External Assessment Report 2013

Subject(s)	**Physics**
Level(s)	**Higher**

The statistics used in this report are pre-appeal.

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

Comments on candidate performance

General comments

There has been a decrease this year in the number of candidates sitting the examination paper for the traditional Higher Physics course. This is due to more centres deciding to present candidates for the revised Higher examination (available for the second time in this examination diet). The total number of candidates sitting Higher Physics this year (traditional plus revised) is approximately 9700 candidates.

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, although every question was correctly answered by at least a proportion of the candidates, as a whole the examination was found to be more demanding than in recent years. 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.

Generally, candidates continue to be better at answering questions which involve numerical calculations and are poorer in their attempts to answer those questions requiring descriptions and explanations.

There are some signs that areas of weakness which have been highlighted in previous external assessment reports have been answered to a better standard this year. However, many issues highlighted in recent external assessment reports have still not improved.

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, 6, 15 and 16 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 22 (c): In the main, candidates' provided very good answers (though sometimes not 100% complete) as they described how the kinetic model explains the change in pressure as the temperature of the gas in the tennis ball increases. Most candidates now know that they must describe, somewhere in their answer, the basic reason why there is a pressure (ie that moving molecules collide with the walls of the container). They must then fully describe all the reasons why an increase in temperature affects those collisions and the resulting pressure on the walls.

Question 24 (a): This question required candidates to substitute values for pressure and force into $P = F/A$ and then calculate the area of the piston. This was well done by most. There were a few candidates, however, who made an error trying to convert their answer from square metres into square centimetres (a conversion which was not required by the question). This error appeared to be because they failed to realise that although there are 100 centimetres in one metre, there are 10 000 square centimetres in one square metre. A few other candidates made a similar conversion error when they tried to express their answer in square millimetres.

Question 26: In part (a), most candidates were able to use the oscilloscope trace and the timebase setting to calculate the frequency of the signal.

In part (b), a very high proportion of candidates were able to select the relationship between the peak and rms voltages and then correctly work out the peak voltage. There were some, however, who showed lack of familiarity of using this relationship as they worked out the square root of '2 x V_{rms}' rather than just $\sqrt{2}$.

Question 27: This question was about the charging and discharging of a capacitor in a camera's flash unit. Part (a)(i) asked for a calculation of the initial charging current – this was very well done. Part (a)(iii) asked candidates to 'show' that the energy stored in the fully charged capacitor was 14·7 J. Like question 21(a), most candidates correctly stated the relationship, substituted and gave the required answer as their final line. This was slightly trickier than in 21(a) as rounding was required.

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

Areas which candidates found demanding

In the multiple-choice section of the examination, there were two questions that were answered correctly by less than half of the candidates (question 10 [43%] and question 11 [44%]). Both of these questions are about capacitors.

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 accelerating uniformly.

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.

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):

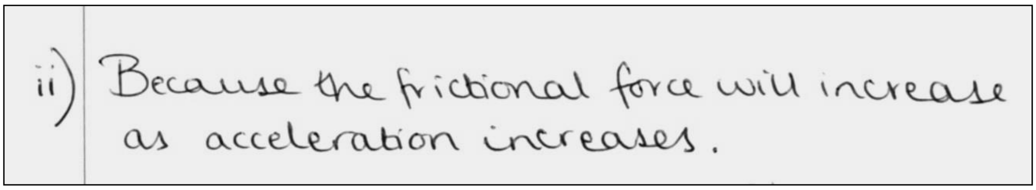
- This question asked for the value of the force of friction acting on the motorcycle. Candidates needed to use $F = ma$ to calculate the unbalanced force and then subtract this value from the driving force. However, a significant number of candidates stopped after finding the unbalanced force.

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*.

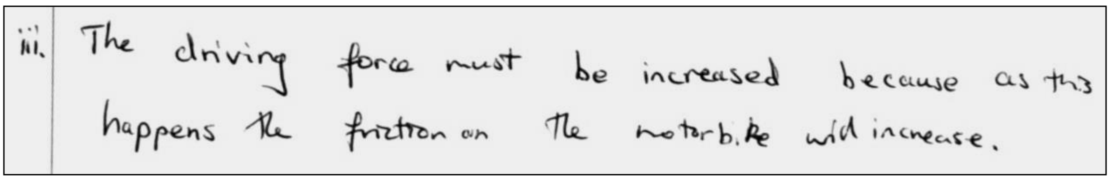
Examples of candidates' answers to question 21:

1. For part (c)(ii),


ii) Because the frictional force will increase as acceleration increases.

Comment: In this question the acceleration does not increase. This candidate is possibly confusing the terms 'acceleration' and 'velocity'. No reference has been made to the unbalanced force and that it must be kept constant.

2. For part (c)(ii),


iii. The driving force must be increased because as this happens the friction on the motorbike will increase.

Comment: There is nothing wrong stated here, but neither is there any real explanation.
A marker wonders what '*as this happens*' means. As *what* happens?
(Remember that the question asked 'Explain why the driving force must be increased with time to maintain a constant acceleration.')
The marker cannot even be sure that the candidate understands that frictional forces increase because the speed of the motorcycle is increasing with time.

3.

ii) If forces are balanced then the motorcycle will remain at a constant speed and will not accelerate.

Comment: There is no wrong Physics in this sentence. However, it does not answer the question! Candidates should keep re-reading to check that their answers actually do answer the questions.

4.

ii) Because if the ~~forces were balanced the~~ driving force was balanced the motor-cyclist would remain at a constant speed, so the driving force must be ~~unbalanced to achieved a constant~~ increased and there fore unbalanced to achieve a constant acceleration.

Comment: This candidate writes about the driving force being 'balanced' and (later) 'unbalanced'. However, a correct answer should be discussing the *overall* force on the motorcycle (ie the driving force minus friction) being unbalanced and having a constant value to ensure constant acceleration.

Question 22 – The context of this question is a tennis player hitting a ball over the net. It provides opportunities for numerical analyses of projectile motion and, in part (c), a kinetic theory explanation of pressure changes inside the ball.
Part (a) was neither well done nor poorly done. Part (b) was very poorly answered. Part (c) was quite well done but many candidates' answers could have been better.

Specific areas of weakness in the answers from candidates were:

Part (a):

- A few candidates failed to use the value of '*g*' given in the data sheet (page two of the examination paper). The value used should have been 9.8 m s^{-2}.
- Many candidates correctly calculated the distance fallen by the ball in the given time of 0·50 seconds but then stopped there. They failed to go on and subtract this value from the initial height of the ball to find the *height* of the ball at 0·50 s.

