External Assessment Report 2015

Subject(s)	Physics
Level(s)	Higher (Traditional)

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

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

Comments on candidate performance

General comments

This is the final examination paper for the Traditional Higher Physics Course. The first paper was in 2000.

There has been an unsurprising decrease in the number of candidates sitting this year's examination paper as centres have been moving over to the new Higher course under Curriculum for Excellence. The total number of candidates sitting Traditional Higher Physics this year is just over 5 400.

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

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

Areas in which candidates performed well

The multiple choice section of the examination was found to be reasonably straightforward by the majority of candidates, with questions 5, 8, 10, 11, 15, 16 and 19 being answered particularly well (at least 80% of candidates choosing the correct answers).

In Section B, as in previous years, the areas in which candidates performed best were those that required straightforward calculations to be performed.

Question 21

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

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

Question 23
In part (a)(i), the vast majority of candidates were able to use an impulse relationship to carry out a correct calculation to find the average force on the ball when struck by the hockey stick.

Question 24
In part (b), many candidates carried out a correct calculation using the gas law relationship to find the new pressure of the air at the new temperature. A few candidates wrongly substituted temperatures in Celsius. This is wrong Physics and only allows marks to be awarded for the relationship being quoted correctly. Candidates were free to choose ‘starting’ values from the given graph. However, some candidates ended up quoting their final answers to too many significant figures for the data they had chosen.

In part (c), (using the kinetic model to explain the effects on pressure of reducing temperature) many answers were very good. Weaknesses in other answers will be described in the next section of this report.

Question 26
Part (a)(i), where candidates were asked to show that the resistance of the lamp is 12 Ω, was very well done.

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

Part (b)(i) required candidates to redraw the circuit to show an LED connected in place of the lamp (with the LED emitting light). This was quite well done, but a significant number of candidates demonstrated that they did not know the symbol for an LED. Of those who did know the symbol, many failed to show it connected with the correct polarity.

Question 27
This question used the context of a defibrillator to ask about the charge and energy stored by a capacitor. A very high proportion of candidates answered the whole question very well.

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

Question 28
In part (b)(ii), most candidates were able to use the inverting mode relationship to calculate the output voltage of the op-amp. However, many then forgot to take into account the effects of saturation in part (b)(iii).

Question 30
In part (a)(ii), a high proportion of candidates were able to use the relationship between refractive index and velocity to calculate the speed of the red light in the prism.

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

Question 31

In part (b)(i), most candidates were able to show that the equivalent dose rate is 22 μSv h^{-1}. However, some candidates failed to start their answer by quoting the relevant relationship. It is not appropriate in a 'show' question simply to 'juggle' with numbers.

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 14. Only 38% of candidates correctly chose answer A; 41% of candidates chose distractor 'C'. This question gave three student statements about a wave. Those who chose distractor C were wrongly matching the term '*period'* to the definition of '*frequency'*.

Question 21

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

Specific areas of weakness in answers from candidates were:

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

- Very few candidates used a correct method to find the time taken for the shot to fall from its maximum height. The time for the shot to reach maximum height from the thrower's hand was given as 0·76 s. Many candidates simply doubled this time, showing a lack of understanding that the time to fall a greater distance to the ground would be longer than 0·76 s.
- Some started correctly with a relevant relationship (such as $s = ut + ½at^2$) but then made an error during substitution - for example, giving opposite signs to *s* and *a*.

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

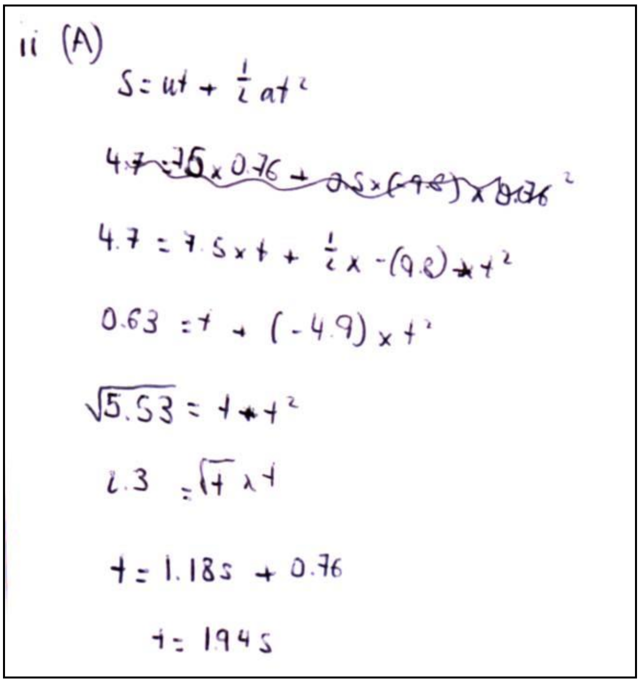
- It was disappointing that so few candidates realised that this part is answered by putting the constant horizontal component of velocity into the relationship between *distance*, *speed* and *time*. Some started by quoting $s = ut + ½at^2$ and then substituted a non-zero value for *a*. Others started with $s = ½ (u + v) \text{ x } t$ and then substituted values for *u* and *v* that were different from each other.

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

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

Examples of candidates' answers to question 21:

1. For part (a)(ii)(A):


ii (A)

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

~~$4.7 = 7.5 \times 0.76 + 0.5 \times (-9.8) \times 0.76^2$~~

$4.7 = 7.5 \times t + \frac{1}{2} \times -(9.8) \times t^2$

$0.63 = t + (-4.9) \times t^2$

$\sqrt{5.53} = t \times t^2$

$2.3 = \sqrt{t} \times t$

$t = 1.18s + 0.76$

$t = 1.94s$

Comment: This candidate has started with the correct relationship but has made two errors in the substitution line:

- for this situation, *s* and *a* should have the same sign as each other
- as the shot is falling from its maximum height, *u* should be zero

There are further problems in how the candidate has simplified and rearranged in subsequent lines, but markers stop allocating marks anyway at the stage of wrong substitution.

2. For part (a)(ii)(A):

ii. A. $u = 7.5 \text{ m s}^{-1}$

$a = -9.8 \text{ m s}^{-2}$

$s = -1.8 \text{ m}$

$t = ?$

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

$(-1.8) = (7.5)t + \frac{1}{2}(-9.8)t^2$

$-4.9t^2 + 7.5t + 1.8 = 0$

$a = -4.9, \quad b = 7.5, \quad c = 1.8$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$= \frac{-7.5 \pm \sqrt{7.5^2 - 4(-4.9)(1.8)}}{2(-4.9)}$

$x = -0.2$ or, $x = 1.7$

Since shot hits ground after it is thrown, $t > 0$

$\therefore t = 1.7 \text{ s}$

Comment: This method was not seen very often by markers. The candidate has considered the motion of the shot from the moment of launch until it hits the ground again. The upward direction has been taken to be positive — so the shot ends up on the ground with a displacement, *s*, of -1·8 m relative to the launch position. The acceleration due to gravity is correctly given as -9·8 m s^{-2} for this sign convention. The candidate has correctly solved the quadratic equation and given a clear reason for choosing the positive solution. This is an excellent answer.

