use the given terms (*electrons, valence band and conduction band*) to describe how conduction takes place in a pure semiconductor, but their answers only proved that they did not understand the process at all.
- Many candidates seem to believe that the movement of electrons from the valence band to the conduction band is the process of conduction, rather than the movement of electrons within the conduction band once they have received sufficient energy to be there.

Part (b):

- Most candidates correctly selected the two relationships, '$v = f\lambda$' and '$E = hf$'. To find the maximum energy of a photon emitted from the LED, candidates needed to use the maximum frequency which corresponds to the minimum wavelength. This is where many candidates made a mistake. Many candidates chose the maximum wavelength. Many others selected the wavelength at the peak of the graph.
- Some candidates showed that they did not know the meaning/value of the prefix 'nano'.
- Some candidates worked out the maximum frequency but rounded this value too much and ended up with an inaccurate final answer for the energy.

Examples of candidates' answers to question 31:

1.

> 31(a) In a semiconductor (such as silicon) there is a small gap between the valence band and the conduction band. This allows <u>some</u> conduction to take place at room temperature. The conductivity of the semiconductor can be increased in response to impurities such as light. Conduction is when free electrons in the metal move from the valence band to the conduction band.

Comment: The reference to the small gap between the valence band and the conduction band is correct. Since the question is about 'a pure semiconductor' there should not be any reference made to 'impurities' (the reference to 'light' being an impurity is wrong anyway). There needs to be some comment about energy (eg thermal energy from the room) being required in order to give electrons energy to be raised from the valence band to the conduction band. This candidate seems to think 'conduction' is the movement of electrons from the valence band to the conduction band (rather than the subsequent movement of electrons within the conduction band when an appropriate p.d. is applied).

2.

(36a) In a semi-conductor the band gap between the valence and the conduction bands is smaller than that of a insulator but bigger than a conductor. This means that if enough energy is applied the electrons are able to jump from the valence to the conduction bands. Once in this band they can be used to create a current.

Comment: Everything said in this answer is correct. It would have been improved by saying that the majority of electrons are in the valence band and by explaining more about how to ‘create a current’ (see the comment for the previous answer).

3.

31. (a) In a Semiconductor such as silicon, the distance between the valence band and the conduction band is very small. If the electrons in the valence band receive enough energy or a potential difference is induced across the semiconductor, then the electrons in the valence band will rise up into the conduction band. In the conduction band, these electrons are free to move and conduct electricity

Comment: This is a good answer. Reference to the majority of electrons being in the valence band would have made an improvement.

4.

c) Max wavelength = 900 nm = 900×10^{-9}

$$f = \frac{v}{\lambda}$$

$$= \frac{3 \times 10^{8}}{900 \times 10^{-9}}$$

$$= 3.3 \times 10^{14} \text{ Hz}$$

$$E = hf$$

$$= 6.63 \times 10^{-34} \times 3.3 \times 10^{14}$$

$$= \underline{2.2 \times 10^{-19} \text{ J}}$$

Comment: This candidate has chosen the wrong wavelength for the maximum energy. The marks for the two correctly selected relationships can be awarded.

Question 32 – This question is about skills related to experimental design and evaluation using the context of the magnetic field around a coil of wire in which there is a current. It also provides opportunity for candidates to demonstrate their abilities of graph drawing and data analysis.

Part (b) was quite well done. The answers to parts (a) and (c) were mediocre and part (d) was very poorly answered.

Specific areas of weakness in the answers from candidates were:

Part (a): (Designing an appropriate circuit and drawing the circuit diagram.)

- Candidates' attempts to design and draw a circuit diagram to vary and measure the current in the coil were disappointingly and surprisingly poor.

Errors made by candidates included:

1. Failure to include an ammeter.
2. Showing an ammeter connected in parallel.
3. Failure to include any method of varying the current (eg showing only a fixed resistor).
4. Incorrect symbols used for components (eg a battery with cells of opposing polarities at either end).
5. Showing a voltmeter connected in series.
6. Diagrams which were so roughly drawn as to be incorrect (eg an incomplete circuit because a line representing a connecting wire did not join up to one of the components).

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

Candidates were asked to use square ruled paper and plot a graph of magnetic field strength against current.