Part (b):

- Despite the hint in the question ('By scale drawing, or otherwise ….') most candidates failed to realise that it was necessary to carry out a vector addition of the horizontal and vertical velocity vectors just before the ball hits the ground.
- Few who used the vector diagram method drew it on square-ruled paper. Doing this could have improved the accuracy of their answers.
- Many candidates attempted to use an equation of motion (such as $v^2 = u^2 + 2as$) but substituted a 'mixture' of horizontal and vertical values, apparently not realising that this must result in wrong Physics.
- When using an equation of motion in this part of the question '*a*' and '*s*' must have the same sign (ie both negative or both positive). Some candidates used different

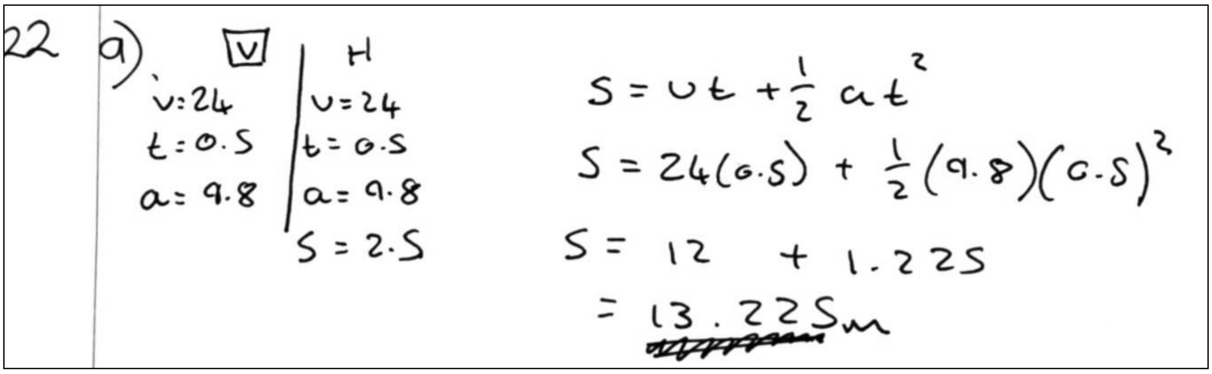
signs for ‘*a*’ and ‘*s*’ – this is a wrong substitution and no further marks can be awarded.

- A significant number of candidates drew a diagram that consisted of a vertical displacement vector ‘added’ to a horizontal velocity vector. They obviously did not realise that this was meaningless.
- Many who correctly calculated the magnitude of the ball’s velocity did not attempt to work out its direction – they seemed to forget that a direction needs to be quoted as well as a magnitude when giving a vector as a final answer.
- 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 velocity of the ball should be in relation to the horizontal (or vertical). North is neither defined nor relevant in this question.

Part (c):

- Some candidates failed to say that pressure is due to moving gas molecules colliding with the walls of the tennis ball. This is the fundamental starting point for a kinetic theory explanation.
- Many candidates stated that the increase in temperature gave molecules ‘*more energy*’ rather than ‘*more kinetic energy*’.
- Some candidates did say that an increase in temperature results in gas molecules moving faster, but they failed to mention *both* of the resulting effects on the molecular collisions with the walls, ie that they are *more frequent* and that *each collision is harder*. Many candidates provided incomplete answers such as ‘*more collisions*’ rather than ‘*more collisions per second*’ or ‘*more frequent collisions*’.
- Candidates should use *words* to express the terms ’increasing’ and ‘decreasing’. There are still some candidates using up (↑) and down (↓) arrows in their descriptions. Markers have repeatedly said that this is not acceptable in examination answers.
- The question asked for a description of how the pressure of the gas is affected by increasing temperature. Candidates who failed to conclude that the pressure increases could not be awarded marks.

Examples of candidates’ answers to question 22:


22 a) V: v: 24, t: 0.5, a: 9.8 | H: v = 24, t = 0.5, a = 9.8, S = 2.5

$S = ut + \frac{1}{2}at^2$

$S = 24(0.5) + \frac{1}{2}(9.8)(0.5)^2$

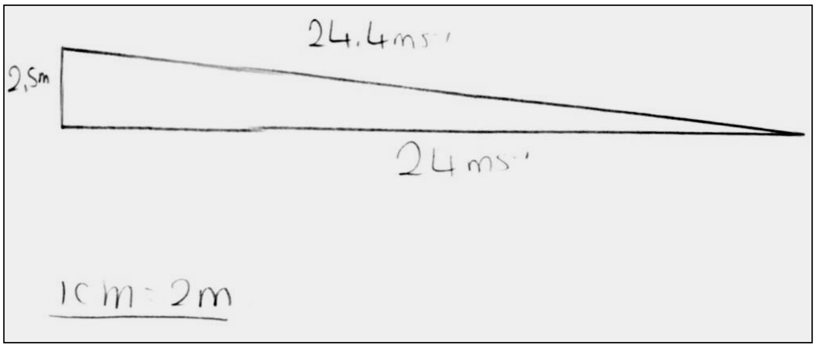
$S = 12 + 1.225$

$= 13.225 m$

1.

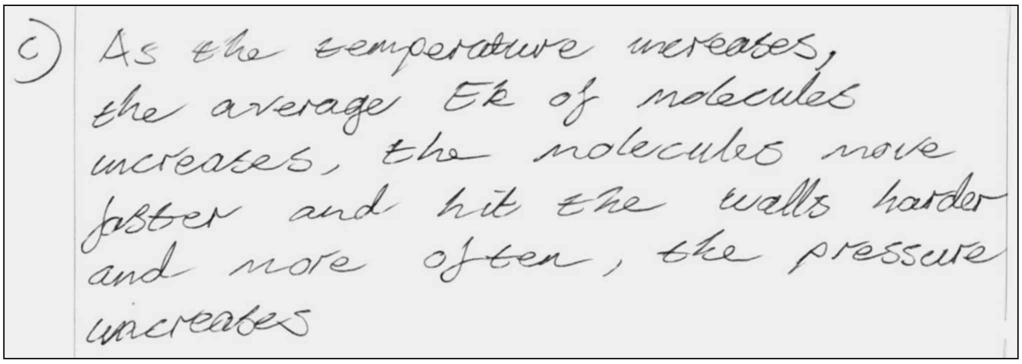
Comment: This shows the selection of the correct equation of motion. However, the answer is wrong at the substitution stage as the candidate has used a horizontal value for ‘*u*’ along with a vertical value for ‘*a*’. This ‘mixing’ of horizontal and vertical velocities or accelerations in a single equation of motion always results in a meaningless answer.

2.



Comment: This answer shows one candidate's attempt to add a vertical displacement to a horizontal velocity. There is no correct Physics in doing this and the outcome is meaningless.