3. For part (b):

b) When the angle of projection is increased the release speed is decreased due to gravity and air resistance acting on the put more effectively.

Comment: Despite there being some correct statements, this does not answer the question as there is no comment about what happens to the kinetic energy.

Question 22
This question uses the context of a spacecraft and rover vehicle descending towards the surface of a moon in order to probe candidates' understanding of the relationship between force and motion as well as their ability to handle components of forces.

Candidates did not answer either part of this question well.

Specific areas of weakness in the answers from candidates were:

Part (a):

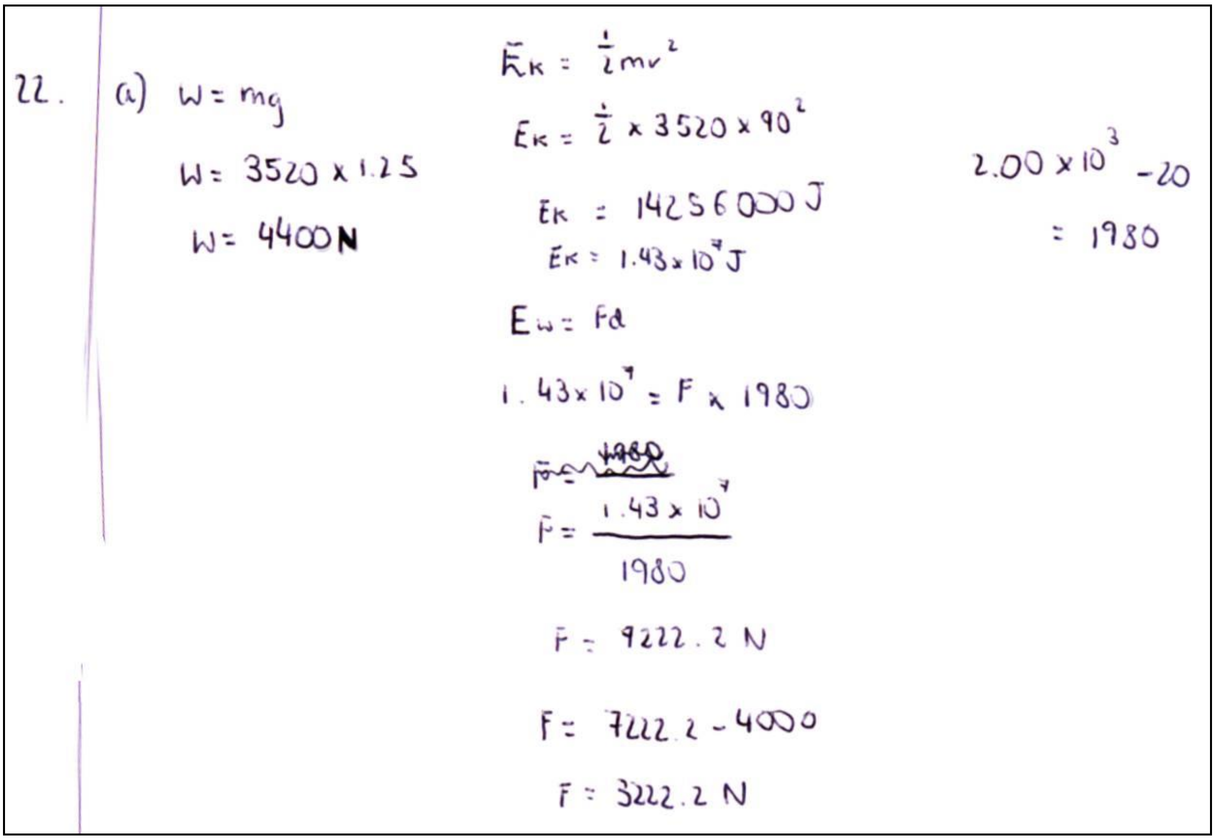
- Many candidates used $v^2 = u^2 + 2as$ to calculate the deceleration of the spacecraft for subsequent use in $F = ma$, but rounded their value for a too much, meaning that their answer for F was inaccurate.
- The rocket engines provide sufficient upward force to produce the deceleration **and also**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

Part (b):

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

Example of a candidate's answer to question 22:

For part (a):


22. (a) $W = mg$

$W = 3520 \times 1.25$

$W = 4400\ N$

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

$E_K = \frac{1}{2} \times 3520 \times 90^2$

$E_K = 14256000\ J$

$E_K = 1.43 \times 10^7\ J$

$E_w = Fd$

$1.43 \times 10^7 = F \times 1980$

$F = \frac{1.43 \times 10^7}{1980}$

$F = 7222.2\ N$

$F = 7222.2 - 4000$

$F = 3222.2\ N$

$2.00 \times 10^3 - 20$

$= 1980$

Comment:
This candidate has decided to answer by considering energy changes. However only the kinetic energy has been calculated – the change in potential energy should also have been added before equating with $F \times d$.

Although the weight of the spacecraft has been correctly calculated (top left), the candidate has made a subsequent mistake and changed its value from 4400 to 4000 in the second last line of the answer. Also, the weight should be added (not subtracted) in that line.

The candidate also shows a weakness in handling significant figures. The value for the kinetic energy has been rounded from 5 to 3 significant figures in the middle of the calculation, but the candidate still seems to believe that there is nothing wrong with then quoting the final answer for the force to 5 significant figures in the last line.

Question 23
This question uses the context of a penalty shot in hockey to allow candidates to show their knowledge about impulse and change in momentum. It also tests their abilities to sketch force/time graphs and to consider any changes resulting from using a softer ball (for the same change in momentum).

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

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

Specific areas of weakness in the answers from candidates were:

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

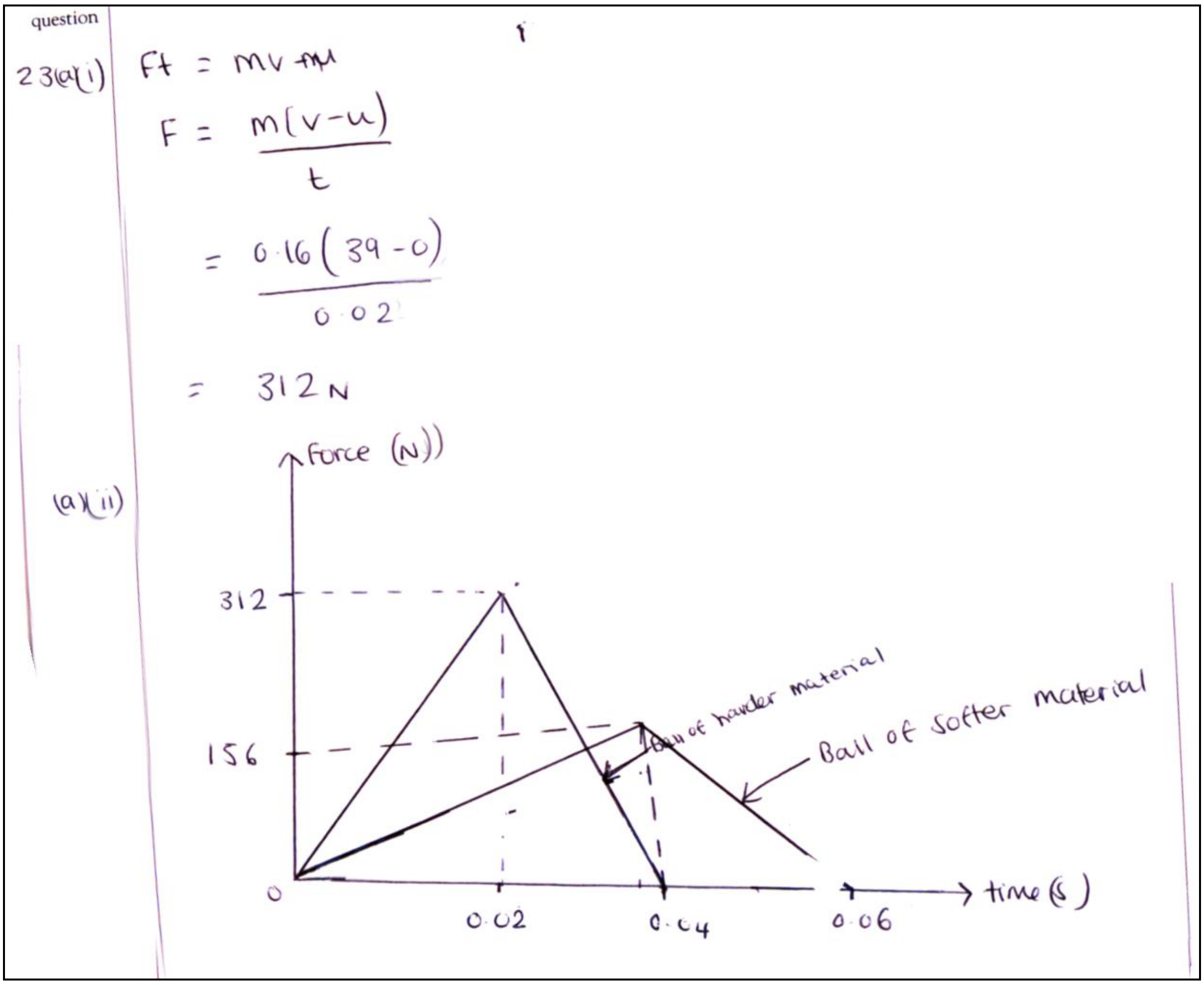
- Unlabelled axes
- Unlabelled origin
- The peak force being given the value of the average force from part (a)(i)
- The peak force being labelled as occurring at the total time of contact (0·02 s)
- Most candidates drew a triangular shape for the graph. Although this was not wrong, it was surprising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

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

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

Examples of candidates' answers to question 23:

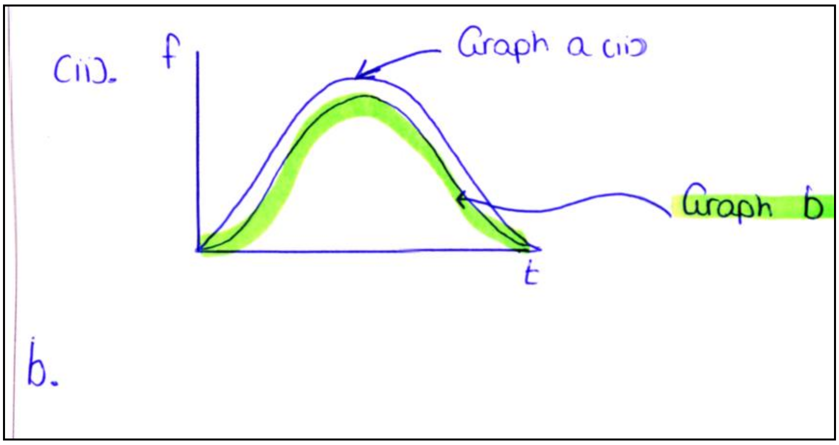
1. For parts (a) and (b):



Comment: The answer to part (a)(i) is clearly set out and is correct.

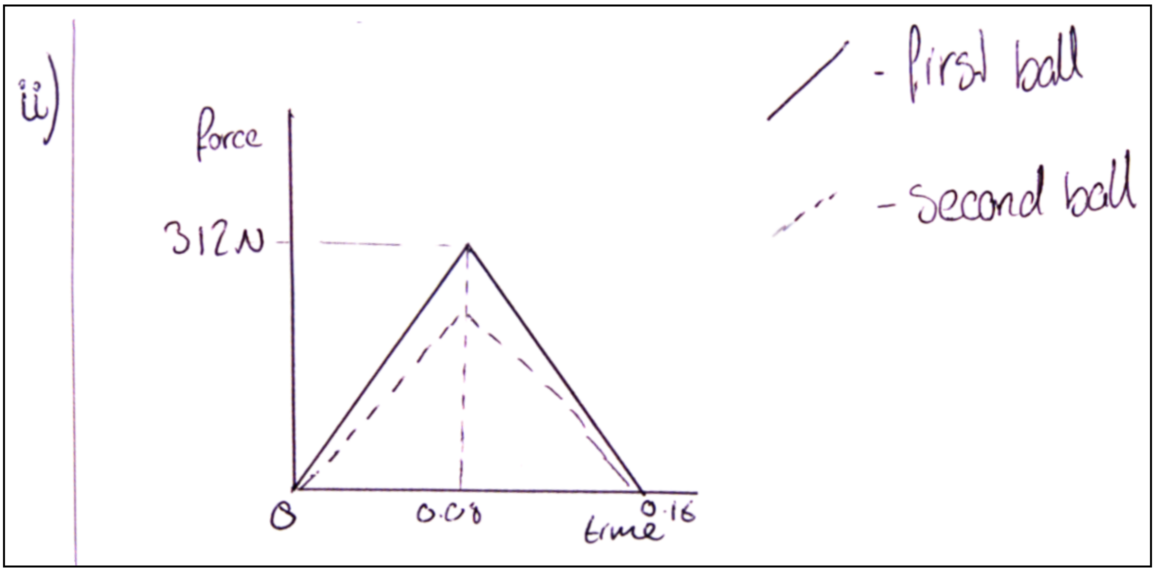
For part (a)(ii), the graph for the harder material shows wrong values on both axes at the peak force. There is no '(b)' label but the graph for the softer ball is clearly labelled – this correctly shows both of the points being looked for by markers (despite the dotted reference lines not being parallel to the axes).

