Pearson Edexcel

Examiners' Report
June 2019

IAL Physics WPH11 01

ResultsPlus

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications come from Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk.

Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

ResultsPlus

Giving you insight to inform next steps

ResultsPlus is Pearson's free online service giving instant and detailed analysis of your students' exam results.

- See students' scores for every exam question.
- Understand how your students' performance compares with class and national averages.
- Identify potential topics, skills and types of question where students may need to develop their learning further.

For more information on ResultsPlus, or to log in, visit www.edexcel.com/resultsplus.
Your exams officer will be able to set up your ResultsPlus account in minutes via Edexcel Online.

Pearson: helping people progress, everywhere

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk.

June 2019
Publications Code WPH11_01_1906_ER

Introduction

This is the second time that the Pearson Edexcel International AS paper WPH11, Mechanics and Materials, has been sat by candidates. Section A of the paper is worth 10 marks and consists of 10 multiple choice questions. This is followed by Section B, consisting of 8 questions of increasing length comprising of short, open-response, calculation and extended writing style questions.

The assessment for WPH11 is mostly similar to the legacy IAL specification. The specification has been broadened to include recognising vector notation (specification point 4), conservation of momentum in 1 direction (specification point 14), moments (specification point 15) and the efficiency equation (specification point 30). This specification now includes three core practicals, to determine the acceleration of free-fall, to use a falling ball method to determine the viscosity of a fluid and a method to determine the Young modulus of a material. These have been examined in the past but, to mirror the home 8PH01 specifications, these have now been designated specification points making them a compulsory rather than optional part of the course. The content of the materials section of the specification has been reduced with fluid flow diagrams and definitions of mechanical properties such as brittle, ductile, hard, malleable and tough not included. In line with the new IAL qualification, the new assessment objective AO2b allocates about 10 marks of the paper to questions that require candidates to draw a conclusion. In addition to this the legacy QWC questions have been replaced by one 6 mark linkage question, question 16(c) for this exam series.

This paper enabled candidates of all abilities to apply their knowledge to a variety of styles of examination questions. Many candidates showed a good progression from GCSE to AS Level, with prior knowledge extended and new concepts taught and understood well. Candidates found the length of some of the calculations to be challenging, often missing out key steps therefore only scoring 1 or 2 marks for interim steps. Some questions were not answered as well as would have been expected by many candidates; this was particularly evident in the 6 mark linkage question (Q16(c)) which was set within the familiar context of the experiment to measure the Young modulus of a wire. The new regions of the specification, in particular moments, were answered as expected if not better. It was the problem-solving nature of some of the questions as well as the requirement for explanations in an unstructured setting that many found to be challenging.

Candidates who had a sound understanding of the physics involved did not always demonstrate this in their responses due to a lack of precision of the language and terminology used. Some missed exactly what the question was actually asking, Q11 being an example, where answers were sometimes given in terms of forces and not of momentum, as the question requested. However, candidates from across all ability ranges usually managed to score some marks within these questions. While the mathematical ability seen was strong, application to the context was not as expected. Further time spent understanding the context, before attempting the question would help candidates appreciate the requirement of the task at hand.

Section A – Multiple Choice

	Subject	Percentage of candidates who answered correctly	Most common incorrect response
1	Units, scalars and vectors	77	A
2	Newton's second law	25	A
3	Upthrust and weight	34	C
4	Projectile motion	62	D
5	Stoke's law	61	C
6	Properties of materials	84	A
7	Kinetic energy and power	66	D
8	Acceleration-time graph	19	D
9	Vector diagrams	39	A
10	Use of $\Sigma F = ma$	61	B

Most candidates scored between 5 and 7 out of 10, the mean being 5.2 for the multiple-choice items. More able candidates did not perform as expected on this section, questions 2, 3 and 8 in particular as well as some on 9.

Timing was not an issue on the paper, however, some low scoring candidates fared better on the multiple-choice items than their higher scoring counterparts. Thus demonstrating that a disproportionate amount of time was spent by some on this section.

Explanations of the distractors are included in the mark scheme but a few, more significant, points are mentioned below. Questions 4, 7 and 9 are based upon straightforward substitutions into an equation and it had been expected that these would be answered correctly by all candidates of E grade ability and above.

Q02 – Newton's second law primarily explains the acceleration of an object due to the presence of a resultant force. It is Newton's first law that expains why an object without a resultant force continues with a uniform velocity. Hence, the two distactors for uniform motion, A and B, were incorrect. While Newton's third law can be used to explain the presence of each force acting on the rocket, ie weight and thrust, it cannot solely be used to explain the subsequent acceleration, hence distractor D was incorrect.

Q03 – When the object floats, the volume of water displaced is equal to the weight of the sphere. If the sphere is completely submerged, twice the volume of water is now displaced, so the upthrust is doubled. This means that there must now be an additional force acting downwards on the sphere, equal to the difference in the two upthrusts, ie 2.5 N and response B.

Q05 – D is the correct answer as a lower viscosity reduces the drag force at any speed, so a greater terminal velocity would be reached in order for the drag to be large enough to equal the weight and the sand to reach terminal velocity. To reach the correct response of D, the other distractors had to be evaluated to be discounted.

The following distractors are incorrect because:

(A) was incorrect as smaller particles of sand have a smaller weight so reach terminal velocity more quickly and travel downwards at a lower speed.

(B) was incorrect as water of a lower temperature will have a greater viscosity which would increase the time.

(C) was incorrect as a smaller terminal velocity would increase the time taken to reach the bottom of the beaker.

Q08 – Once the fuel runs out, the only forces acting would be the weight and drag forces. These are both acting downwards, so the resultant force and hence acceleration would also change direction and act downwards, changing the direction of the acceleration to negative. Therefore, distractors B and D are incorrect as they have the change in direction of the acceleration at T and not before T. C is correct over response A as the stem describes a constant upwards thrust. This would give a constant acceleration and not an increasing acceleration so A is incorrect.

Q09 – The final displacement is the resultant of the two displacement vectors. It was expected that candidates would be able to construct the vector triangle to identify the direction and relative size of the resultant displacement. Without the need for a protractor, a ruler could be placed on the 12km displacement and moved across to the top of the 20km displacement so that the resultant, response B, could be identified. If this method is used and a line of the same magnitude as the one moved across, the correct direction can be obtained. If the line moved across is too short then the direction of the resultant will be reversed, as was the case with many who thought A to be the correct answer.

Question 11

This question specified that it should be answered in terms of momentum. Therefore responses that only explained the context of the child and skateboard moving in an opposite direction, at a lower velocity in terms of forces alone, could only usually score MP5 for the explanation of a lower velocity.

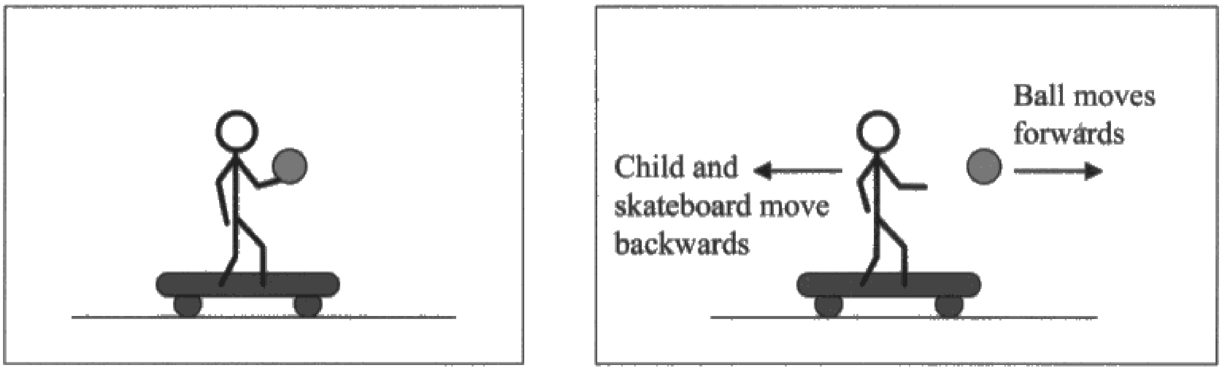
The question required the candidates to address both the equal magnitude and the opposite direction. Those that started using the initial momentum of zero and linked this to the final momentum being zero gave the basis of a good explanation. However, many omitted to address both parts of the question.

The precison of the terminology used, for example the inaccurate wording of the law of conservation of momentum was notable for many.

Many candidates managed to score a minimum of 1 mark for the idea of a lower speed of the child and skateboard, often without quite meeting the requirements of the other marking points.

This response scored 2 marks. MP3 for the idea that the momenta of the ball and skateboarder and child would be the same after the ball is thrown. MP5 for the explanation that as the mass of the skateboard and child is greater, their velocity will be lower.

11 A child is standing on a skateboard and both are stationary. The child throws a ball forward at a high velocity and the child and the skateboard move backwards at a lower velocity.



Before After

Explain, in terms of momentum, why the child and the skateboard move backwards at a lower velocity.

(4)

Momentum before a collision before a collision is same as momentum after a collision provided that no external forces act. Since momentum is conserved, ~~the~~ ~~ba~~ for the same momentum, the ball has lower mass, so it will go at a higher velocity. While the skateboard and the child has greater mass, so for the same momentum, it will have lower velocity

ResultsPlus
Examiner Comments

This candidate has attempted to state the conservation of momentum (MP2) but has missed out the total as it is the total momentum before and after the event that are equal. It was also required that a reference to conservation of momentum was made which this response gives in line 4.

Therefore, this candidate has addressed the lower velocity aspect of the motion of the skateboarder and the child but not the opposite. They have not explained either why the momenta would be the same. This reasoning needs to originate from the initial momentum being zero, hence, using the conservation of momentum, the final momentum is greater etc.

ResultsPlus
Examiner Tip

Learn laws accurately and make sure you understand the significance of the 'total' in the law of conservation of momentum so it isn't forgotten.

If a question asks you to explain two points, make sure you refer to these points in your explanations. If necessary, highlight or underline parts of the command sentence to prompt you.

Just 1 mark was awarded for this response. MP5 for the explanation of the lower velocity.

According to the conservation of linear momentum, momentum before collision is equal ~~to~~ the momentum after collision provided that no external forces acts on the system. In the picture the child was on a skateboard holding ~~it~~ a ball. When the ~~ch~~ child throws the ball, ~~it according to~~ ~~Newton's~~ the child exerts a force on the ball and according to Newton's ~~third~~ Third Law, the ball exerts an equal force on the child. Since momentum is conserved the child will move backwards with a lower velocity since it contains a higher mass compared to the mass of the ~~balloon~~ ball. ~~$m_1v_1 = m_2v_2$~~ $m_1v_1 - m_2v_1 = m_1v_2 - m_2v_3$ ~~where m_1 is the mass of the child, m_2 the mass of the b~~

(Total for Question 11 = 4 marks)

ResultsPlus
Examiner Comments

Again, MP2 could not be awarded for the definition of the law of conservation of momentum as the 'total' was omitted.