3.



c) As the temperature increases, the average Ek of molecules increases, the molecules move faster and hit the walls harder and more often, the pressure increases

Comment: This is a good answer. It includes the basis of the kinetic model (molecules of the gas in random motion), states why this causes a pressure (the molecules collide with the walls) and describes the effects of increasing the temperature (molecules move faster and so have harder and more frequent collisions with the walls). The essential conclusion is then stated (the pressure increases).

Question 23 – 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 moderately well. Part (c) was poorly done.

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):

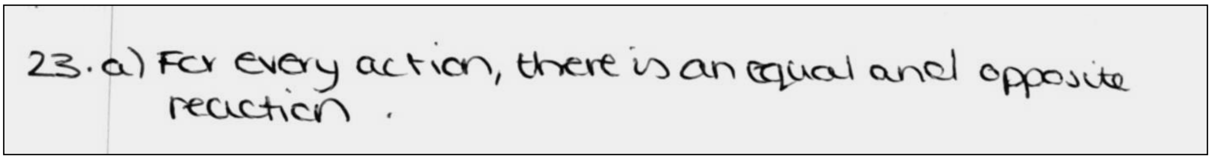
- The change in momentum in an interaction is defined as 'final momentum – initial momentum' (ie $\Delta p = mv - mu$). Many candidates performed the subtraction the wrong way round. This is equivalent to substituting '*u*' and '*v*' round the wrong way in the relationship and is regarded as wrong Physics.
- 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):

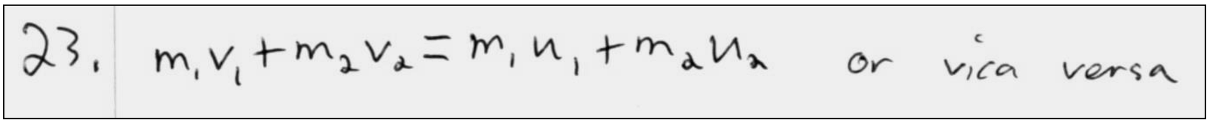
- This part of the question has 3 marks allocated. Candidates should have realised that this means that more was required than a single, simple calculation. Alternative methods of answering were possible but all required at least two separate calculations (eg an equation of motion to find acceleration 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 1·4 x 10^4 N), although F = 14 030 N (or 1·403 x 10^4 N) is within the acceptable range for significant figures.

Examples of candidates' answers to question 23:

1.



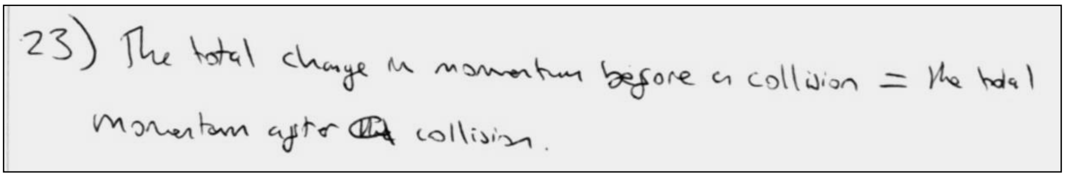
23. a) For every action, there is an equal and opposite reaction.



23. $m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$ or vica versa

Comment: These are not statements of the law of conservation of linear momentum.

2.



23) The total change in momentum before a collision = the total momentum after collision.

Comment: The candidate has mistakenly added the word 'change' in the left hand side. This totally changes the meaning and makes it a wrong answer.

3.

> 23a. momentum is conserved when the kinetic energy before a collision equals the kinetic energy after.

Comment: The candidate has,

- not stated the law of conservation of momentum
- has not said *total* momentum
- has used the word ‘conserved’ when the answer should be explaining the meaning of that word
- has limited the statement to covering only elastic collisions (ie when total E_k is also constant).

4.

> 23b) $p = mv - mu$
>
> $= 1200 \times 0 - 1200 \times 134$
>
> $= 16080\ kgms^{-1}$

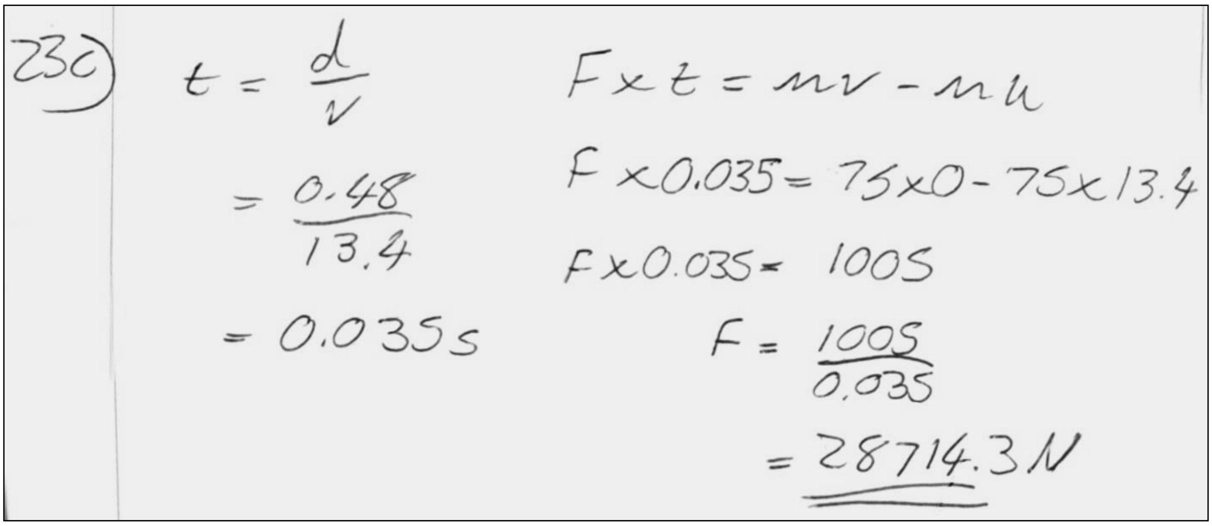
Comment: Firstly, the symbol ‘*p*’ represents momentum, not ‘change in momentum’ - candidates should be more precise in their use of symbols and terminology. Secondly, the result of this calculation should be a negative answer. This candidate has just ‘dropped’ the negative sign from the second line to the third line – doing this is never correct.

5.

> (b) Momentum before collision:
>
> $p = mv$
>
> $= 1200 \times 13.4$
>
> $= 16080\ kg\ ms^{-1}$
>
> momentum after collision:
>
> $p = mv$
>
> $= 1200 \times 0$
>
> $= 0\ kg\ ms^{-1}$
>
> change in momentum $= 16080 - 0$
>
> $= 16080\ kg\ ms^{-1}$

Comment: This candidate is clearly finding change in momentum by subtracting the final momentum from the initial momentum. This is not the definition of change in momentum – it is the same as if they had written ‘$\Delta p = mu - mv$’. No marks can be awarded.