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



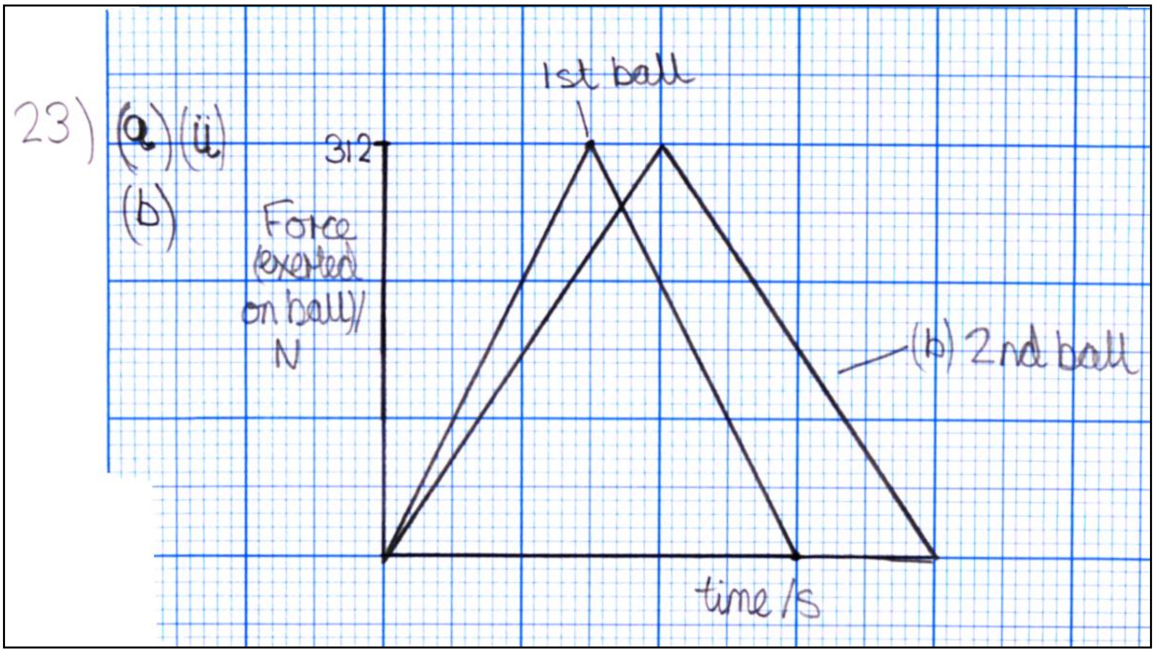
Comment: Both graphs have been clearly labelled — this is essential. The origin has not been labelled — this is important as the marker needs to know that the force starts from a zero value. The second graph only shows a smaller peak force; the time of contact is the same.

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



Comment: Both graphs have been clearly labelled – this is essential. Both the peak force and the time of contact are wrong for the first graph. The second graph only shows a smaller peak force; the time of contact has not changed.

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



Comment: The candidate has followed the suggestion in the question to use square-ruled paper. Doing this generally helps candidates to produce neater answers. Again both graphs have been clearly labelled. For the first graph, the origin has not been labelled and the peak has wrongly been given the value of the average force. The second graph only shows a longer time of contact; the peak force is the same.

Question 24

This question tests candidates' knowledge of the gas laws and kinetic theory in the context of an experimental set-up where a container of trapped gas is held in a bath of heated oil.

Generally this question was well done. However, markers did see weaknesses.

Specific areas of weakness in the answers from candidates were:

Part (a): (How does the graph prove that pressure is not directly proportional to temperature in degrees Celsius?)

Markers were simply looking for answers which said that the graph line was 'not a straight line through the origin'.

- Many answers said that the temperature should be in Kelvin, not Celsius. Such a statement does not answer the question.

Part (b): (Calculation of the new value of pressure when the temperature is increased.)

- Although many candidates carried out a correct calculation using the gas law relationship, a few wrongly substituted temperature values in Celsius. This is wrong physics and only allows marks to be awarded for the relationship being quoted correctly.

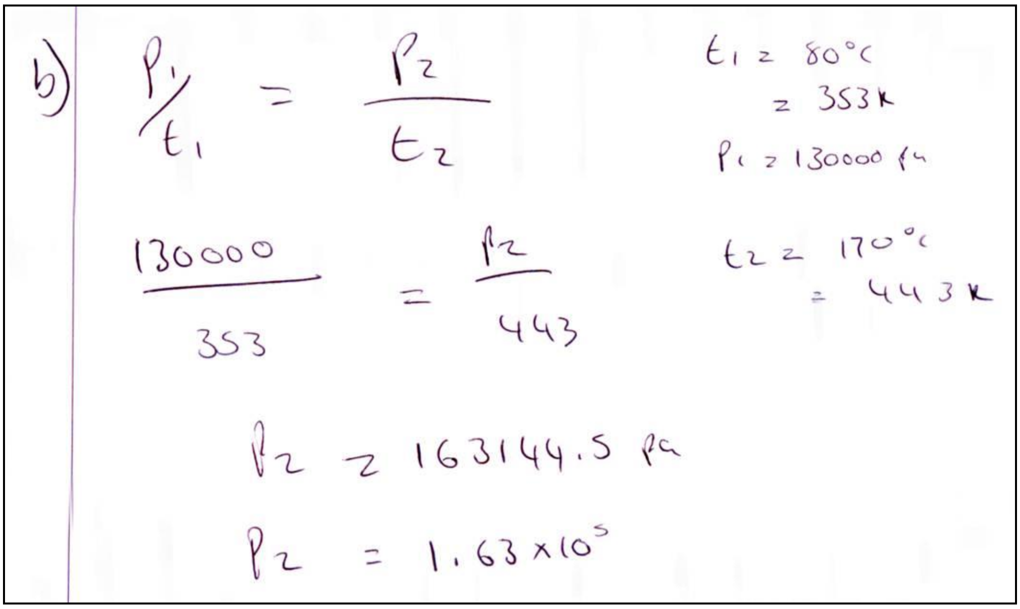
- Candidates were free to choose 'starting' values from the given graph. However, some candidates ended up quoting their final answers to too many significant figures for the data they had chosen.

Part (c): (This part requires candidates to use the kinetic model to explain what happens to the pressure of the gas when its temperature decreases.)

- Some candidates failed to say that pressure is due to moving gas molecules colliding with the walls of the container. This is the fundamental starting point for a kinetic theory explanation.
- The question asks for a description of how the pressure of the gas is affected by decreasing the temperature. Candidates who failed to conclude that the pressure decreases could not be awarded the marks.
- There are two separate effects of decreased molecular velocity. One is the less frequent collisions that they have with the container walls – this reduces the overall force on the walls. The second effect is that the individual molecular collisions with the walls are less hard – this also reduces the overall force on the walls. Many candidates failed to mention both issues.
- Many candidates provided incomplete answers such as '*fewer collisions*' rather than '*fewer collisions per second*' or '*less frequent collisions*'.
- Candidates should use the **words** 'increasing' and 'decreasing'. There are still a few candidates using up (↑) and down (↓) arrows in their descriptions. Markers have repeatedly said that this is not acceptable in examination answers.