This candidate then attempted to describe this context in terms of forces which did not pick up any marks.

The response does revert back to momentum but none of the quantites in the given equation are defined, so the equation can't form part of the explanation and be credited.

ResultsPlus
Examiner Tip

Read the question. If it asks you to refer to a specific quantity as part of the response, don't discuss another.

This response scored 4 marks. MPs 1, 2, 3 and 5. The direction was not addressed but the rest of the explanation was methodically given.

By the law of conservation of momentum ~~principle of moments~~, the total ~~mass~~ momentum of the child, skateboard and ball before throwing it is equal to ~~tot~~ total momentum after the throw. Total momentum before is equal to zero, because ~~it~~ p=mv and v=0. After throwing the total momentum (sum of momenta) has to be 0 too, ~~So that~~ so ~~f~~ mass child+skateboard × $velocity_{c+s}$ + mass of ball × $velocity_b$ = 0

~~The In order for that to be correct, one of the~~ ~~Forwards~~ Forwards force is exerted on ball and backwards force on child + skateboard, so the velocity of child + skateboard is negative (therefore go backwards). p=mv, so if child+skateboard momentum = ball momentum, but child + skateboard have a bigger mass, they will move with a lower velocity.

ResultsPlus
Examiner Comments

The equation given in line 5 for the total momentum after the collision was then rearranged to a statement that child + skateboard momentum = ball momentum and a negative sign should have been used which would have made MP4 possible.

Question 12

This was a context based question where candidates were required to determine if the efficiency of the machine, ie the ramp and pulley system, was greater than 90%.

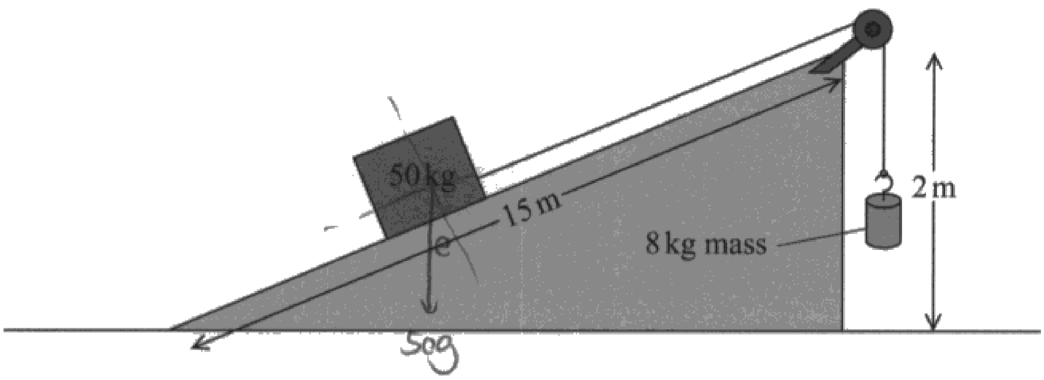
The 8kg mass could only fall through a maximum height of 2m and therefore the 50kg mass could only move a maximum distance along the slope of 2m or maximum vertical height of (2 × sin theta) ie 4/15. While many responses managed, as a minimum, to score the interim working marks for use of the work done and efficiency equations, few fully appreciated the context and understood which mass the work was done by and which mass the work was being done on.

It was quite common for candidates to gain a plausible answer of 83.3% but only gain MP2 and MP3 by working out *mgh* for the 50kg mass with an incorrect distance of 2m, and then dividing by *mgh* for the 8kg mass with an incorrect distance of 15m, highlighting a failure to link work done to the corresponding distance. It was rare to award MP1 and MP4, with some calculating the angle but failing to use it. Others didn't gain MP3 as they gained an incorrect useful energy for the 50kg mass, which was larger than the output energy, and then perhaps because they knew that efficiency should be less than 1, inverted the energies, rather than checking for errors in their energy calculations.

This response scored 2 marks for MP1 and MP2.

12 Machines make work easier by changing the size or direction of a force. A student designed a simple machine to lift a box of mass 50 kg. The student claimed the efficiency of the machine was greater than 90%.

The machine used a slope of height 2.0 m and length 15 m to move the box. The box was connected to an 8.0 kg mass by a rope over a pulley as shown. As the 8.0 kg mass fell, the box moved up the slope at a steady speed.



Determine whether the maximum efficiency of the machine was greater than 90%.

(4)

E=8x9.81 x 2 = 157 J sinθ = 2m/15m

E= 50 x 9.81 x sinθ x 15 m

= 50 x 9.81 x 2/15 x 15

= 981 J 100% x 157 J / 981 J = 16%.

50x9.81 x 2 m = 981 J

Not greater than 90%.

ResultsPlus
Examiner Comments

The candidate has identified that $\sin\theta = 2/15$, scoring MP1.

The candidate has also used $E_{grav} = mgh$ for the 8kg mass correctly, scoring MP2.

The work done on the 50kg mass has not been calculated correctly as the distance moved along the ramp is 2m and not 15m therefore an incorrect vertical height has been calculated.

No credit could be given for use of the efficiency equation as they have used work done by the 8kg mass divided by their work done on the 50kg mass, ie have used input energy / output energy which is effectively the wrong equation for efficiency.

ResultsPlus
Examiner Tip

Invest the time to understand the context of the question. If the 8kg mass can only move down by 2m then the 50kg mass would only be able to move 2m along the slope, and not 15m.

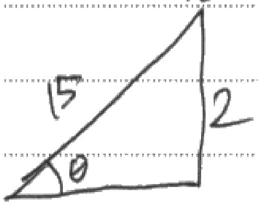
A well set out response scoring all 4 marks.

Input = $mg\Delta h$ Output = $F \times \Delta s$

$= 8g \times 2$ $= 50g\sin 7.66° \times 2$

$= 16g$ J $= 130.76$ J

$= 156.96$ J



Max. Efficiency = $\frac{130.76}{156.96} \times 100\%$

$= 83\%$, so it is less than 90%

$\theta = \sin^{-1}\left(\frac{2}{15}\right) = 7.66°$

![ResultsPlus Examiner Comments]

ResultsPlus
Examiner Comments

The component of the weight of the 50kg mass acting down the ramp, 50*g*sin7.66 has been used in the gravitational potential energy equation to determine the work done on the 50kg mass (output energy).

The work done on the 50kg mass (output) energy has then been divided by the work done by the 8kg mass (input) to calculate a correct value for the efficiency.

ResultsPlus
Examiner Tip

When using the efficiency equation always make it very clear as to which calculated energy or power is the input and which is the output.

Use a triangle when using trigonometry to determine an angle. It helps to prevent the wrong trig function from being selected.

A very common response scoring 2 marks, MP2 and MP3.

mgh = 50×9.81×2 = 981 J

ΔW = Force × distance travelled = 8×9.81×15 = 1177.2

∴ Efficiency = $\frac{\text{useful energy output}}{\text{total input energy}}$ ×100 ~~output energy~~

= $\frac{981}{1177.2}$ ×100

= 83.3%

∴ The maximum efficiency was less than 90%.

ResultsPlus
Examiner Comments

Had the 8kg mass been able to fall through a height of 15m, the 50kg mass would have been raised by a vertical height of 2m. However, the question referred to the machine in the diagram, and values had to be used for this machine. Therefore only interim marks could be awarded, even though the correct efficiency was determined.

The work done on the 50kg mass was awarded MP2 for use of the gravitational potential energy equation but the wrong vertical height was used. The work done by the 8kg mass also used an incorrect distance for this context, as a height of 15m was used.

The candidate did go on to use the efficiency equation the right way up and could be credited with MP3.

No MP4 could be awarded as the (albeit correct) value was obtained using an incorrect method.

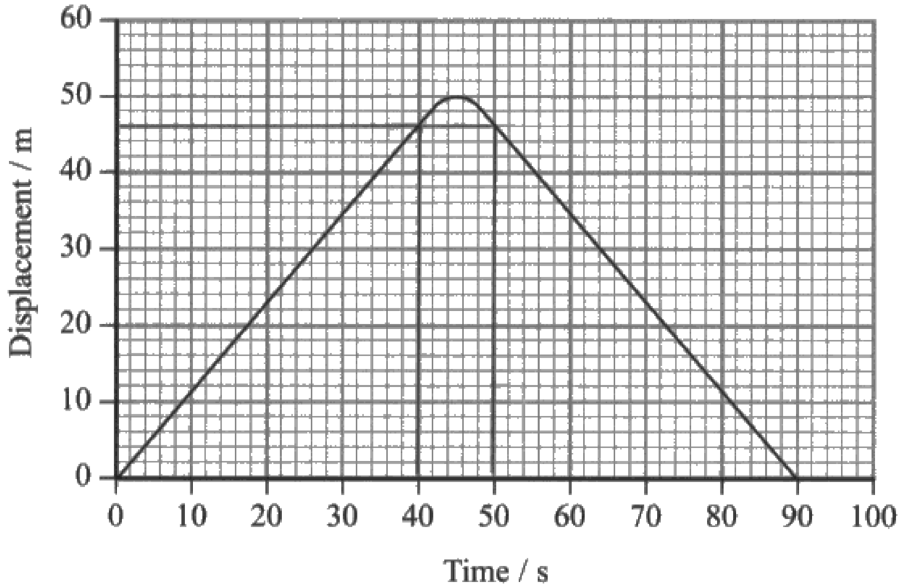
Question 13 (a)

Most candidates were able to extract information and use the gradient or points from the given displacement-time graph to determine at least 1 value, in range, of the velocity of the swimmer. Many were able to calculate the velocity out and in but some mistakenly gave a different value for the return velocity.

Marks tended to be dropped at the graph drawing stage, usually due to the scaling of the axes. It was expected that any graph drawn would cover at least 50% of the axes. Therefore a 1cm to 1m s^{-1} scale would have prevented MP3 from being scored, as would no scaling at all, and just placing +1.1 and -1.1 at the appropriate places be it 2cm or 2.1cm up from the origin was not deemed sufficient for a scale. A proper scale needed to be marked on the velocity axis, the minimum required was a 1, –1, at 2cm above and below the origin. Most candidates remembered to end their graph at 90s, in line with the corresponding displacement-time graph above and could draw some type of connecting line or curve between the positive and negative velocities from 42 to 48s, enabling MP4 to be awarded.

A good response scoring all 4 marks.