6.



Comment: The calculation of time, on the left hand side, is wrong. The time of 0·035 s would only be correct for a car travelling at a *constant* speed of 13·4 m s^{-1} through a distance of 0·48 m. The correct value of time could have been found using *s* = (*u* + *v*)/*t* with *u* = 13·4 and *v* = 0.

On the right hand side, the candidate has written the correct relationship for impulse being equal to change in momentum. This could have been used to calculate the value for the force with the correct value of time.

The final answer should be rounded to an appropriate number of significant figures – in this case two or three significant figures. Even if the time value had been correct, this candidate has not rounded appropriately for the data being used.

Question 24 – The context of this question is a simple pressure gauge consisting of gas trapped in a cylinder with a moveable piston. This provides opportunities for questions on *P* = *F*/*A*, *P* = *ρgh* and, in part (c), linking the gauge to an op-amp in differential mode.

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

Specific areas of weakness in the answers from candidates were:

Part (a):

- As mentioned earlier, there were a few candidates who made an error trying to convert their answer from square metres into square centimetres (a conversion which was not required by the question). This error appeared to be because they failed to realise that although there are 100 centimetres in one metre, there are 10 000 square centimetres in one square metre. A few other candidates made a similar conversion error when they tried to express their answer in square millimetres.
- Some candidates failed to round their final answer to an appropriate number of significant figures. A calculator might show ‘2·594059406 x 10^{-3}’, but since there were three significant figures in the given data, the answer should have been rounded to ‘2·59 x 10^{-3}’ square metres.

Part (b)(i):

- Although the vast majority of candidates correctly selected ‘*P* = *ρgh*’ as the appropriate relationship to use for this calculation, most did not seem to realise that, in this formula, ‘*P*’ stands for the extra pressure due to the liquid. They incorrectly substituted the *total* pressure (ie fluid pressure plus atmospheric pressure). This was wrong Physics and a costly mistake.

Part (b)(ii):

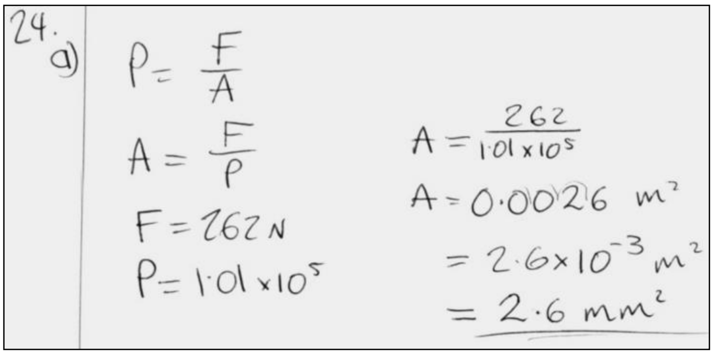
- A small number of candidates failed to answer the question as they did not make any statement about what happens to the volume of the bubble. The practice of reading the question again immediately after writing their answer would help to avoid such errors.

Part (c):

- Many candidates showed poor knowledge and/or experience of analysing potential divider circuits in their attempts to calculate 'V_1' and 'V_2'.
- Many candidates correctly selected the relationship $V_o = (V_2 – V_1)R_f/R_i$, but demonstrated that they did not know which is 'V_1' and which is 'V_2'.
- Of those who correctly used the differential mode relationship to calculate V_o = - 18 V, a significant number did not realise that saturation of the op-amp occurs and that this means V_o will actually be -15 V (and often a few volts less than this in reality).

Examples of candidates' answers to question 24:

1.



24. a) $P = \frac{F}{A}$

$A = \frac{F}{P}$

$F = 262\,N$

$P = 1{\cdot}01 \times 10^5$

$A = \frac{262}{1{\cdot}01 \times 10^5}$

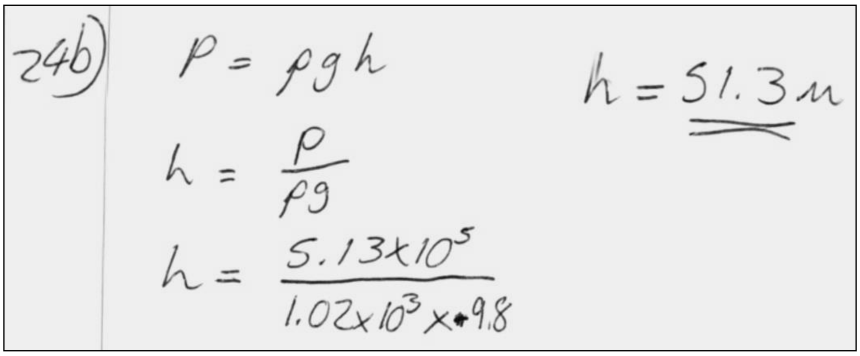
$A = 0{\cdot}0026\ m^2$

$= 2{\cdot}6 \times 10^{-3}\ m^2$

$= 2{\cdot}6\ mm^2$

Comment: This candidate has done everything correctly to get the answer of $2{\cdot}6 \times 10^{-3}\ m^2$, but has then gone on (unnecessarily) to convert it (wrongly) to mm^2.

2.