Examples of candidates' answers to question 24:

1. For part (b):


b) $P_1 / t_1 = \frac{P_2}{t_2}$

$t_1 = 80°C = 353K$

$P_1 = 130000$ Pa

$\frac{130000}{353} = \frac{P_2}{443}$

$t_2 = 170°C = 443K$

$P_2 = 163144.5$ Pa

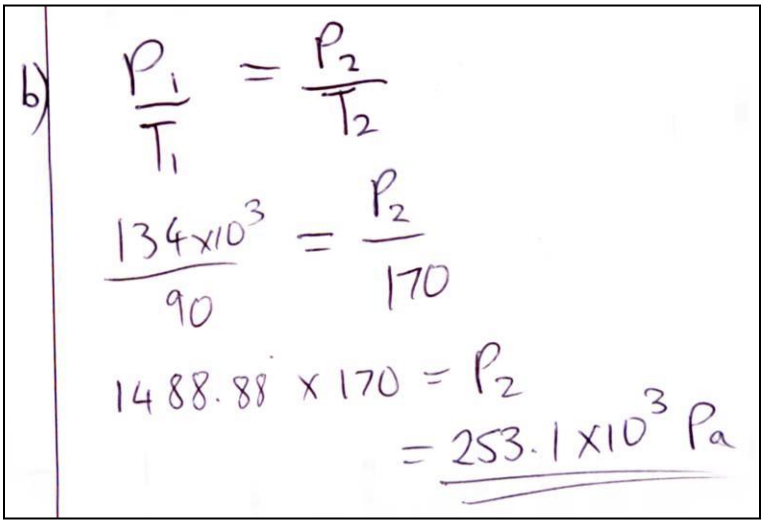
$P_2 = 1.63 \times 10^5$

Comment: It would be preferable for the candidate to use the standard symbol of '*T*' for *temperature*. Lower case '*t*' is used for *time*.

The data for the chosen starting point is fine.

No units are provided beside the final answer. Although the second last line does show units (has the candidate written ‘pa’ rather than ‘Pa’?), marking instructions always allocate any unit mark as part of the final answer.

2. For part (b):


b) $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

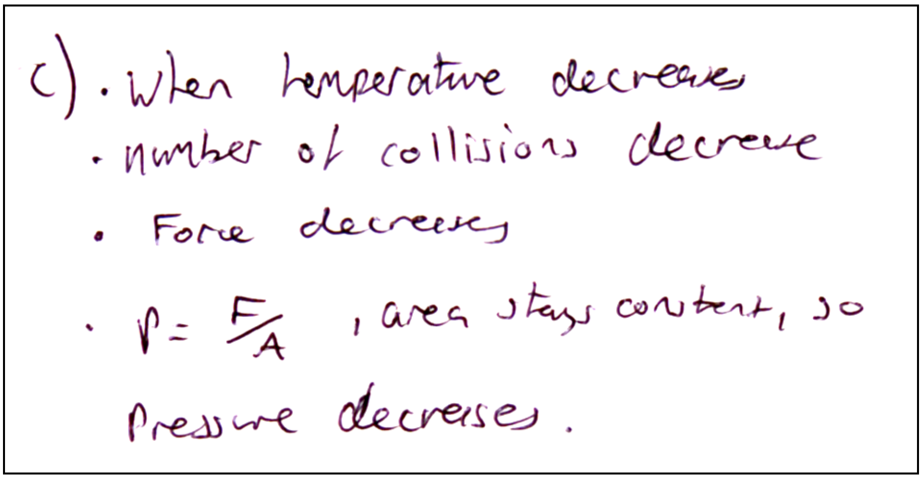
$\frac{134 \times 10^3}{90} = \frac{P_2}{170}$

$1488.8\dot{8} \times 170 = P_2$

$= 253.1 \times 10^3$ Pa

Comment: This example shows the quite common error of failing to change temperature values to kelvin (the marker then stops marking as it is wrong substitution).

3. For part (c):


c) • When temperature decreases

• number of collisions decrease

• Force decreases

• $P = F/A$, area stays constant, so pressure decreases.

Comment: This answer fails to gain any marks. This is not because it is presented as bullet points but because it fails to describe the basics of the kinetic model. Although it does use the word ‘collisions’, it does not mention the **molecules** of the gas or that they are colliding with the container **walls**.

Question 25

This question is about potential dividers and the combination of resistances in the context of circuits designed by two students to produce an output voltage of 5·0 V.

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

Specific areas of weakness in the answers from candidates were:

Part (a)(i):

- This is a 'show' question. However, a significant number of candidates did not start their answer with a relevant formula – they simply started by writing down numbers.

Part (a)(ii):

- Some candidates did not combine the resistors correctly. They failed to realise that the output voltage is now across 500 Ω (ie two 1000 Ω resistors in parallel) and that the total circuit resistance is now 1300 Ω.
- Some candidates thought that the potential difference across parallel resistors is halved to get the value across each one.
- Many answers were not clearly set out, making it difficult for the marker to follow the logic of the candidate's analysis.

Part (b):

- Many candidates tried to answer this part by recalculation. This is perfectly valid. However, there were again many who failed to combine resistors correctly and/or who could not work out the correct p.d. across a particular resistance.
- Many of those who tried to give a descriptive explanation only succeeded in showing weaknesses in their understanding of the relationships between current, voltage and resistance in series and parallel combinations.

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

25(a)(i)

$$V_2 = \left(\frac{R_2}{R_1+R_2}\right) \times V_S$$

$$V_2 = \left(\frac{1000}{1000+800}\right) \times 9$$

$$= 5V$$

$$\therefore V_O = 5V.$$

25 (ii)

$$V_2 = \left(\frac{R_2}{R_1+R_2}\right) \times V_S$$

$$V_2 = \left(\frac{500}{800+500}\right) \times 9$$

$$V_O = 3.46V$$

Resistance of parallel resistors

$$= \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_T} = \frac{1}{1000} + \frac{1}{1000}$$

$$\frac{1}{R_T} = \frac{1}{500}$$

$$\therefore R_T = 500\Omega$$

(b)

$$V_2 = \left(\frac{R_2}{R_1+R_2}\right) \times V_S$$

$$= \frac{909.09}{8909.09} \times 9$$

$$V_O = 0.816V$$

Student A achieves an output voltage closer to 5V as the output was 3.46V whereas Student B produced an output voltage of 0.816V.

Comment: This is an example of a very good answer for question 25.

Part (a)(i) starts with an appropriate relationship. The substitution is clear and the answer is equated to V_o.

Part (a)(ii) is also very clearly set out. It is easy to follow the calculation for combining the parallel resistances. The substitutions in the potential divider formula are also very clear.

Part (b) is almost perfect also. Only an arithmetic error in reaching the last line prevents full marks being awarded. (V_o should be 0·92 V, not 0·816 V).

Question 26

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

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

Parts (b)(ii)(B) and (b)(iii) were answered quite poorly.

Specific areas of weakness in the answers from candidates were:

Part (b)(i): (Candidates were asked to redraw the circuit diagram to show the LED connected in place of the lamp.)

- Many candidates did not know the symbol for an LED
- Many candidates who did know the LED symbol could not show it connected in forward bias.