13 A swimmer swims a 100 m race. A simplified displacement-time graph for the swimmer is shown.

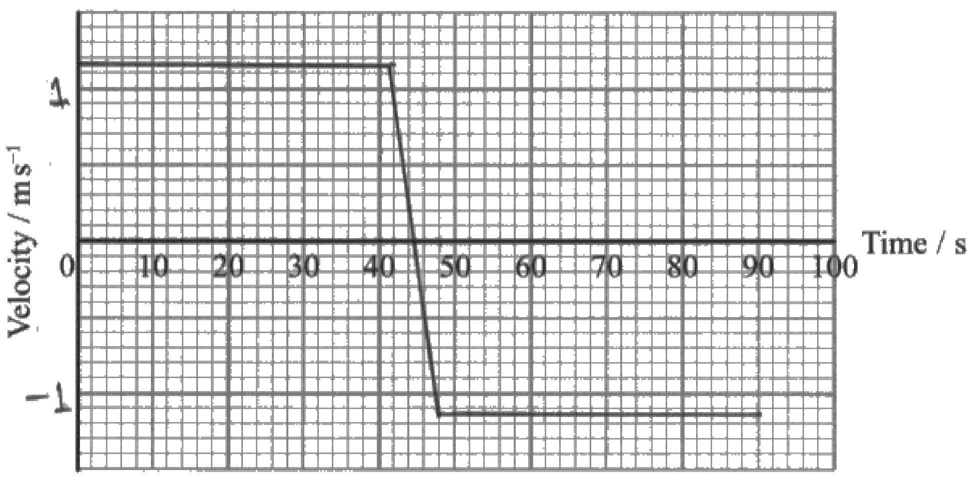


(a) Draw a corresponding velocity-time graph for the motion of the swimmer on the axes below. Show all working in the space below.

(4)

velocity (0 - 40) s = gradient = $\frac{46 - 0}{40 - 0}$ = 1.15 ms^{-1}

velocity (50 - 90 s) = $\frac{46 - 0}{90 - 50}$ = 1.15 ms^{-1}



ResultsPlus
Examiner Comments

MP1 and MP2 awarded for a correct value for velocity, in range.

MP3 awarded as a correct scale has been marked onto the velocity axis. The velocity of 1.15 has been drawn correctly, with a horizontal line between 0 and 42s and 48 and 90s with a connecting line between these two values, thus scoring MP4.

ResultsPlus
Examiner Tip

Remember to take note of any maximum and minimum values when translating information from one graph to another.

This response scored 3 marks: MPs 1, 2 and 3.

(a) Draw a corresponding velocity-time graph for the motion of the swimmer on the axes below. Show all working in the space below.

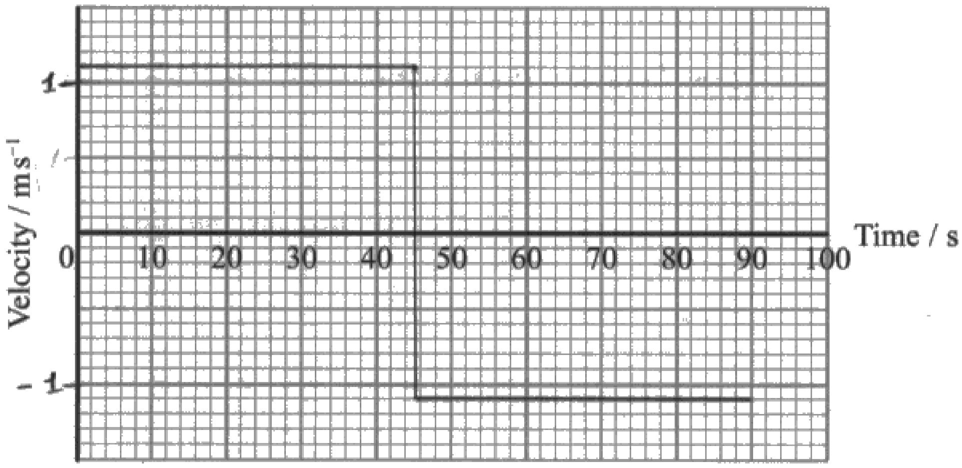
(4)

First half ~~displacement~~ velocity = $\frac{50}{45}$

$= 1.1 \text{ ms}^{-1}$

Second half velocity = $\frac{-50}{45}$

$= -1.1 \text{ ms}^{-1}$



ResultsPlus
Examiner Comments

Although the graph has been correctly scaled and a value for the velocity of the swimmer has been calculated in range, the graph has not been correctly drawn, preventing MP4 from being awarded.

The horizontal line extends to 45s and then continues, with a negative velocity from 45s rather than allowing time for the change in direction of the swimmer.

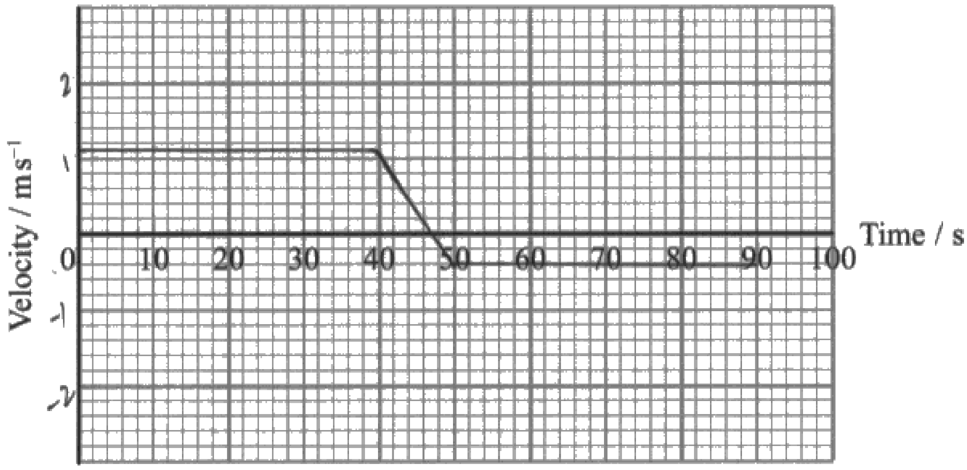
MP1 and MP2 only scored here.

(a) Draw a corresponding velocity-time graph for the motion of the swimmer on the axes below. Show all working in the space below.

(4)

$v_1 = \frac{30-0}{26}$ $\quad$ $V_2 = \frac{0-26}{64-0}$

$= 1.15$ m/s $\quad$ $= -0.4$



ResultsPlus Examiner Comments

One calculated velocity is in range so MP1 and MP2 awarded.

The scale used on the graph is too small so no MP3.

Although the graph has been drawn correctly using both calculated values, as the second velocity calculated was not in range, this is penalised here as the second line should be at the same magnitude velocity as the initial velocity line. No MP4 could be awarded.

ResultsPlus Examiner Tip

The gradient of a displacement-time graph is the velocity. If a displacement-time graph is symmetrical, then the velocities will have the same magnitude, just, as in this case, one will be negative.

Question 13 (b) (i)

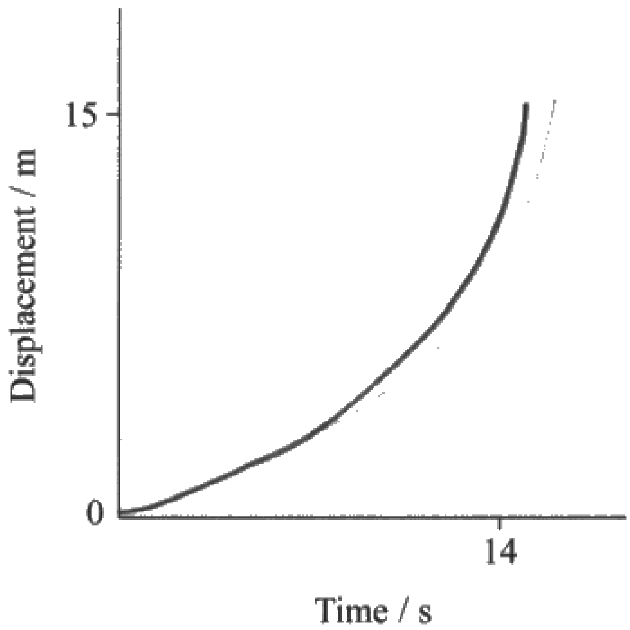
During a glide only frictional forces act on the swimmer, as the arms and legs are not used to provide a forwards force. The velocity of the swimmer will decrease from the start due to the resultant force, opposite to the direction of motion. It was expected that a graph with a decreasing gradient, from the origin, would be drawn.

For this response, 1 mark was awarded for an initial curve. No second mark as the gradient increases and does not decrease.

(b) To increase her initial speed, the swimmer began the race by gliding underwater for 15 m and then began to use her arms and legs. This was not represented on the simplified displacement-time graph.

(i) Sketch onto the axes below to show the actual variation of displacement with time for the first 15 m of the race.

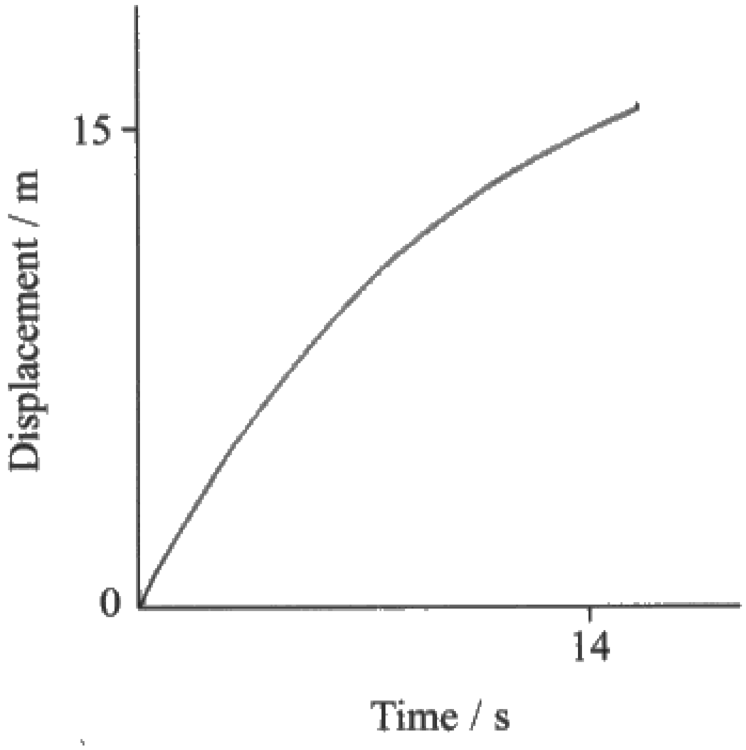
(2)



ResultsPlus
Examiner Comments

The speed of the swimmer would decrease, due to frictional forces if the swimmer does not apply any additional forces during the glide. Therefore the graph would have a decreasing gradient as they would be slowing down.

Both marks scored.



ResultsPlus
Examiner Comments

The graph has a decreasing gradient from 0 seconds demonstrating the decreasing velocity of the swimmer.

Question 13 (b) (ii)

Q13b(i) involved one limitation for the simplified displacement-time graph. Q13b(ii) required the identification and explanation of a second simplification that had been used to produce the graph given at the beginning of Q13. 1 mark was awarded most frequently for noting that the simplified graph showed velocity as constant. Few explained that this wasn't correct because of, for instance, variations of velocity during each stroke or the force varied within the stroke, or that the swimmer moved above and below the water or that the speed would change going from gliding to swimming.

Both marks were awarded to this response.

(ii) Explain one other way in which the motion of the swimmer has been simplified when drawing the displacement-time graph.