24b) $P = \rho g h$

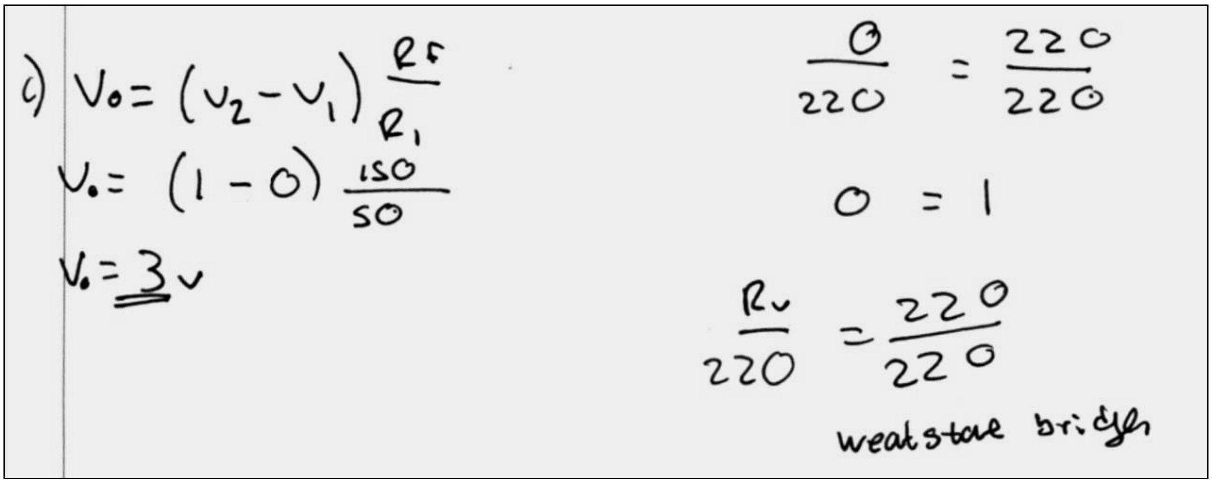
$h = \frac{P}{\rho g}$

$h = \frac{5.13 \times 10^5}{1.02 \times 10^3 \times 9.8}$

$h = 51.3\,m$

Comment: This was a frequently seen wrong answer. The candidate has failed to subtract atmospheric pressure before substituting into the relationship.

3.



c) $V_o = (V_2 - V_1)\frac{R_f}{R_1}$

$V_o = (1 - 0)\frac{150}{50}$

$V_o = 3\,V$

$\frac{0}{220} = \frac{220}{220}$

$0 = 1$

$\frac{R_v}{220} = \frac{220}{220}$

weatstone bridge

Comment: The correct relationship has been selected for the op-amp in differential mode. The candidate has incorrectly calculated values for V_1 and V_2.

Question 25 – 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.

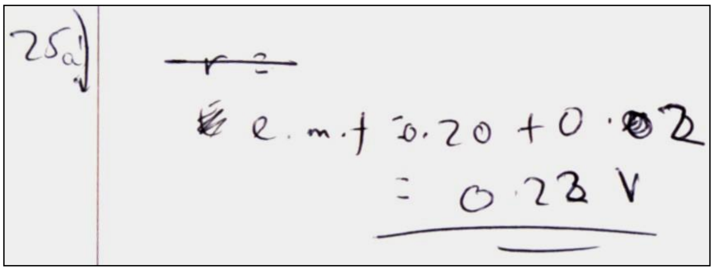
Part (a)(ii):

- 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.

Examples of a candidate's answer to question 25(a):



Comment: This is an example of a candidate 'overwriting', resulting in an unclear answer.

Question 26 – This question is based on a 'standard' circuit used for comparing the output voltages of a.c. and d.c. supplies.

Parts (a) and (b) were well done, but part (c) was answered relatively poorly.

Specific areas of weakness in the answers from candidates were:

Part (a):

- A few candidates correctly selected the relationship '$f = 1/T$', but could not 'find' the correct value of 'T' (= time for one wave).

Part (b):

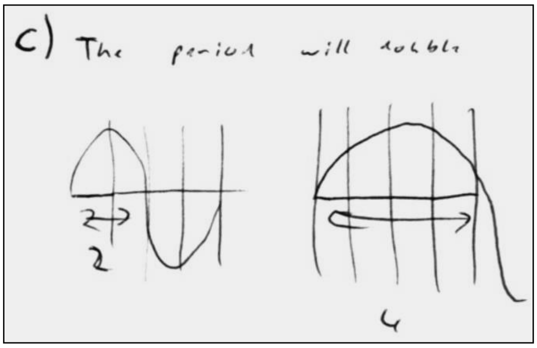
- Most candidates correctly chose the relationship '$V_p = \sqrt{2}\ V_{rms}$', and used it correctly. However, a few thought that the square root applied to the whole of the right hand side of the equation and not just to '2'. Some others made a wrong substitution for the value of V_{rms}. This was surprising as there is no value other than 2·30 V given in the question.

Part (c):

- Although many candidates correctly said that there would be no change in the reading on the meter, they failed to justify this by saying that current is independent of frequency in a resistive circuit.
- Despite the question clearly saying 'State what happens to the reading on the light meter …', a significant number of candidates described what they believed would happen to the trace on the oscilloscope. Again, re-reading the question might help reduce this type of error.

Examples of candidates' answers to part (c):

1.



Comment: This candidate seems to think that the question has asked what changes will be seen on the screen of the oscilloscope. Their answer would have been wrong anyway as doubling the frequency would have doubled the number of waves on the screen (the period is half).

2.

c.) The reading remains the same because frequency does not affect it.

Comment: This is a poor attempt at a justification. Candidates should attempt to state some relevant Physics about the situation.

Question 27 – This question uses the context of a capacitor in a camera flash circuit to ask about initial current, voltage during charging, energy and power as well as factors affecting charging rate.

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

Specific areas of weakness in the answers from candidates were:

Part (a)(i):

- Although this question was well done generally, many candidates incorrectly rounded the answer to the calculation for current. The display on their calculators was 0·016666666. Many wrongly rounded this to 0·016 A (or 16 mA). The answer should have been rounded up to 0·017 A (or 17 mA).

Part (a)(ii):

- During charging of the capacitor, the graph of the voltage should increase from zero and gradually curve over to flatten off at the value of the supply voltage (in this case 250 V). Many candidates lost marks because their graphs were poorly drawn. This is disappointing as last year's external assessment report listed the mistakes made in a similar question.
  Errors seen by markers again this year included,
- unlabelled axes
- unlabelled origin
- freehand lines curving the wrong way (ie upwards)
- carelessly drawn freehand lines which did not stay at a steady level
- the graph line flattening out above (or below) the 250 V value
- the graph line stopped, but *still on a rising trend*, when the 250 V value is reached
- the value of '250' shown, but no units given anywhere on the voltage axis
- a gap between the start of the graph line and the origin
- Some candidates produced two *conflicting* answers to this question – one in their booklet and another on separate graph paper. Markers need to be clear which version the candidate wishes to be marked. Candidates should delete any draft answer(s).

Part (a)(iii):

- This is a 'Show' question and the candidate must start by writing the relevant formula ($E = ½ CV^2$ 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 14·7 J (not 14·6875 J).

Part (b):

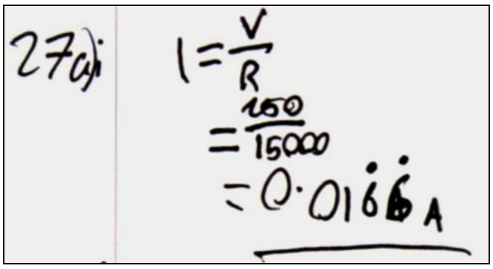
- A significant proportion of candidates could not change '200 μs' into the value of '200 x 10^{-6}' required in the calculation. The values of prefixes need to be memorised.