Issues and errors noted by markers include:

- No graph line was drawn through the plotted points.
- An inappropriate line was drawn through the points (eg a 'wavy' line rather than a best fit straight line).
- Poor attempts at drawing the best fit line (ie line too steep or too shallow).
- A series of straight lines drawn from dot-to-dot through the plotted points.
- The graph line drawn in ink rather than pencil, thus preventing easy correction.
- Axes not labelled with both the name of the quantity and its units.

Part (c): (Suggesting a reason why the data implies a systematic uncertainty.)

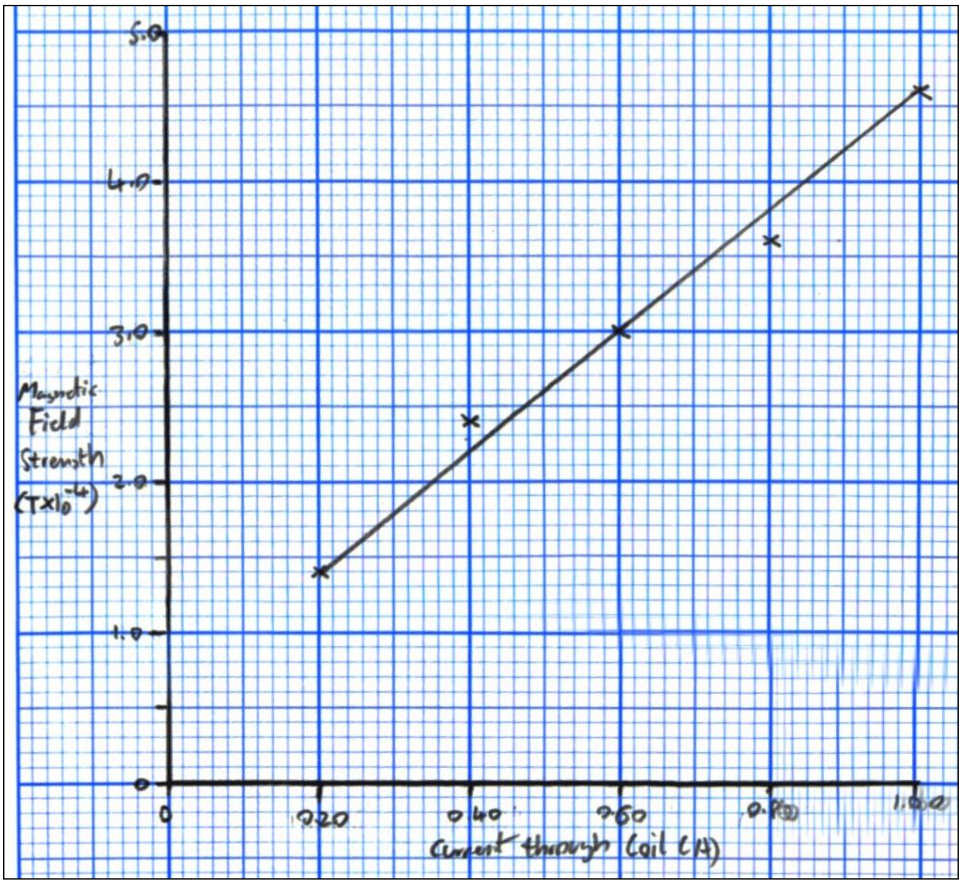
- A high proportion of candidates were unable to say that this is because the graph does not pass through the origin (or the magnetic field is not zero when the current is zero).

Part (d): (Using the gradient of the graph and the given relationship to calculate the number of turns on the coil.)

- Despite the clue to use the given relationship and '*the gradient of your graph…*', many candidates failed to use their gradient at all.
- Some candidates had difficulty calculating the gradient of their graph.
- Many picked one pair of results from the table and substituted for I and B into the relationship. They did not appear to appreciate a major reason for plotting a graph is that it allows the 'averaging out' of variations in experimental results.