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

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

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

Part (b)(iii): (Using the given words, explain how light is produced in an LED.)

Markers were looking for candidates to state that 'electrons and holes combine at the p-n junction and that each (re)combination causes a photon to be released'.

- A significant proportion of candidates showed confusion between what happens in an LED and what happens in a photodiode (where an incoming photon separates an electron from a hole, ie it creates an electron-hole pair).

- Some candidates stated that an LED produces light when it is reverse biased.

Examples of candidates' answers to question 26:

For part (a)(ii):

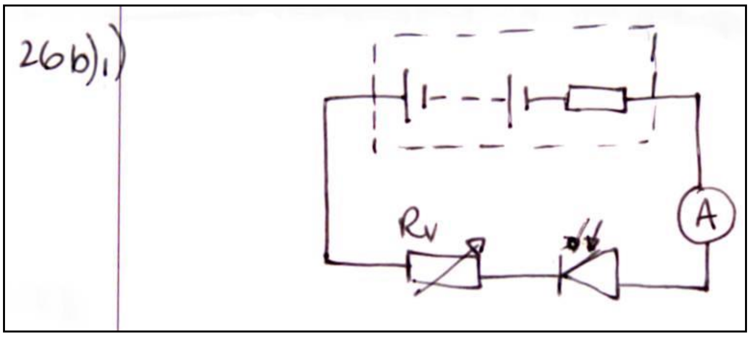
ii) $P = V^2 R$

$= 3.6^2 \times 12$

$= 155.52 W.$

Comment: This answer is completely wrong. Despite having the data booklet to refer to, this candidate's first line shows a wrong relationship.

For part (b)(i):



Comment: This candidate has confused the symbol for an LED with that for a photodiode. The polarity is also wrong for it to be forward biased.

For part (b)(iii):

(iii) Light is produced when a photon passes enough energy to an electron to move out of a hole

(iii) When light is shown on the electrons, they form holes which releases photons.

iii) As photons are emitted, holes are formed. Electrons fill the holes but leave holes open that they were previously in. Light is produced this way.

Comment: Each of the above answers makes it clear that those candidates do not understand what is happening in an LED.

Question 27

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

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

Specific areas of weakness in the answers from candidates were:

Part (a):

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

Part (b):

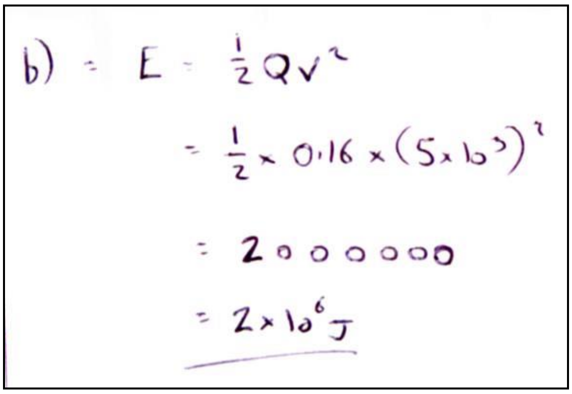
- Some candidates chose to use the relationship $E = ½ CV^2$, but then used the value of the charge when substituting for *C*.

Part (c):

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

Examples of candidates' answers to question 27:

For part (b):


b) $E = \frac{1}{2}QV^2$

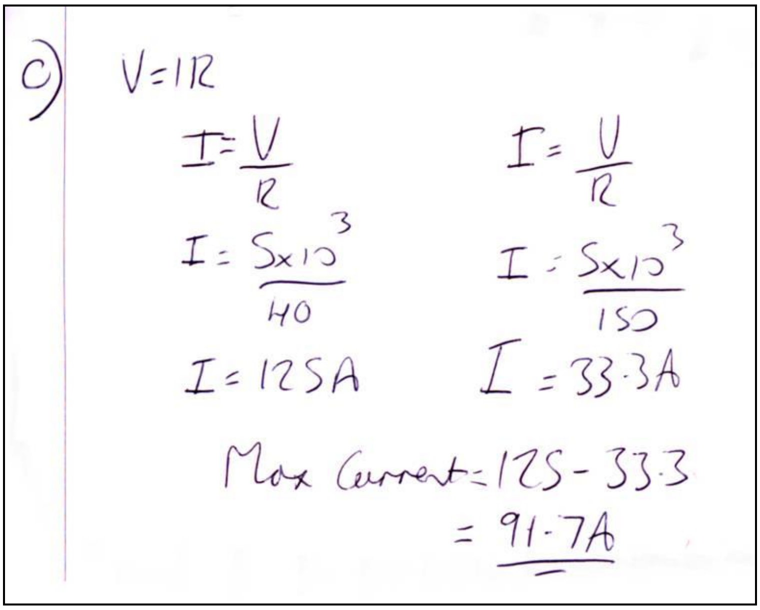
$= \frac{1}{2} \times 0.16 \times (5 \times 10^3)^2$

$= 2000000$

$= 2 \times 10^6$ J

Comment: This answer is completely wrong. Despite having the data booklet to refer to, this candidate's first line shows a wrong relationship.

For part (c):


c) $V = IR$

$I = \frac{V}{R}$ $\qquad$ $I = \frac{V}{R}$

$I = \frac{5 \times 10^3}{40}$ $\qquad$ $I = \frac{5 \times 10^3}{150}$

$I = 125$ A $\qquad$ $I = 33.3$ A

Max Current $= 125 - 33.3$

$= 91.7$ A

Comment: This candidate has carried out two calculations for the current, using the minimum and then the maximum resistances. However, rather than then state that the maximum current is therefore 125 A, the candidate has decided to calculate the difference between them. Perhaps re-reading the question at this stage would have corrected his/her thinking?

Question 28

This question asks candidates about two terms used in semiconductor physics. It then poses questions around an op-amp circuit that has an input voltage provided by a photodiode.

Only part (b)(ii) was well done.

Specific areas of weakness in the answers from candidates were:

Part (a)(i): (State what is meant by the term *doping*.)

- Many answers were too vague or included wrong physics.

Part (a)(ii): (State what is meant by the term *n-type semiconductor*.)

- As in part (a)(i), many answers were too vague or included wrong physics.

Part (b)(i): (In which mode is the photodiode being used?)

- Many candidates must not have read the question carefully as they answered ‘inverting’. This would have been the correct answer if the question had asked for the mode of the op-amp.
- There were several examples of ‘photovoltaic’ being spelled incorrectly. Candidates should take particular care to spell technical terms correctly.

Part (b)(ii):

- Some candidates failed to give a negative value for the output voltage.

Part (b)(iii):

- Many candidates failed to realise that the op-amp saturates and that their calculated value of -24 V for V_o is not possible here.
- Of those who realised that saturation occurs, some said V_o = -15V, which is not possible with the ±12 V supply shown in the question.
- Some candidates wrongly stated that ‘the output voltage saturates’ rather than ‘the op-amp saturates’.

Example of a candidate’s answer to question 28:

28(a)(i) doping is adding an impurity to certiam insulators and when added they become semi-conductors.