(2)

The ~~[illegible]~~ displacement - time graph shows the swimmers average speed and doesn't show if the swimmer does some parts faster than others. When the swimmer uses ~~the~~ their arms and legs each pull or kick will change their speed – it will not be constant.

(Total for Question 13 = 8 marks)

ResultsPlus
Examiner Comments

MP1 for identifying that the average rather than instantaneous speed was plotted. MP2 was given for a suitable corresponding explanation as to why this was not representative of the speed of the swimmer, with a clear explanation that the speed will change during a stroke due to the use of the arms and legs providing a force on the water.

ResultsPlus
Examiner Tip

Explain as a command term here requires a statement of a simplification followed by an explanation.

MP1 only for a simplification.

the velocity was not constant yet, in the Displacement time graph it was shown to be constant. Total distance in the graph ~~or di~~ is not 100m.

ResultsPlus
Examiner Comments

The explanation that the distance is not 100m is not correct so this response just scored 1 mark for identifying that the velocity is not constant.

Question 14 (a) (i)

This question required a straightforward use of equations of motion or equating the gravitational potential energy to the kinetic energy of the firework to determine the vertical launch velocity of the firework.

Those who did not fully consider the directions and assumed that the initial velocity was 0 and g was positive were not able to score MP2 and could only access MP1 for use of the correct equations of motion.

Use of $v^2 = u^2 + 2as$ was the most common method used. This question was answered well and the vast majority of candidates that attained an E grade or above on this paper scored both marks.

1 mark only scored here.

14 A firework is launched into the air and explodes once it reaches a maximum height.

	V	1H
S	350	
U	= 6	
V		
a	= 9.81	0
t		

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

$v^2 = u^2 + 2as$

$v = u + at$

(a) The firework is designed to explode at a maximum height of 350 m.

(i) Show that the vertical component of the velocity at launch is about 80 m s^{-1}.

(2)

$v^2 = u^2 + 2as$

$v^2 = 0^2 + 2 \times -9.81 \times 350$

$v^2 = 6867$

$v = 82.867 \text{ ms}^{-1}$ $\quad v = 82.9 \text{ ms}^{-1}$ (3sf) $\approx 80 \text{ ms}^{-1}$

ResultsPlus
Examiner Comments

An initial velocity of 0 has been used here and the final velocity has been determined. The direction of g and s are not consistent as, if the candidate was working out the equivalent velocity after falling through the same vertical displacement then a and s should have the same direction. Here, according to their calculation, they would have had to square root a negative number.

ResultsPlus
Examiner Tip

Think carefully about the directions of all substituted values. Make sure that *g* has an opposite direction to any quantities in the upwards direction.

A good response scoring both marks.

s 350 m

u u

v = 0

a = -9.81

t

$v^2 = u^2 + 2as$

$0 = u^2 + 2(-9.81)(350)$

$\sqrt{u^2} = \sqrt{6867}$

$u = 82.9\ ms^{-1}$

$= 83\ ms^{-1}$

ResultsPlus
Examiner Comments

$v = 0$ was used and a negative value of g (and positive value of s) used leading to a correctly obtained correct answer of 82.9m s^{-1} .

Question 14 (a) (ii)

This question required the candidates to draw a graph of the initial velocity against the launch angle up to the maximum height of 350m. The initial velocity calculated in part (a)(i) was for the example where the firework is fired straight up into the air with only vertical motion, ie with a launch angle (to the horizontal) of 90°. As the angle to the horizontal decreased, to reach the maximum height of 350m, a greater initial speed was required. Therefore, what was considered to be the most straightforward mark, MP1 was for a graph with a negative gradient.

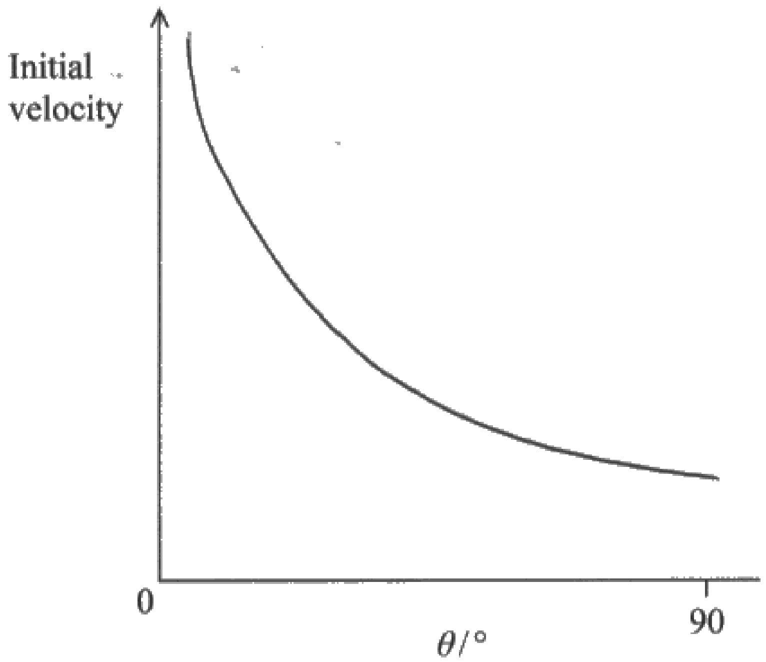
The reasoning behind this question did stretch some with many lacking a quantitative appreciation of how the angle varied with velocity, and so failed to obtain the first, second and fourth marking points. The curve was frequently drawn convex instead of concave or even as a straight line. Candidates rarely gained the third marking point and teachers should remind their students that any key values should be labelled on sketch graphs.

This response scored 3 marks. MP1, MP2 and MP4 were awarded.

(ii) The vertical component of the velocity at launch depends on both the initial velocity of the firework and θ, the angle between the initial velocity and the horizontal.

Sketch a graph showing how the initial velocity required for the firework to reach the maximum height of 350 m varies with θ for the firework.

(4)



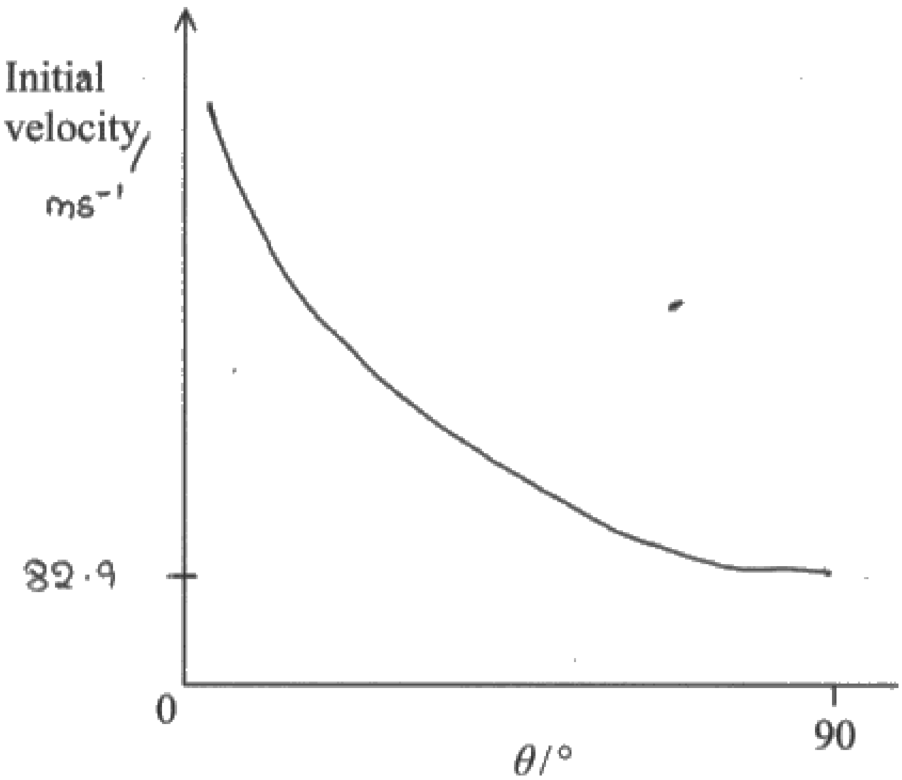
ResultsPlus
Examiner Comments

Q14(a)(i) and (a)(ii) were both part of Q14(a), hence it was expected that candidates should know that part (ii) would lead on from part (i) and any values used in part (i) may be needed in part (ii). Therefore the value of the minimum vertical velocity should have been plotted on the graph. Part (i) was given as a 'show that' question so that candidates would have a value to plot in part (ii).

ResultsPlus
Examiner Tip

If you are asked to sketch a graph, remember to add to the axes any information that you may have been given or determined yourself earlier in the question.

This response scored all 4 marks.



ResultsPlus
Examiner Comments

Those candidates that realised that the graph would be a concave curve, more often than not, used the initial velocity axis as an asymptote, enabling them to score MP4.

ResultsPlus
Examiner Tip

Even if you are not entirely sure how to sketch a graph, it is always sensible to try to plot any values that you have, including the maximum and minimum values as this will usually give you the correct shape and relationship.

Question 14 (b)

This question asked the candidates to explain how the time taken for the sound to reach the student and the angle between the top and the bottom of the firework could be used to determine the diameter of the firework. Many realised that speed × time was required to calculate the distance to the firework but some responses referred to the speed of light or the speed of the firework rather than the speed of sound.

Few managed to successfully identify that trigonometry could be used with this calculated distance and an opposite angle of $\varphi/2$ to determine the radius, and hence the diameter of the firework. Many used an incorrect trig function, used an arc length or referred to φ and not $\varphi/2$. For MP2, a description of how to determine the radius was accepted as not all candidates remembered to multiply this distance by 2 to obtain the diameter.

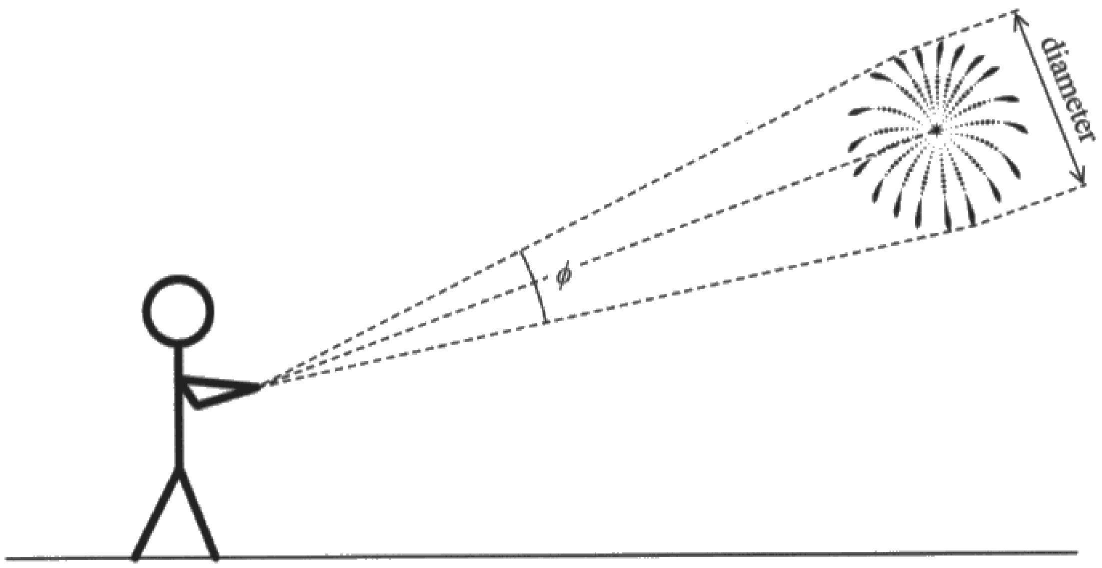
Generally, many candidates had a good idea of how to calculate the diameter but their explanations lacked the required detail. This was not one of the more challenging questions on the paper, but required the 2 minutes that the 2 marks suggested to reach a creative solution to what was more of a problem solving question rather than one that required an application of their knowledge.