Examples of candidates' answers to question 32:

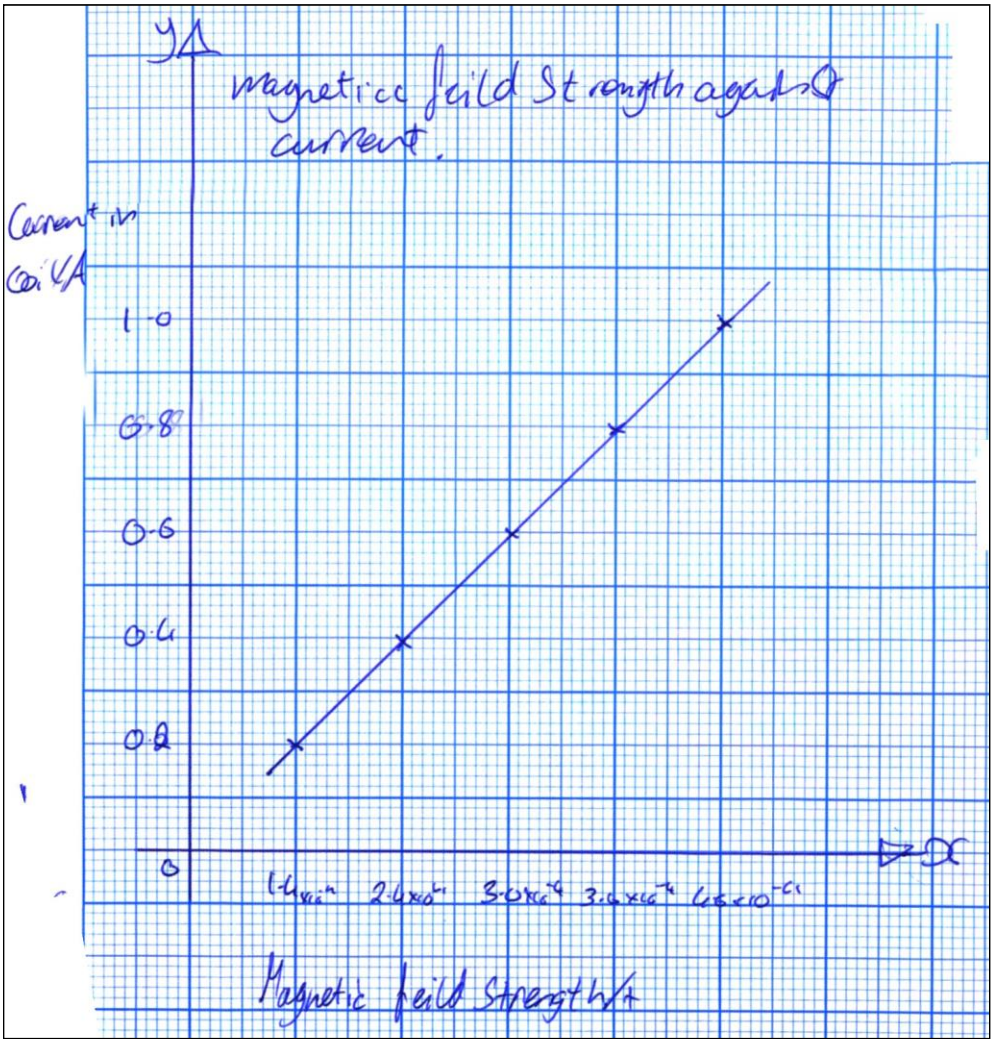
1.



Comment: This is a good answer.