(ii) n-type semi conductor is a negative semi-conductor because an element with an extra electron has been added which makes it negative. the free electron then acts as a charge carrier and allows it to conduct.

(b)(i) inverting mode

(ii) $\frac{V_1}{V_2} = \frac{-R_f}{R_1}$ $\frac{0.60}{V_1} = \frac{-45\times10^3}{5.0\times10^3}$ $V = -0.66$

$0.60\times5.0\times10^3 = V_2\times -45\times10^3$

$\frac{3000}{-45\times10^3} = V_2$

$V_2 = -0.06$

Comment: In part (a)(i), it is wrong to say that doping causes them to ‘become’ semiconductors.

In part (a)(ii), an n-type semiconductor is electrically neutral — it is incorrect to say it is ‘negative’. The ‘n’ is used because the majority charge carriers are negative electrons.

In part (b)(i), the photodiode is being used in photovoltaic mode.

In part (b(ii), the relationship is not one from the data booklet. The numbers are then substituted in a way which cannot produce the correct answer and so no marks can be awarded.

Question 29
This question probes candidates' knowledge and understanding of the photoelectric effect.

Only part (a)(ii) was reasonably well done – the answers to the other parts were poor.

Specific areas of weakness in the answers from candidates were:

Part (a)(i): (State what is meant by the term *work function*.)

- Many candidates said that it is 'the energy required to release an electron from the surface of a metal'. Such an answer is missing the essential word 'minimum' in front of energy.
- Many said it was the energy required to release a **photon**.
- Some candidates confused *work function* with *threshold frequency*.

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

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

Part (b)(i): (Calculation of the maximum speed of a photoelectron.)

In this question, candidates were told that a photoelectron is released from the photocathode with a kinetic energy of $1{\cdot}36 \times 10^{-19}$ J and that it is then accelerated though a potential difference of 120 V.

- Many ignored the effect of the accelerating voltage and just worked out the speed of a photoelectron that has a kinetic energy of $1{\cdot}36 \times 10^{-19}$ J.
- Many ignored the initial kinetic energy and worked out the speed of the photoelectron as if it had been accelerated from rest.
- Errors with significant figures were common.

Part (b)(ii): (Does doubling the accelerating voltage double the speed of the photoelectron?)

In this part, candidates could have answered either in terms of the constant value of kinetic energy which has to be added or they could have explained that the relationship between the velocity and the accelerating voltage is not a linear one.

- Few candidates seemed to understand, or be able to explain, that the relationship between *v* and *V* is not linear. Only a few were able to explain that because $v = (2QV/m)^{½}$, doubling the voltage only increases the speed by $\sqrt{2}$.

Examples of candidates' answers to question 29:

For part (a)(i):

29a) work function is the minimum energy a photon is required to produce light

29a)i) Work function - the minimum energy required for a photon to be emitted from the surface of a material.

29. a)i) The work function is the minimum energy required to get an electron to Jump.

Comment: These candidates have clearly demonstrated a lack of understanding of the term *work function*.

For part (a)(ii):

ii)

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

$= \frac{3 \times 10^8}{425 \times 10^{-9}}$

$= 7{\cdot}05 \times 10^{14}$

$E_k = hf - hf_0$

$= (6{\cdot}63 \times 10^{-34})(7{\cdot}05 \times 10^{14}) - (3{\cdot}2 \times 10^{-19})$

$= 1{\cdot}47 \times 10^{-19}$ J.

Comment: This candidate has calculated the frequency for the given wavelength, but has rounded incorrectly (the answer is $7{\cdot}05882353 \times 10^{14}$, which if rounded to 3 sig. figs. is $7{\cdot}06 \times 10^{14}$.) This error has caused the final answer to be inaccurate.

Candidates should either retain any intermediate answer within their calculator all the way through to the final answer or they should round their intermediate answer to a greater number of significant figures so that the final answer is not affected (to the number of significant figures they wish to quote). For example, keeping intermediate rounding to 5 significant figures and so using $f = 7{\cdot}0588 \times 10^{14}$, gives E_k correctly as $1{\cdot}48 \times 10^{-19}$ J.

For part (b)(i):

(b) (i) mass of electron = 9.11×10^{-31} kg

$$E_k = \frac{1}{2} m v^2$$

$$1{\cdot}36 \times 10^{-19} = \frac{1}{2}(9.11 \times 10^{-31} v^2)$$

$$2{\cdot}72 \times 10^{-19} = 9.11 \times 10^{-31} v^2$$

$$v^2 = \frac{2{\cdot}72 \times 10^{-19}}{9.11 \times 10^{-31}}$$

$$v = 5{\cdot}5 \times 10^5 \text{ ms}^{-1}$$

Comment: This is an example of a commonly seen wrong answer. The candidate has simply used the given value of the initial kinetic energy. She/He has failed to calculate the additional kinetic energy given to the electron by the accelerating electric field. The only mark that can be awarded is for selecting the kinetic energy formula.

For part (b)(ii):

ii) No. Total kinetic energy at electrode A is the initial kinetic energy ($1{\cdot}36 \times 10^{-19}$ J) plus the gained kinetic energy, so although doubling the potential difference to 240 V will double the E_k gained (since $E_k = W = QV$), it will not double to total kinetic energy. Furthermore, 'E_k' and 'v' (speed) are not directly proportional, since $E_k = \frac{1}{2} m v^2$, therefore the speed isn't doubled.

Comment: This answer is included to show that some candidates do have a good grasp of physics!

Question 30

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

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

Specific areas of weakness in the answers from candidates were:

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

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

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

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

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

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

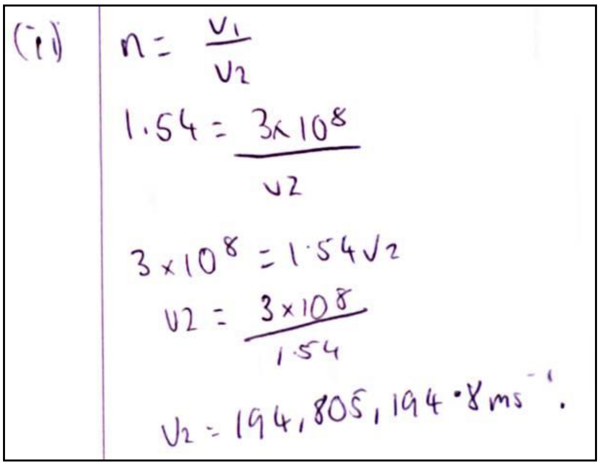
Part (b)(ii): (Explain why the angle to the second order maximum is different for blue light than for red light.)