Part (c): {'*How could the circuit be modified to reduce the recycle time [the time for the capacitor to be recharged] without altering the power output of the flash?*'}

- A disappointingly small proportion of candidates realised that the capacitor would charge more quickly (resulting in a shorter recycle time) if a smaller value of resistance was used.
- Some suggested using a higher supply voltage – but this would change the power output of the flash.
- Some suggested using a lower value of capacitance – but this would also change the power output of the flash.
- Some suggested using ‘a smaller resistor’ or ‘a lower resistor’. These are examples of poor use of terminology which are not accepted in Physics examination answers.

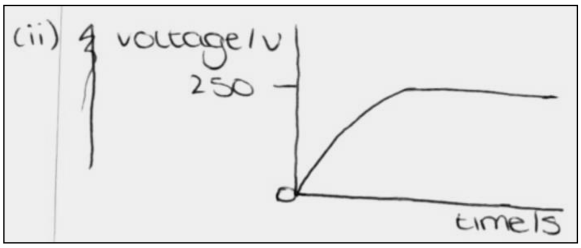
Examples of candidates’ answers to question 27:

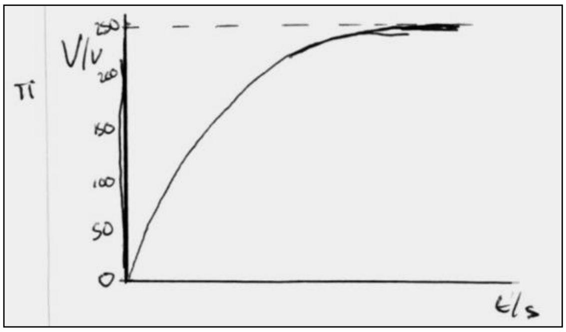
1.

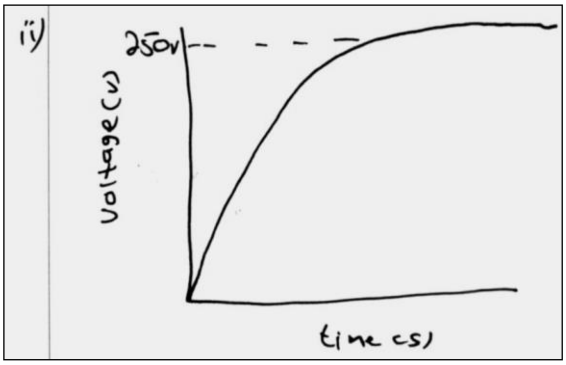


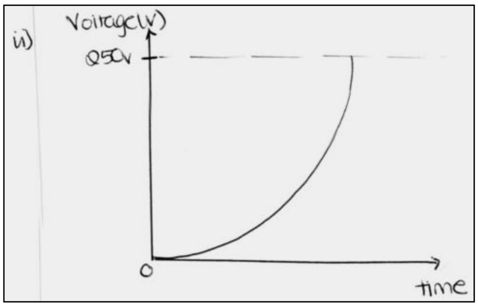
Comment: This candidate’s final answer is unclear. Is it ‘0·016’ or is it ‘0·0166’? Neither of these options would be correct anyway, as the value of ‘250/15000’ is equal to ‘0·0166666666’. When this value is correctly rounded, the final digit should be ‘7’.
The ‘dot’ above the final digit in the candidate’s answer indicates that the calculation gives ‘6’s repeated indefinitely. This produces an inappropriate number of significant figures – this ‘dot’ should not be used in any Physics answer where the candidate has to make a decision about how many significant figures to give in their answer.

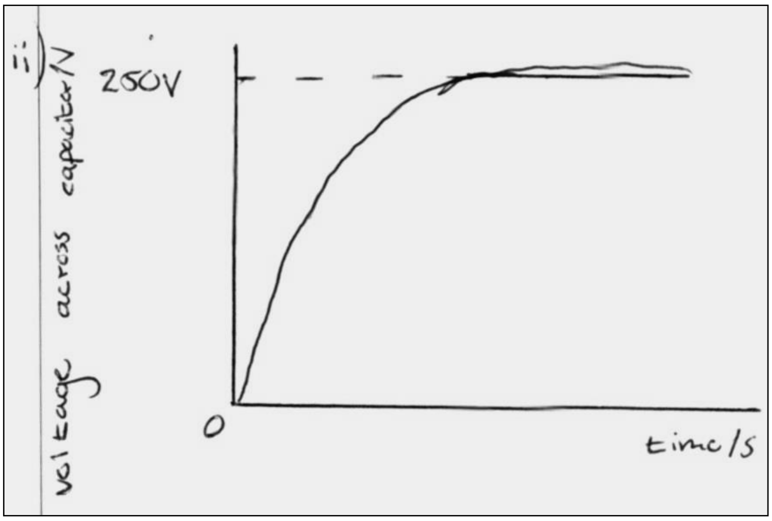
2. Some examples of weak answers to part (a)(ii),



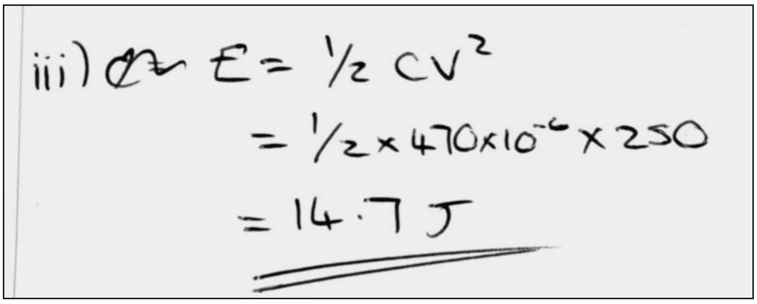








2.

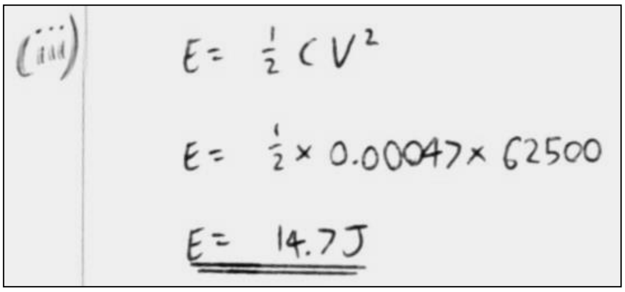

iii) $E = \frac{1}{2} CV^2$

$= \frac{1}{2} \times 470 \times 10^{-6} \times 250$

$= 14 \cdot 7$ J

Comment: The candidate has failed to square the 250 V in the second line. The answer to the calculation is then not the required 14·7 J.

3.