This response scored both marks.

(b) A student wanted to estimate the maximum diameter of the firework after exploding.

The student estimated:

- the time taken between seeing the firework explode and hearing the firework explode
- the angle ϕ from the top to the bottom of the firework



Describe how the student could determine the maximum diameter of the exploded firework using the estimated data.

(2)

~~thing~~ When seeing the explosion, that's true to when it happened, measuring time from then to when the sound is heard gives distance ($s = ut + \frac{1}{2}at^2$) u = speed of sound and $a = 0$ so speed of sound × time = distance then $s \times \tan\left(\frac{\phi}{2}\right) = o$

s = distance, o = half the diameter so $2s\tan\left(\frac{\phi}{2}\right)$ = diameter

ResultsPlus
Examiner Comments

The candidate has suggested the distance (*s*) will be the speed of sound × time and then $2s\tan(\varphi/2)$ = diameter.

The statement in the penultimate line is a little ambiguous as they appear to have the radius, $s \times \tan(\varphi/2)$ equal to 0, but this has been explained in the final line so both marks could be awarded.

ResultsPlus
Examiner Tip

This is a good response that clearly defines any values used. So, when a value to be used could be one of a few values that are relevant to the question, state what it represents.

This response scored 1 mark for MP2.

(2)

Distance from student to firework is calculated using ~~vertical component~~ initial velocity of velocity and the time interval ~~as~~ as $d = vt$.

Then ~~used~~ using $\tan \frac{\phi}{2} = \frac{r}{d}$, radius is calculated.

Finally diameter is calculated using $d = 2r$.

ResultsPlus
Examiner Comments

This candidate has referred to the initial velocity of the firework rather than the speed of sound. Otherwise, this is a clear explanation which scored MP2 for the explanation of how to use the calculated distance and φ/2 to determine the radius and diameter.

This response scored just 1 mark for MP1.

The student can find the distance to the firework using distance = speed of sound in air × time difference between seeing and hearing. Then the student can construct a right angle triangle and use $\sin\left(\frac{\theta}{2}\right) = \frac{\text{distance}}{\text{radius}}$, and multiply the radius by 2 to get the diameter.

ResultsPlus
Examiner Comments

The distance to the firework has been correctly described but they have used the incorrect trig function of sine rather than tan when determining the radius. Otherwise this was a good, clear description.

ResultsPlus
Examiner Tip

When deciding which trig function to select it could be a good idea to draw a small triangle at the side of any given diagram and add the values known, making sure that you identify the right angle in the triangle so that the correct trig function can be selected.

Question 15 (a)

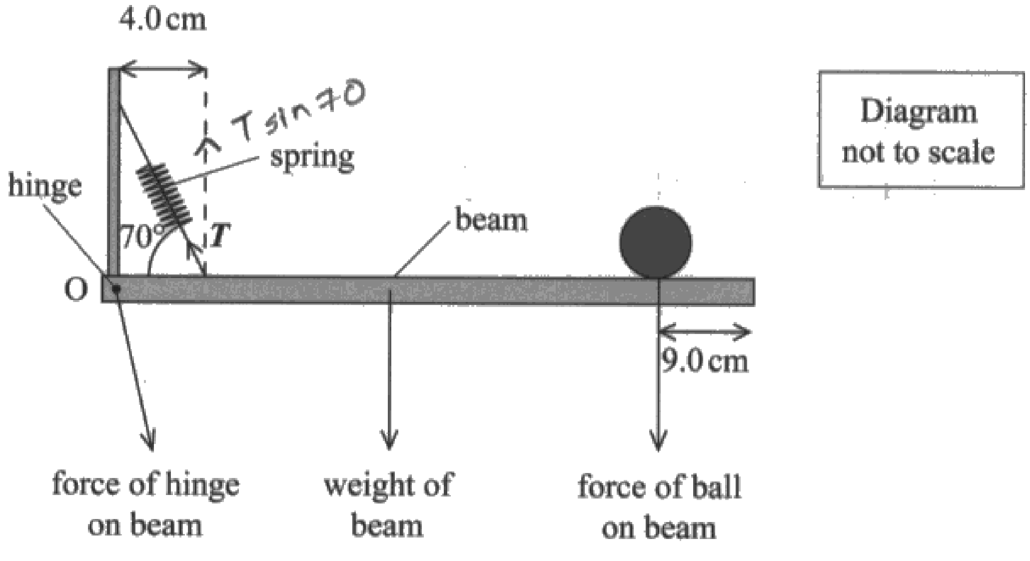
Candidates were expected to estimate the length of their forearm before attempting the required moments calculation. The diagram at the beginning of the question should have clued those who were not familiar with this term as to which region of the arm the question was referring to. A large range of 30-50cm was provided but some used the length of the entire arm, with some responses quoting about 60cm while others, who did not appreciate the area concerned, quoted some very small lengths of less than 10cm. However, those with a length out of range could, and usually did, score MPs 3, 4 and 5 for the correct use of trigonomentry, use of the moments equation and correct use of the principle of moments.

The use of the moments equation and application of the principle of moments was generally answered far more successfully than in previous exam series, with a large proportion of candidates successfully using trigonometry to determine the vertical component of the tension. Due to many approaching the calculation using just one line of working, a number of responses did contain arithmetic errors and candidates should try to spend the time double checking their calculations, particularly where multiple steps are combined.

Some candidates left the estimate line blank, referring to a letter in place of the length in their subsequent equations. Unless it was clear that the letter referred to was the length of the forearm, then no credit could be given. Therefore candidates should make sure that they complete all parts of the question, in this case even just replacing an estimate with a letter so that it is defined.

This was a good response scoring all 5 marks. This calculation was very clearly set out with a length in the middle of the accepted range of 40cm.

A student modelled the forces on the forearm using a uniform beam and spring arrangement as shown below. The length and weight of the beam were the same as the length and weight of the forearm.



(a) It can be assumed that the biceps muscle acts as a spring at an angle of 70° to the beam, 4.0 cm from the pivot O.

Determine the magnitude of T. You will need to estimate the total length of the forearm and hand.

force of ball on beam = 4.5 N
weight of beam = 15 N

(5)

Estimate of total length of forearm and hand = 40.0 cm

Taking moment about point O

anticlockwise moment = clockwise moments

$(T\sin 70 \times \frac{4}{100}) = (15 \times \frac{20}{100}) + (4.5 \times \frac{31}{100})$

$T\sin 70 \times 0.04 = 3 + 1.395$

$T\sin 70 = 109.875$

$T =$ ~~~~ ~~~~ 116.9 N

$T =$ 117 N

ResultsPlus
Examiner Comments

The candidate has clearly set out the clockwise and the anti-clockwise moments, using their value for the length of the forearm of 40cm. They have converted all lengths to metres but this was not necessary as long as the units for each moment were consistent with each other.

ResultsPlus
Examiner Tip

Show all stages in the working out, explaining in words if necessary what each equation represents, eg clockwise moments and anti-clockwise moments.

This response scored 3 marks: MPs 3, 4, and 5.

Estimate of total length of forearm and hand = ~~24.7 cm and~~ 29 cm.

1.1 cm → 4 cm. => ~~6.8~~ 8 cm → ~~24.7~~ 29 cm (Length of forearm and hand).

~~Taking~~ Taking moments at pivot.

$T \sin 70 \times 0.04 = 15 \times 0.145 + 4.5 \times 0.20$

$\Rightarrow T = \dfrac{2.175 + 0.9}{0.04 \sin 70^{\circ}}$

$\Rightarrow T = 81.8\ \text{N}$

$T =$ 81.8 N.

ResultsPlus
Examiner Comments

Unfortunately the estimate of the length of the forearm was slightly below the range, so MP1 and MP5 could not be awarded. However this candidate, using clearly set out working, demonstrated that they could use the principle of moments accurately scoring all of the method marks.

ResultsPlus
Examiner Tip

Practice making sensible estimates. In this question, the length required was from the elbow to the fingertips so make sure you are aware of exactly the region you should be estimating.

This response scored 2 marks. This was for MP3 and MP4.

Estimate of total length of forearm and hand = ~~10~~ 23 cm

Taking O as a pivot, (↓ +ve)

$4.5 \times \frac{(23-9)}{100} + \cancel{45}15 \times \frac{11.5}{100} = T\cos 70 \times \frac{4}{100}$

$\Rightarrow 2.355 = T\cos 70 \times \cancel{\frac{4}{100}}\ 0.04$

$\Rightarrow T = 172.1\text{N}$

$\therefore T = 172\text{N}$

$T =$ 172 N

ResultsPlus
Examiner Comments

The estimation of the length of the forearm is too small and out of range. However, this candidate has correctly used this length in the moment equation and has attempted to use the principle of moments. The horizontal, not the vertical, component of the tension has been determined, hence MP2 and MP5 could not be awarded. However, they have the correct length of 4cm for the tension so this could be credited for use of the principle of moments, scoring MP4 as well.

ResultsPlus
Examiner Tip

Don't guess which trig function to select when resolving forces. If necessary, draw a triangle, with the correct angle to help you select the correct unit.

Question 15 (b)

The main assumption when completing the calculation in part (a) was that the beam is uniform, so therefore the weight acts in the centre of the beam. It was expected that this would be applied to the arm when discussing the limitations of the beam and spring as a model for the arm. Therefore, the arm is not uniform and so the centre of gravity would not act through the centre. Some good explanations were seen but many compared the different materials of the beam and arm or the use of a spring to model the muscle in the arm.

In the majority of questions a converse argument, ie using the converse of the marking points, can be used to explain an answer. However in this question, just stating that the beam is uniform, as stated in the question, was not sufficient for implying that the arm is not uniform.

This response scored 0.

(b) Explain a limitation of using a beam to model the forearm.

(2)

The weight of the beam acts on half the length of it as it is a uniform beam. therefore it is estimated that the weight of the forearm acts on the ~~midd~~ half the length of it despite its irregularity.

ResultsPlus
Examiner Comments

'Half the length' has been repeatedly referred to and this candidate may have meant 'in the centre', however, this was unclear. Therefore MP2 could not be awarded. They have stated that the beam is uniform but did not state that the arm is not uniform and this has not been implied sufficiently to award MP1.