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

Examples of candidates' answers to question 30:

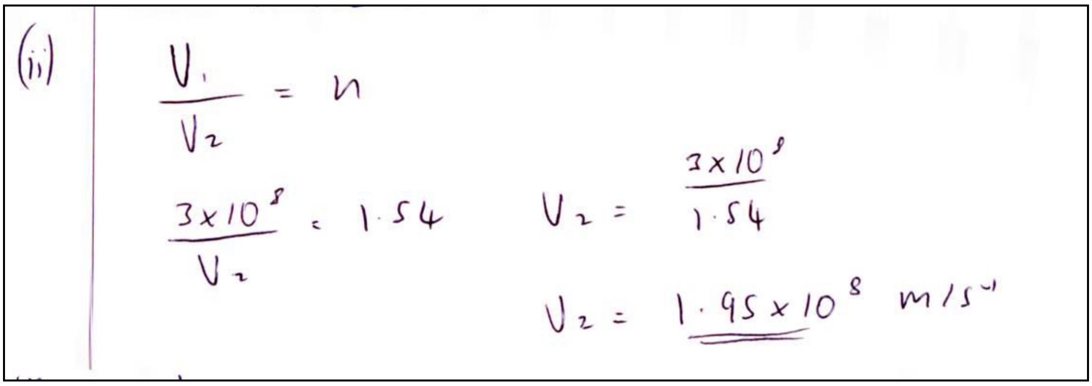
For part (a)(ii):

1.



Comment: This answer is fine until the last line. For some reason, despite the given data being to three significant figures, the candidate believes that it is appropriate to quote the final answer to ten significant figures!

2.



Comment: This answer also goes wrong at the last line – this time for wrong units. The S.I. units of speed/velocity are metres per second which can be written as m/s or m s^{-1}.

or part (b)(i):

1.

b)(i) $\sin\theta = n\lambda$

$d\ (\sin 19) = 2 \times \left(\frac{3\times10^{8}}{4.57\times10^{14}}\right)$

$d\ \sin 19 = 1.31\times10^{-6}$

$d = \frac{1.31\times10^{-6}}{0.326}$

$d = 4.018\times10^{-6}\ m$

Comment: This candidate has worked out the value for sin19 in the middle of the calculation. However, he/she has only given it to three sig. figs. and this has resulted in an inaccurate final answer. The candidate then further shows lack of understanding of significant figures by quoting the final answer to four significant figures.

2.

b) i) $d \sin\theta = n\lambda$

$v = f\lambda$

$3\times10^{8} = 4.75\times10^{14}\lambda$

$\frac{3\times10^{8}}{4.75\times10^{14}} = \lambda$

$\lambda = 6.3\times10^{-7}$

$d = \frac{2(6.3\times10^{-7})}{\sin 19}$

$= 3.87\times10^{-6}\ m$

Comment: This candidate has made a mistake using the data given in the question.

In the examination paper, the frequency of the red light is given as 4·57 x 10^{14} Hz. However, the candidate has substituted a value of 4·75 x 10^{14}. This is a costly error as the marker can then only award the marks for the correct relationships.

For part (b)(ii):

> ii) Blue light has a higher frequency than red light and so has a smaller wavelength, and since $d \sin\theta = n\lambda$ and 'd' and 'n' are constants, a decrease in 'λ' will cause a decrease in 'sinθ', which means that 'θ' (the angle to the 2nd order maximum) is smaller.

Comment: A very good answer.

Question 31

This final question is about mass being converted into energy in a fusion reaction, followed by some handling of dosimetry relationships.

Part (b)(i) was moderately well done, but the answers to parts (a) and (b)(ii) were disappointing.

Specific areas of weakness in the answers from candidates were:

Part (a): (Candidates were given a statement describing a fusion reaction and a table of some of the particle masses. They were asked to calculate the mass of the nitrogen nucleus.)

- There was a significant number of candidates who did not realise that there was a need to use $E = mc^2$. Without its use, no marks could be awarded.
- All of the masses in the table are given to six significant figures. Some candidates decided to round these values before carrying out calculations. Candidates should know that the changes in mass are so small that no rounding of the data should be performed.
- Having calculated the lost mass from the given value of energy, many candidates did not know which side of the 'equation' to add it to.

Part (b)(i): (Show that the equivalent dose rate is 22 μSv h^{-1})

- This is a 'show' question but many candidates did not start their answer by quoting the appropriate relationship.
- Candidates often showed that they were confused about the meaning and use of each of the terms: *equivalent dose*, *absorbed dose*, *equivalent dose rate* and *absorbed dose rate*.

Part (b)(ii): (Calculate the radiation weighting factor)

- Again candidates often showed that they were confused about the meaning and use of each of the terms: *equivalent dose*, *absorbed dose*, *equivalent dose rate* and *absorbed dose rate*.

Other general issues

- Many markers complained about the difficulty they had in reading the answers from some candidates due to unclear handwriting.
- A few candidates made more than one attempt at answering a question. For example, some produced two sketch graphs for question 23(a)(ii), one in the answer booklet and another on square-ruled paper. This causes problems when there are inconsistencies between the two answers. A marker cannot be expected only to choose the correct part(s) and ignore inconsistencies.
- Markers reported that the structure within the more complex numerical calculations was often of a poor standard and difficult to follow.

Advice to centres for preparation of future candidates

General

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

Many of the following points have already been made in the external assessment reports of recent 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 square-ruled 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 consider direction as well as magnitude when dealing with vector quantities.

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

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

- Candidates must be aware that, in a ‘must justify’ question, no marks can be awarded if no attempt is made 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, ‘*the op-amp saturates*’, not ‘*the output voltage saturates*’) and correct spelling (for example, ‘*photovoltaic*’, not ‘*photovoltic*’). Careful study of the content statements for the course could help candidates with these issues.

- Candidates must understand that to ‘sketch’ a graph does not mean that the graph can be untidy or inaccurate. The instruction to ‘sketch’ a graph only means that **it does not have to be drawn to scale**. Care should still be taken to present these sketches as neatly as possible. For example, a ruler should be used to draw the axes and any straight sections of the graph line. The origin and axes on sketch graphs must be labelled and any important values carefully shown. It is useful to link these important values to the relevant parts of the graph line using dotted reference lines. It is wise to use a pencil when attempting to draw the graph line – any wrong line(s) can then be erased to leave a neat, clear, single line as the final answer.

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

- In numerical calculations, candidates should round off values only at their **final** answer for a part of a question. The answer(s) to any intermediate calculation(s) should not be rounded to the extent of causing inaccuracy in the final answer. This could also involve advice being given about the efficient use of handling data on a calculator.

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

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

Statistical information: update on Courses

Number of resulted entries in 2014	9098

Number of resulted entries in 2015	5401

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	30.0%	30.0%	1620	64
B	23.3%	53.3%	1261	53
C	22.8%	76.2%	1234	42
D	9.1%	85.3%	490	36
No award	14.7%	-	796	-

For this course, the intention was to set an assessment with grade boundaries as close to the notional values of 50% for a Grade C and 70% for a Grade A. The starting point for discussion was the 2014 set grade boundaries as instructed by the panel in 2014. A 1 mark adjustment was made for the general intended easing of the multiple choice section of the paper. A 1 mark adjustment was made for Q21 (b) as it did not function as intended. A further 3 mark adjustment was made to the 'C' boundary, 2 marks for the 'A' boundary and 1 mark for the upper 'A' boundary for the general action that the setting team made to ease the paper from 2014.

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.