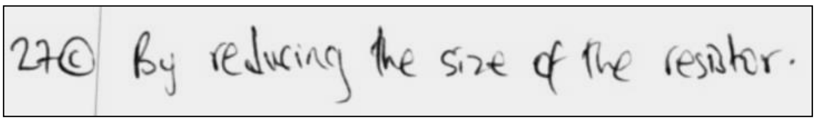

(iii) $E = \frac{1}{2} CV^2$

$E = \frac{1}{2} \times 0.00047 \times 62500$

$E = 14.7$ J

Comment: This is not an acceptable answer for a ‘Show’ question. The second line should just show the substitution for V^2 (ie 250^2) and not the result of squaring the 250 V.

4.


27(c) By reducing the size of the resistor.

Comment: This answer is wrong because it is referring to the physical size of the resistor, not the value of its resistance.

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.

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)(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):

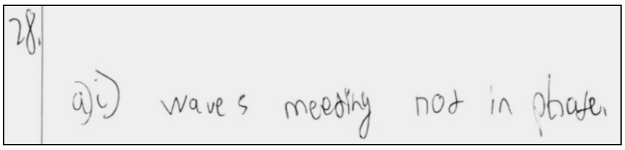
- Although many candidates gave correct answers to this part, there were a significant number who, having correctly worked out that the path difference was 84 mm, then wrongly subtracted this from 620 mm. Perhaps re-reading the question would have reminded them that the distance to S_2 must be larger,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

Part (b):

- Many candidates were able to use the relationship ‘$n\lambda = d \sin\theta$’ 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. Very 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’.

Example of candidates’ answers to question 28:

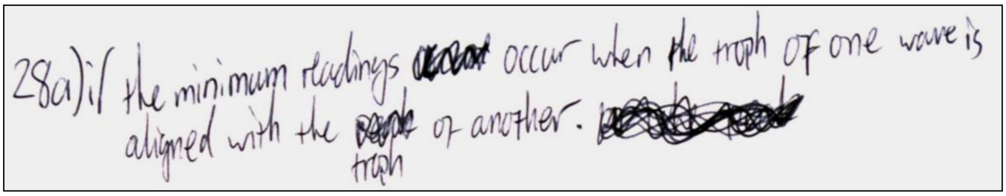
1.



28. a)i) waves meeting not in phase.

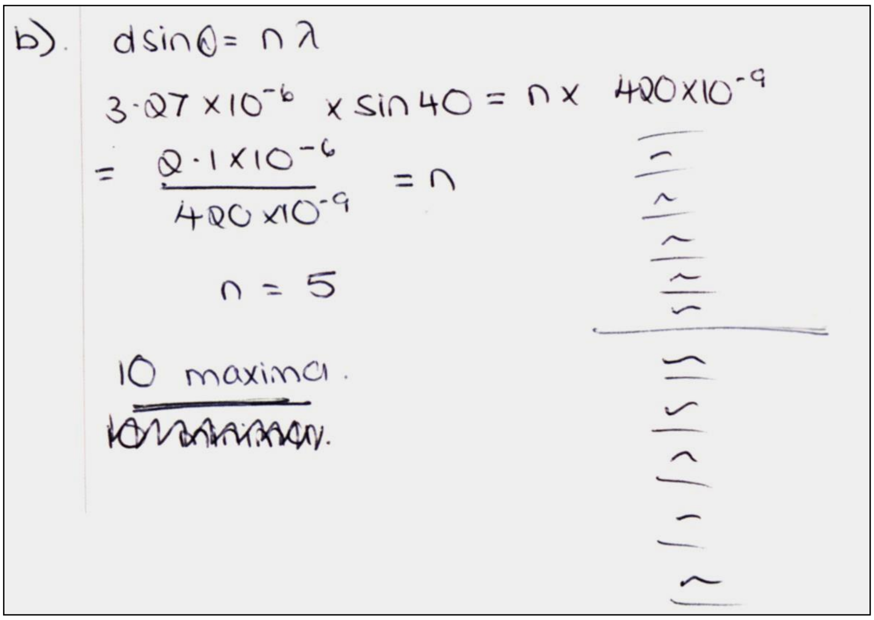
Comment: The statement ‘*not in phase*’ does not mean the same as ‘*perfectly out of phase*’. It is possible for two sets of waves to be very slightly out of phase (ie ‘*not in phase*’) and constructive interference would occur.

2.



Comment: A few candidates wrongly thought that a minimum is due to troughs meeting.

3.



Comment: This candidate has correctly identified that there are 5 maxima on either side of the central line. Their diagram also seems to show the central maximum but, for some reason, they have only doubled the ‘5’ to ‘10’ and have failed to add ‘1’ for the central maximum.

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):

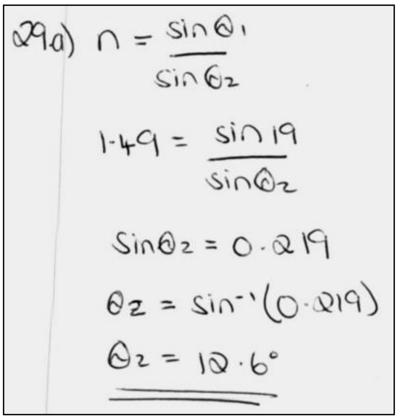
- This question was answered well. However, there were a few candidates who performed inappropriate intermediate rounding when evaluating ‘1/1·49’ and who therefore ended up with an inaccurate final answer. They should have kept the ‘full’ answer in their calculators in order to find $\sin^{-1}(1/1{\cdot}49)$.

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.

Example of candidates’ answers to question 29:

1.



29a) $n = \frac{\sin\theta_1}{\sin\theta_2}$

$1{\cdot}49 = \frac{\sin 19}{\sin\theta_2}$

$\sin\theta_2 = 0{\cdot}219$

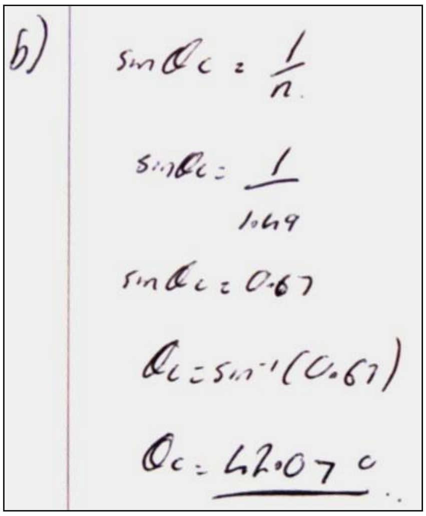
$\theta_2 = \sin^{-1}(0{\cdot}219)$

$\theta_2 = 12{\cdot}6°$

This is an answer which was seen frequently by markers.

The relationship stated at the beginning is fine, but the substitution is wrong.