This response scored 1 mark, MP1.

Forearm is not a uniform body.
and forearm also contains muscles, which the beam cannot model it completely.

ResultsPlus
Examiner Comments

The candidate has correctly identified that the forearm isn't uniform. Just stating that it has muscles alone is not enough to imply this.

This response scored both marks.

The actual forearm may not be uniform and there will be more than one muscle to within weight.
The centre of gravity of forearm may not be in the centre.
so the weight may not act in the middle.

ResultsPlus
Examiner Comments

A clear explanation identifying that the arm is not uniform and so the centre of gravity is not in the centre and so the weight would not act through the centre.

ResultsPlus
Examiner Tip

When modelling a complex object, a variety of 'compromises' or simplifications will have to be made. When comparing the model to the object, only consider the simplifications that directly affect any measurements that will be taken.

Question 16 (a)

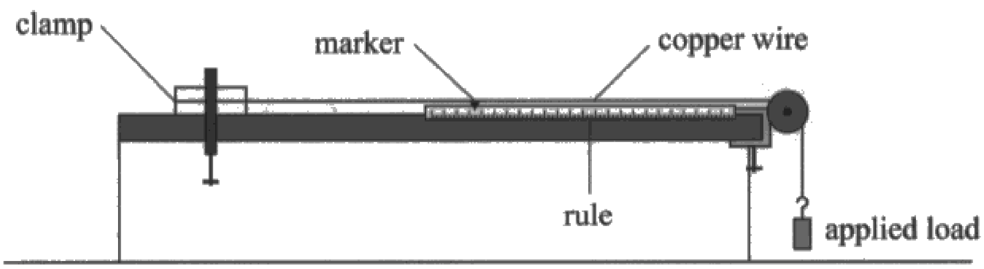
Question 16 involved a very familiar context, the core practical to determine the Young modulus of a material.

When core practicals are examined on papers WPH11 and WPH12, the assessment objective covered will usually be AO1, ie knowledge and understanding. Any application of these practicals will be examined in WPH13. Therefore, this question really only examines recall and basic understanding of the techniques involved.

Q16(a) was answered extremely well with the vast majority of responses scoring all 3 marks and just the odd response dropping a mark, usually due to forgetting to mention that the repeated measurements should be taken at different places or orientations. Most candidates referred to a micrometer rather than a digital caliper and most referred to measuring at different places rather than different orientations.

All 3 marks awarded.

16 A student carried out an experiment to determine the Young modulus of copper. She used the apparatus below to observe the position of a marker as a copper wire extended under increasing applied loads.



(a) Describe how the diameter of the wire should have been determined.

(3)

Diameter of the wire should be measured using micrometer screw gauge which has a precision of 0.01 mm. ~~Diameter should b~~ The wire may not be uniform so the diameter should be measured at different orientation and find mean.

ResultsPlus
Examiner Comments

This candidate has included references to a micrometer (screw gauge), measurements at different orientations and calculating a mean so all 3 marks awarded.

MP1 only awarded.

We need a micrometer screw gauge to determine the diameter

ResultsPlus
Examiner Comments

Only reference has been made to the measuring device and not about the technique used so no further marks could be awarded.

ResultsPlus
Examiner Tip

Use the number of marks as a guide to the minimum number of points to make.

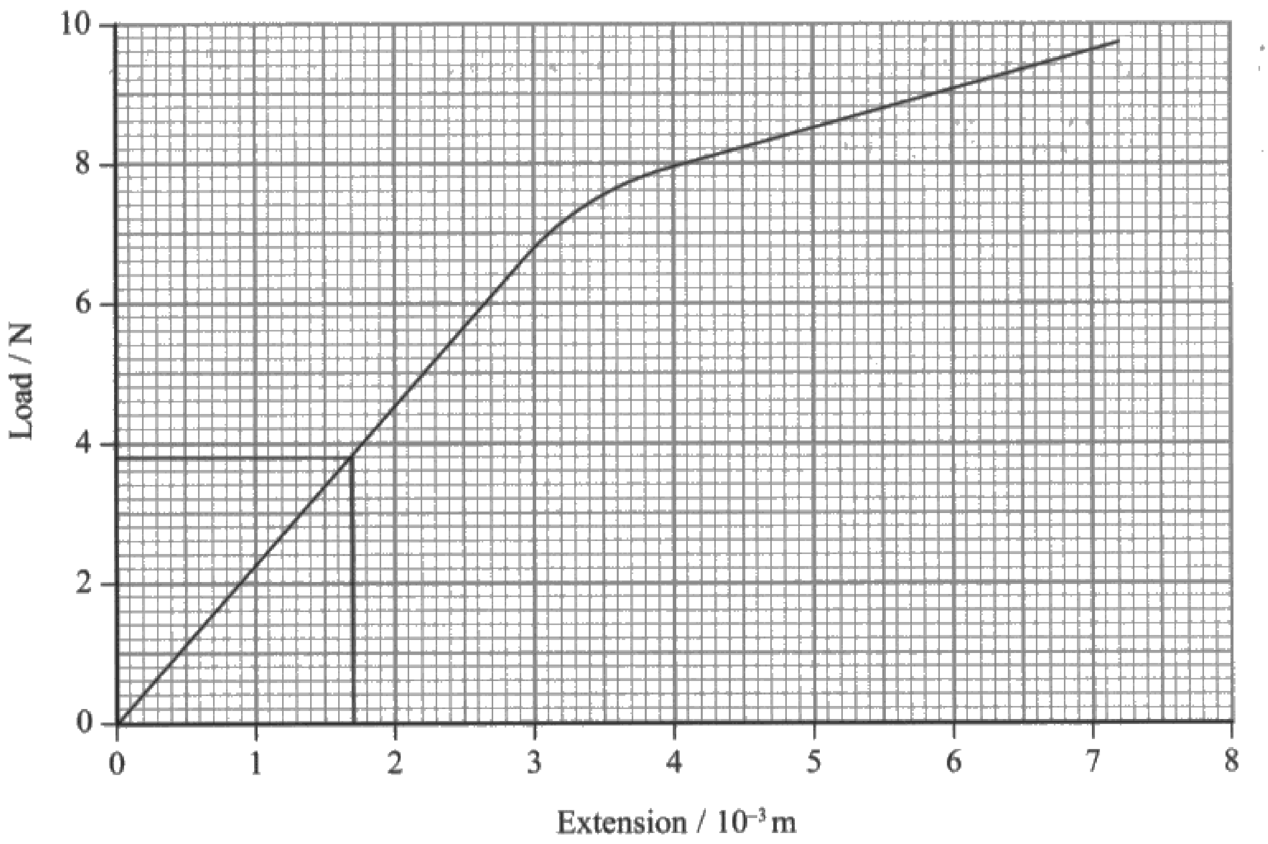
Question 16 (b)

This was a standard question where it was expected that candidates would use the gradient or a pair of points from the linear region of the graph to determine a value for the Young modulus of the wire. Whereas most candidates used values from the linear region of the graph and used the equations correctly, most errors were due to a missing unit or due to a power of 10 error, omitting the 10^{-3} from the extension axis when reading from the graph.

This was answered extremely well with most candidates of middle ability or higher scoring all 4 marks. However, most that attained an E or above on the paper still managed to score 3 marks, usually dropping the final mark as discussed above.

This response scored all 4 marks.

(b) The student calculated the extension of the copper wire for each applied load. She then plotted a graph of load against extension.



Determine a value for the Young modulus of copper.

original length of copper wire = 2.4 m
diameter of copper wire = 2.3×10^{-4} m

(4)

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

$= \frac{3.8}{\frac{\pi (2.3 \times 10^{-4})^2}{4}}$

$= 91.5 \times 10^6$ Pa

$\epsilon = \frac{e}{l}$

$= \frac{1.7 \times 10^{-3}}{2.4}$

$= 7.08 \times 10^{-4}$

$\therefore E = \frac{\sigma}{\epsilon}$

$= \frac{91.5 \times 10^6}{7.08 \times 10^{-4}}$

$= 1.29 \times 10^{11}$ Pa

Young modulus of copper = 1.29×10^{11} Pa

ResultsPlus
Examiner Comments

A corresponding force and extension of 3.8N and 1.7 x 10^{-3} m have been used from midway through the linear region. The candidate has sensibly calculated the stress and strain separately and then combined them using the Young modulus equation to give an answer, in range, with a unit.

ResultsPlus
Examiner Tip

Although many candidates try to learn a combined equation of E =Fx/AΔx for the Young modulus, it can be safer to complete the interim stages and calculate separate values for the stress and strain first. In addition to this, those that try to complete the calculation in one step often trip up when rearranging a fraction divided by a fraction ie E = F/A ÷ x/Δx. Therefore, it is better to spend the time setting out each step clearly.

This response did not score any marks.

young modulus = $\frac{\text{Stress } \sigma}{\text{Strain } \varepsilon}$

$= \frac{0.546}{9.583 \times 10^{-5}}$

$= 5697.6$

Total Force = 9.7N

Area = 17.76

Young modulus of copper = 5697.6

ResultsPlus
Examiner Comments

This response has been included in this report as an example of why all working should be shown so that interim steps can be credited.

No working out shown for the area so no credit could be given for any work to reach the incorrect area of 17.76. 9.7N is clearly beyond the end of the linear range so no MP2.

As there is no working out showing how the candidate reached their values for stress and strain, this step and MP3 could not be awarded either.

ResultsPlus
Examiner Tip

Show your working. Use of marks can be awarded, even if arithmetic errors have been made, possily even at each interim stage!

This response scored 2 marks.

$$\text{gradient} = \frac{7.2}{3.3}$$

$$E = \frac{7.2}{3.3} \times \frac{2.4}{\pi \times \left(\frac{2.3 \times 10^{-4}}{2}\right)^2}$$

$$= 1.26 \times 10^{8}$$

Young modulus of copper = 1.26×10^{8} Pa

ResultsPlus
Examiner Comments

The Young modulus of a material is a ratio of the stress to the strain in the region where stress is proportional to the strain ie the linear part of the graph. Although ths is a force-extension graph and not one of stress and strain, the relationship still only holds in the linear region.

This candidate has selected to use a corresponding force and extension (7.2N and 3.3 (x10^{-3} m) from just beyond the linear region so MP2 could not be awarded.

MP1 for the area and MP3 for use of the stress and strain equations could still be credited and no MP4 as this is conditional on MPs 1, 2, 3. The candidate also forgot to include the 10^{-3} when reading the extension from the graph.

ResultsPlus
Examiner Tip

Take note of any unit prefixes or additional powers of 10 when reading values from the graph.

Use a ruler to accurately determine the end of a linear region on a graph; do not do this by eye alone.

Question 16 (c)

This is possibly the first time many of the candidates will have attempted an indicative content question. These are typically 6 mark questions intended to assess a candidate's ability to show a coherent and logically structured answer with linkage and fully sustained reasoning. For this 6 mark question, a maximum of 4 Physics marks were available from a total of 6 indicative content (IC) points and a potential 2 linkage marks depending on the IC points awarded and how they have been linked together. This question replaces the QWC items which typically added up to a total of 8 marks on the legacy specification.