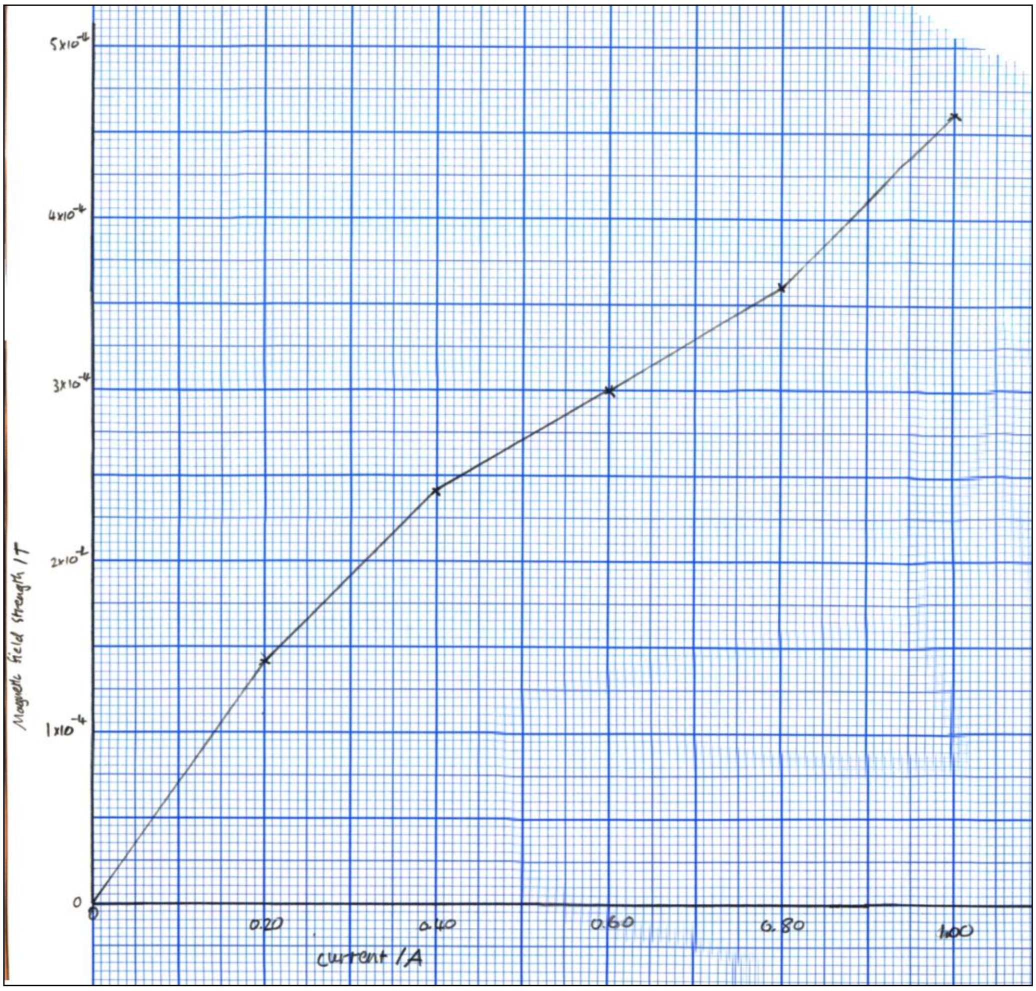
- A reasonable scale has been chosen.
- The axes have been clearly and correctly labelled with both the quantities and their units.
- The points are clearly seen and have been plotted correctly.
- A good, best-fit line has been drawn.
- The graph line has not been extrapolated (ie extended beyond the data points).

2.



Comment: This is not a good answer. The candidate has not set up a proper scale on their horizontal axis. They have simply used the given values of the magnetic field strength for each ‘point’ along the axis (this is why all the points lie exactly on their straight line). This is a fundamental error in graph drawing – NO MARKS CAN BE AWARDED.

3.



Comment: Overall, this is a poor answer for a Higher Physics candidate.

The ‘good’ points are:

- A reasonable scale has been chosen.
- The axes have been clearly and correctly labelled with both the quantities and their units.
- The points are reasonably clearly seen and have been plotted correctly.

The errors are:

- The points have been joined ‘dot-to-dot’ – this is not correct in Physics. The candidate obviously does not understand that no experimental result is ‘perfect’ and that a graph allows the uncertainties to be ‘averaged’ out by drawing a best-fit line.
- The graph line has been extrapolated to the origin.

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

Many of the following points were made in last year's external assessment report. 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 ‘*length*’, not ‘*leangth*’).

- 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 know that, in ‘estimate’ questions, all estimated values should be clearly stated (eg in a list) before any attempt is made to use them in a formula.

- 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 2012	457

Number of resulted entries in 2013	841

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	34.8%	34.8%	293	57
B	22.6%	57.4%	190	48
C	19.5%	76.9%	164	39
D	8.4%	85.4%	71	34
No award	14.6%	100.0%	123	-

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.