2.



b) $\sin\theta_c = \frac{1}{n}$

$\sin\theta_c = \frac{1}{1{\cdot}49}$

$\sin\theta_c = 0{\cdot}67$

$\theta_c = \sin^{-1}(0{\cdot}67)$

$\theta_c = 42{\cdot}07°$

Comment: This is an example of an answer where the candidate has rounded an intermediate calculation (of 1/1.49) to two significant figures. This causes an inaccuracy in the final answer for the angle.

3.

> c) Because white light is made up of lights of different wavelengths which have different refractive indexes so each diffract at a different angle.

Comment: The explanation should be in terms of there being different refractive indexes for different frequencies of light.

The candidate has used the term '*diffract*' wrongly.

Question 30 – The context of this question is a standard laboratory experiment about measuring the irradiance of light from a small lamp at different distances to establish the inverse square law. This is then used to contrast the results which would be obtained when using a laser instead of the lamp and the differences between the light emitted from these two sources in terms of photons.

Part (a) was moderately well done, but the answers to all parts of (b) were poor.

Specific areas of weakness in the answers from candidates were:

Part (a):

- Candidates should have calculated the value of '$I\,d^2$' for each pair of 'I' and 'd' from the given data, stated that these calculated values were approximately equal and so concluded that the lamp *is* behaving like a point source of light. Despite being told by the question to 'Use **all** the results …', some candidates used only two or three sets. Like any 'real' experiment, the given data produced small variations in the calculated values of '$I\,d^2$'. A significant number of candidates used this to conclude that the lamp was *not* a point source of light. Markers thought that this raises a question about how much exposure these candidates had had to the results of 'real' experiments during their study of the course?

Part (b)(i):

- A surprisingly high number of candidates showed lack of knowledge and understanding of the light emitted by a laser. Too few correctly referred to the light diverging only a small amount as distance increases. Some candidates even said, wrongly, that a laser '*is a point source*' (perhaps because it produces a 'point 'of light?).

Part (b)(ii):

- Many candidates attempted to use the relationship '$I = Nhf$' to answer this part. However, 'N' in that relationship is defined as the 'number of photons per second, incident on a square metre of a surface', not the rate of photons emitted by the laser.
- Again, some candidates showed that they did not know the meaning/value of the prefix 'nano'.

Part (b)(iii):

- The question clearly asked candidates to 'Describe, in terms of photons, two differences between the light (from the laser and the lamp)'. The answers of many candidates made no reference to photons. This is another example of where careful re-reading of the question after writing an answer could help avoid a costly error.

Question 31 – The first part of this question is about a nuclear reaction and requires candidates to identify one of the reactants and then carry out a calculation using the relationship '$E = mc^2$'. The second part of the question requires candidates to carry out a calculation using dosimetry relationships.

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

Specific areas of weakness in the answers from candidates were:

Part (a)(i):

- A large proportion of candidates did not correctly identify '**X**' as lithium. As very few candidates showed any 'working', it is impossible to say where they were making errors in their analysis.

Part (a)(ii):

- Many candidates were able to use '$E = mc^2$' with the given value of energy to calculate '*m*'. However, few were then able to use this value to work out the mass of '**X**' on the left hand side of the statement. Many wrongly subtracted '*m*' from the mass of the right hand side rather than adding it.
- A significant number of candidates 'mixed' values of energy and mass in their calculations. Without also using appropriate 'c^2' factors, these attempts could not be correct.

Part (b):

- Less than half of candidates were able to answer this question correctly. Most wrote down a dosimetry relationship but then used the given data wrongly in their substitutions. The majority of candidates showed no appreciation of the difference between the rate of receiving a dose and the absolute dose received. For example, markers constantly saw answers which used '*H*' instead of '*H* dot'.

Examples of candidates' answers to question 31:

1.

b) $H = DW_r$.

$= 2\times10^{-6}\times1 + 2\times1.25\times10^{-6} + 10\times0.2\times10^{-6}$

$= 6.5\times10^{-6}\times12$

$= 7.8\times10^{-5}$ Sv

Comment: The relationship at the beginning is an acceptable way to start an answer to this question. However, the substitutions in the second line use values of the absorbed dose *rates* ('*D* dot') given in the question, not the values of '*D*'.
The candidate should have multiplied by the 12 hours *before* substituting into this line. (Or said that $D = 2 \times 10^{-6} \times 12$, etc. in this line). It is not correct to then multiple by 12 in the third line (as this candidate has done).

2.

b $D_1 = \dot{D}_1 t$

$= 2\times10^{-6}\times12$

$= 24\times10^{-6}$ Gy γ

$D_2 = \dot{D}_2 t$

$= 1.25\times10^{-6}\times12$

$= 1.5\times10^{-5}$ Gy Proton

$D_3 = \dot{D}_3 t$

$= 0.2\times10^{-6}\times12$

$= 2.4\times10^{-6}$ Gy F. Neutron

$H = D_1 W_{r_1} + D_2 W_{r_2} + D_3 W_{r_3}$

$= (24\times10^{-6}\times1) + (1.5\times10^{-5}\times2) + (2.4\times10^{-6}\times10)$

$= 24\times10^{-6} + 3\times10^{-5} + 24\times10^{-6}$

$= 4.8\times10^{-5} + 3\times10^{-5}$

$= 7.8\times10^{-5}$ Sv

Comment: This is an example of a good, well set-out answer to this question!

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 often of a poor standard and difficult to follow.
- Markers reported that candidates' diagrams were often carelessly drawn and unclear or inaccurate.
- Markers complained that a significant number of candidates squashed their answers into multiple columns on a page, making it difficult to follow the answers and allocate marks clearly in the margins.

Advice to centres for preparation of future candidates

General

Many of the following points have already been made in the external assessment reports of the last few 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 vector diagrams, sketched graphs and other diagrams such as those showing the path(s) taken by rays of light.

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

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

- 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.

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

- Many candidates would benefit from spending more time learning correct technical terminology (for example, ‘*destructive interference*’, not ‘*deconstructive interference*’) and correct spelling (for example, ‘*trough*’, not ‘*troph*’). Careful study of the content statements for the course could help candidates with this issue.

- 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.

- Many candidates would benefit from further practice at using the various relationships for dosimetry. They need to be given feedback about whether they have selected the appropriate formula(s) and substituted correctly.

- 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.

Statistical information: update on Courses

Number of resulted entries in 2012	9166

Number of resulted entries in 2013	8788

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	27.0%	27.0%	2376	61
B	25.7%	52.7%	2255	50
C	23.5%	76.2%	2065	40
D	9.3%	85.5%	814	35
No award	14.5%	100.0%	1278	-

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.