This question should have been based on a familiar context to candidates and it is hoped that they would have come across the advantages of selecting a long and thin wire to use in this experiment.

Many candidates were able to state that such a wire would have a greater extension (IC1 and IC3) with some suggesting that less load would be needed (to produce the same extension) which was IC6. However, if percentage uncertainties were considered at all, it was often unclear as to which measurement they were referring to, or uncertainties, without reference to the percentage uncertainties were discussed. Candidates should always be clear in stating whether they are describing the absolute or percentage uncertainty. It was rare to see candidates using mathematical descriptions such as proportional or inversely proportional and so IC points 2 and 4 were awarded the least.

Some candidates unsuccessfully tried to approach the question by discussing stress and strain but clearly did not understand that this really needed to be done separately in terms of a longer or a thinner wire. Many did not realise that the Young modulus of the wire could not change and only the stress and strain changing would be responsible for the greater extension.

For a longer wire, the stress would be constant. Therefore to obtain the same strain (and hence Young modulus), the extension would have to be greater. Hence extension is proportional to the original length (as every other quantity involved is constant).

For a thinner wire, the cross-sectional area would be smaller. This would result in a greater stress. For the Young modulus to remain constant, the strain would need to be larger and hence the extension would have to be greater.

Therefore, those that just quoted any formulae without stating which values are constant or mentioning proportional or inversely proportional did not explain IC2 and IC4 sufficiently.

As mentioned above, some confusion was apparent about the significance of the Young modulus. It should be made clear in any teaching that the Young modulus applies to a material (and is independent of its dimensions) and the stiffness constant applies to the object, ie a spring or a sample of wire.

This response scored 1 mark.

*(c) Explain why the sample of wire used in this experiment should be long and thin.

(6)

The sample of the wire should be thin in order to measure its diameter precisely. This reduces uncertainity and hence is less likely to give anomalous value. It should be long beause this produces a larger extension which helps to give a more accurate strain value. Moreover it is also easier to be pulled through the pulley without causing any type of disturbane.

ResultsPlus
Examiner Comments

IC1 for a longer wire, greater extension in lines 3-4.

The candidate has mentioned that the uncertainty is reduced but should have referred specifically to the percentage uncertainty as the absolute uncertainty would be the same.

This candidate has not made any reference to the reduced diameter of the wire, as requested in the command sentence of the question.

1 x IC point = 1 mark (no linkage).

ResultsPlus
Examiner Tip

Make sure that you make it clear as to whether you are referring to the absolute uncertainty or the percentage uncertainty.

This was an excellent response which scored 5 marks.

According to the formula; $\Delta length = \frac{Force \times length}{Area \times Young's\ Modulus}$.

As length is directly proportional to extension longer the wire greater the extension. As Area is inversely proportional to extension, thus thinner the wire greater the extension. As extension range increases, it is easier to determine. Plus, percentage error decreases as value is greater.

ResultsPlus
Examiner Comments

IC1 - greater extension in line 3.

IC2 - length directly proportional to extension in line 2.

IC3 - for the thinner the wire, the greater the extension in lines 5-6.

IC4 - area inversely proportional to extension in lines 4-5.

IC5 - percentage error decreases in the penultimate line. They have implied this is for the extension above.

5 x IC points = 3 marks.

2 x linkage marks.

Total = 5 marks.

This is a response that is typical of those that scored 3 marks.

• If the wire is long, then the percentage uncertainty for length is reduced. • Also, for a longer wire, when the same strain is ~~produced~~ shown by the wire, the extension is larger, because $\varepsilon = \frac{x}{L}$ • so the percentage uncertainty for extension is also reduced.
• If the wire is thin, then it means that it has a small cross-sectional area. • So for the same ~~stress~~ force, the stress will increase, since $\sigma = \frac{F}{A}$, and the percentage uncertainty for stress decreases. • With a smaller cross-sectional area, the extension also increases for the same force, because the spring constant is lower (~~k =~~ $E = k \times \frac{L}{A}$) ($k = \frac{EA}{L}$), so percentage uncertainty for extension is reduced.

ResultsPlus
Examiner Comments

IC1 for extension is larger (line 3).

IC5 for percentage uncertainty for length is reduced (lines 1-2).

IC3 for extension also increases in line 9.

The candidate has identified that a thinner wire will have a greater stress but has not linked this to the strain and hence extension, so no IC4.

3 x IC = 2 marks.

1 linkage mark as this response has 3 IC points including 1 & 5 or 3 & 5.

Total = 2 + 1 = 3 marks.

Question 17 (a) (i)

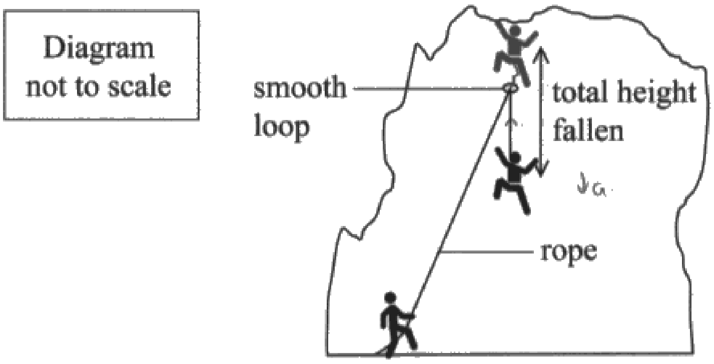
This was a high mark, multiple stage calculation. Due to 4 of the 5 marks being 'use of' marks, the vast majority of candidates of E grade ability or above scored at least 2 marks. Only the best realised that two heights had to be considered for the fall, ie the 'fall' and the height due to the extension of the rope, and went on to score full marks.

The majority of candidates could use the equation for the fall factor and obtain a height fallen of 12m. Likewise, many could use the strain to determine the extension of the rope of 1.35m. Most could go on to use the equation for the gravitational potential energy, usually with 12m and then some equated this to the equation for the elastic potential energy.

This meant that even better candidates often scored only 4 marks, as they then equated their gravitational potential energy for 12m (not 12m +1.35m) to elastic potential energy stored. As mentioned above, few candidates realised that there would be the additional height fallen due to the extension of the rope under the weight of the climber so only a small number reached the final answer of 13 800 N.

A typical response from a strong candidate scoring 4 marks.

17 The diagram shows a climber on a rock face. A rope is kept firmly anchored by a person on the ground and passes through a smooth loop to the climber. The climber slips and falls a short distance as shown.



(a) The 'fall factor' is used by climbers to estimate the severity of a climbing fall and is given by

$$\text{'fall factor'} = \frac{\text{height fallen before the rope begins to stretch}}{\text{total unstretched length of rope}}$$

A climber slips and falls with a 'fall factor' of 0.80 before coming to rest.
The energy from the fall is absorbed by the climbing rope.
The maximum strain in the rope is 9.0%.

(i) Show that the maximum force acting on the climber due to the rope is about 10 kN. Assume the extension of the rope is proportional to its tension.

total unstretched length of rope = 15.0 m
mass of climber = 71 kg

(5)

fall factor $= 0.80 = \frac{S_1}{15}$

$\therefore S_1 = 12\text{m}.$

Strain $= 0.09 = \frac{\Delta x}{x} = \frac{\Delta x}{15}$

$\Delta x = 1.35 \text{ m}.$

$E_{grav} = mg\Delta h$
$= 71 \times 9.81 \times 12$
$= 8358.12 \text{ J}.$

$E_{el} = \frac{1}{2} F\Delta x$
$8358.12 = \frac{1}{2} \times F \times 1.35$
$F = 12382.4 \text{ N}.$

ResultsPlus
Examiner Comments

The height fallen of 12m and the extension of 1.35m have both been calculated correctly. The candidate then calculated E_{grav} for just the fall (and not the extension) and equated this to the elastic potential energy scoring MPs 1, 2, 3, and 4.

A rare but outstanding response, scoring all 5 marks.

Energy absorbed by rope: $\frac{1}{2}FD$ $\quad 0.8 = \frac{x}{15} \quad 15 \times 0.8 = 12$

$0.09 = \frac{\Delta x}{15}$

$0.09 \times 15 = 1.35$

total ΔPE ~~12 × 9.81 × 71 = 8358.12 J~~

~~work done = F × D~~ $\Delta PE = (12 + 1.35) \times 9.81 \times 71$

$= 9298.408$

~~8358.12 = F × 1.35~~ ~~8358.12 / 1.35 = F = 6191.2 N~~

~~9298.408 = F × 1.35~~

~~F = 9298.408 / 1.35 = 6887.7 N~~ $\quad 9298 = \frac{1}{2}F \times 1.35$

$\frac{9298 \times 2}{1.35} = F$

$F = 13774\ N$

ResultsPlus
Examiner Comments

Once the height and the extension had been calculated, this candidate added them to determine the total height fallen of 13.35m. This was then used to determine the total E_{grav} transferred to $E_{elastic}$ and equated to the equation for $E_{elastic}$. Hence the correct force acting on the climber of 13 770N was determined.

ResultsPlus
Examiner Tip

Spend time so that the context of the question is fully understood. Remember to consider all of the stages involved in the motion of an object. Once this has been realised, the physics involved should be fairly straightforward.

A weaker response scoring 2 marks.

$\text{strain} = \frac{\Delta x}{x}$ $\quad\quad$ $0.80 = \frac{h}{15}$

$\Delta x = \frac{9}{100} \times 15 = 1.35 \text{ m}$ $\quad\quad$ $h = 15 \times 0.80 = 12 \text{ m}$

ResultsPlus
Examiner Comments

This standard of response was towards the lower end of those who passed this exam and this candidate did not know what to do once they had used the given fall factor equation and the strain equation.

Question 17 (a) (ii)

Those who had not fully grasped the context of this question struggled to make a relevant and sensible comment on the climber's suggestion. For those who did not make a comment on the velocity or the force, a mark was awarded to those who commented on a greater distance or time falling. The majority of those who managed to score commented that the height fallen or the time would be greater. Few identified that the force acting on the climber would be greater and more often than not, this was part of a list of factors that may or may not change as a result of using a longer rope.

Had a longer rope been used, due to the additional height fallen, the kinetic energy and hence velocity of the the climber would be greater on the full extension of the rope. Hence the deceleration would have to be greater and a greater force would act on the climber.

(ii) A new climber suggests using a longer length of rope between the loop and the climber, as this would absorb more energy after a fall.

Comment on this suggestion.

(2)

- Using a longer length of wire would increase the hieght fallen by the climber.
- Gaining the energy lost would be difficult.
- Suggestion is not very satisfactory.

ResultsPlus
Examiner Comments

This response scored 1 mark for a greater height fallen.

This is a rare but excellent response that scored both marks.

It would absorb more energy after he fell, but the person falling could be going much faster and recieve a greater force of the rope which would be very big and could be harmful.

ResultsPlus
Examiner Comments

This candidate has understood that more energy would have to be absorbed as the climber would be going faster and therefore there would be a greater force of the rope (on the climber).

ResultsPlus
Examiner Tip

In such a context, the energy transfers should be considered. This would help you to appreciate the stages involved had a longer rope been used.

Question 17 (b)

This was a very open ended question and 8 marking points were available for the 6 marks of the question. It was pleasing to see so many candidates discuss more than one idea from the energy, stiffness and breaking stress and although only the best scored 5 or 6 marks here, this was accessible to most with many scoring 3 marks or more. The graphs given for this question enabled the quantitative aspects of the answer to be in terms of the energy stored by the rope or its stiffness. Good candidates referred to the stiffness, the energy stored and the breaking stress of each rope in their comparisons between the old and the new rope.

Probably the easiest way to reach higher marks with this question was to use the area under the graph and link this to the energy stored, MPs1-4. MPs 5-7 were available to those who also referred to the stiffness of the rope. However, MP7 for a comparison of the stiffness of both ropes was difficult to attain due to many not appreciating that the comparison needed to be made at the same force and units had to be included.

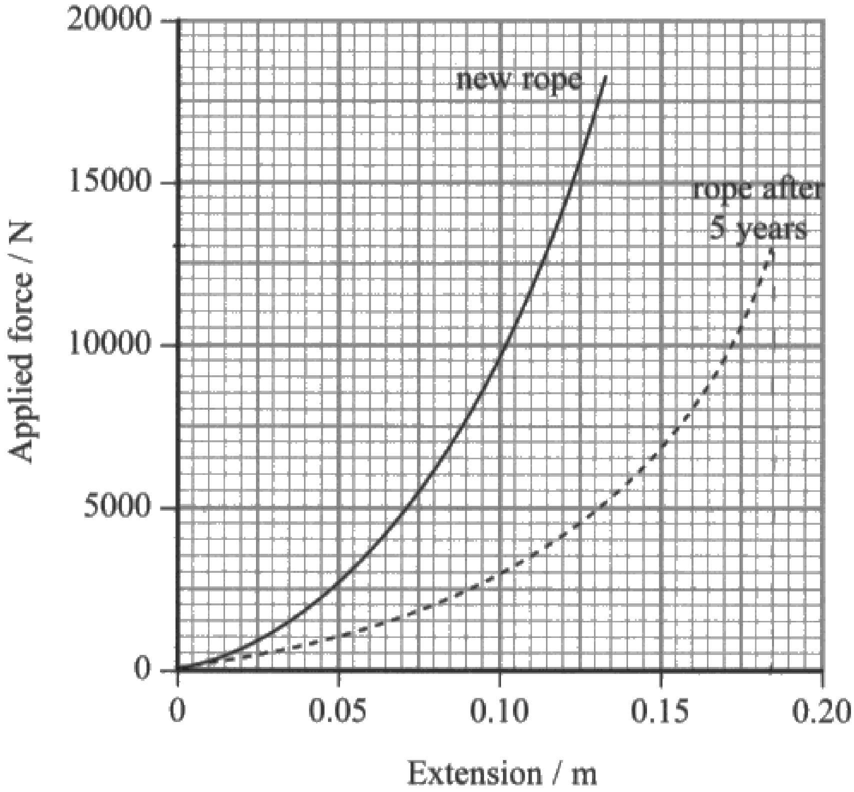
Of those that attempted to determine the energy stored in each rope, few answers were in range, many just approximating the curve to a triangle and obtaining an answer that was much higher than the actual value. However, MP1 could still be scored for the use of the area under the graph. As always, those who counted squares were more successful, with many managing to calculate at least one energy in range. Even without a calculation, it could be seen that the area under the graph for the newer rope was greater so MP4 was quite frequently awarded for a statement referring to the energy stored in the newer rope compared to the older rope. Some candidates were not awarded MP4 if they just referred to the energy in the rope; it had to be a clear understanding that this would be the energy stored by or absorbed by the rope.

For the stiffness of the rope, an instantaneous value of the force/extension was accepted or the gradient of a tangent at a specific force, most commonly the maximum force. Although, by definition, the stiffness is force divided by the extension in the linear region of the graph (based upon Kooke's law) as the material in the question is a rope and not a metal, the rope was essentially changing properties as the applied force increased, hence the force/extension was accepted as a means of determining a relative value for the stiffness.

The most common mark to award was that the newer rope breaks at a greater force. Answers in terms of strength were not accepted as an explanation relating to the graph was required and a statement about the strength was not considered to be a sufficient explanation.

This response scored 2 marks.

(b) Climbing rope manufacturers recommend that ropes are replaced every 5 years.
The force-extension graphs, up to the breaking point, for a one metre length of a rope when new and after 5 years are shown.



Comment on the manufacturers' recommendation. Your answer should include calculations.
(6)

energy absorbed ~~for~~ in new ~~rope~~ rope = $\frac{1}{2} \times 16500 \times 1.325$
= 10931.25 J
= 10900 J

energy absorbed in rope after 5 years = $\frac{1}{2} \times 10600 \times 0.185$
= 980.5 J
= 981 J

The ropes should be ~~rephe~~ replaced in less than 5 years as very less energy is absorbed by the rope after ~~&~~ 5 years. New rope absorbs 10900 J, however, ropes after 5 years only absorb 981 J which is very less and can ~~be~~ be dangerous to use.

ResultsPlus
Examiner Comments

This candidate has approximated the area under each curve to a triangle and obtained areas that are out of range. They did however score MP1 for use of the area under the graph and MP4 for the idea that the older rope absorbs less energy.

No further discussion of the stiffness or the breaking force was given so just two marks for MP1 and MP4.

ResultsPlus
Examiner Tip

If a precise value is needed for the area under the graph then the area should either be obtained by counting squares or by approximating the area to a series of shapes and the area of each shape found.

This response scored 4 marks.

Energy stored in new rope = area under graph
∴ area of one square = 62.5
∴ area of 12.5 boxes = 781.25
∴ energy stored = 780 J

Energy stored in rope after 5 years = 62.5 × 11
= 690 J

~~Energy stored in new rope will be greater~~
Energy stored by the rope after 5 years decreases and the rope is less stiff and has a lower tensile stress compared to the new rope. Hence it is advisable to replace the rope every 5 years.

ResultsPlus
Examiner Comments

The candidate has used a more accurate method to determine the area, counting squares. A value that, to 1 sf, rounds to 700J was obtained for the area under the graph for the older rope and a value that rounds to 1 sf to 800J, was obtained for the newer rope. Thus scoring MPs 1, 2, and 3.

The correct conclusion that the older rope stores less energy, MP4 was awarded and the candidate also identified that the stiffness decreases with age (MP7).

ResultsPlus
Examiner Tip

When referring to the strength of a material, it is the stress at fracture rather than just the stress.

This was an excellent, succinct response, scoring 6 marks. As mentioned in the introduction, candidates were more successful when using energy calculations than stiffness calculations enabling them to pick up MPs 1-4.

~~After 1 years~~, Work done by new rope = 319 squares × 500 × 5×10^{-3} = 800 J.

Work done by old rope = 272 squares × 500 × 5×10^{-3} = 680 J.

Young modulus for new rope is greater.

~~It~~ New rope can absorb more energy.

It has greater breaking stress.

New rope is stronger.

It has smaller extension under same load.

So it is less likely for new rope to break.

ResultsPlus
Examiner Comments

MPs 1, 2, and 3 awarded for accurately counting squares to give the energies, in range, with units.

MP4 for a conclusion linking the energy stored to the rope (line 4).

MP7 for smaller extension under same load, ie stiffer. They have implied that they are talking about the new rope.

MP8 for greater breaking stress, again they have implied for the new rope.

References to stronger were not sufficient alone for MP8.

Question 18 (a) (i)

Question 18(a)(i) should have been very familiar to candidates as questions using the context of an object falling through a fluid were examined many times on the previous specification. Hence it was answered very well with nearly 75% of candidates that attained an E grade or above typically scoring all 4 marks. Most other candidates tended to just drop 1 mark for an inaccurate diagram or omitting to mention that it is a constant or maximum velocity.

Many candidates were able to gain the first 3 marking points as they could describe the forces in equilibrium, draw a labelled diagram showing the force directions and state that the velocity was constant. However, candidates should improve their accuracy in drawing free-body diagrams to a scale. They should be taught:

- to always use a ruler
- all lines should be vertical
- the base of all arrowed lines should touch the dot
- measure lengths used properly - if the object is moving at a constant velocity then the total of the upward arrow lengths should equal the downward arrow length for the weight
- ignore any forces that the question specifically refers to as negligible.

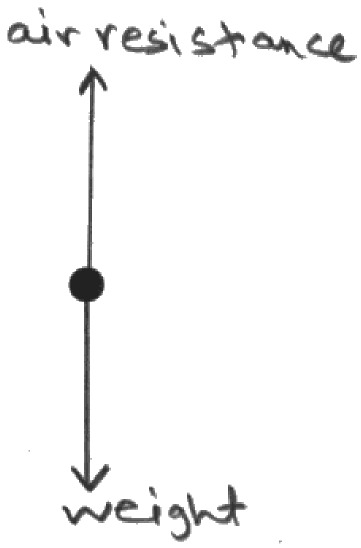
This response scored all 4 marks,

18 When water vapour in the atmosphere cools it condenses, forming tiny drops of water. These drops increase in size by colliding with each other and fall back to the ground as rain.

(a) As a raindrop falls through the air it eventually reaches its terminal velocity. The upthrust on the raindrop can be considered to be negligible.

(i) Explain what is meant by the terminal velocity of the raindrop. Your answer should include a free-body force diagram for the raindrop when terminal velocity has been reached.

(4)



Ans = As the velocity of the raindrop increases, air resistance also increases. ~~So unti~~ So acceleration decreases. Then air resistance becomes equal to weight of the raindrop and resultant force becomes zero, so no acceleration and raindrop reaches a constant velocity which is terminal velocity.

ResultsPlus
Examiner Comments

The arrowed lines have the correct labels and directions (MP3) and are just about the same length, so MP4 could be awarded.

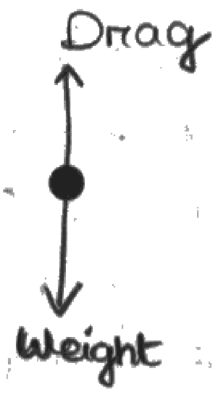
An explanation of the entire motion of the raindrop was not necessary but obviously many just repeated the standard answer. The candidate did identify that at the terminal velocity, the resultant force becomes zero and the raindrop reaches a constant velocity, scoring MP1 and MP2.

ResultsPlus
Examiner Tip

Read the question. The more detail included that is not necessarily required, the more opportunities there are to contradict yourself and introduce errors.

In the question only an explanation at, and not leading up to, the terminal velocity was required.

This response scored 3 marks.



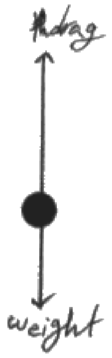
~~Therom~~ Terminal velocity is the velocity of the raindrop when all the resultant force acting on it ~~and all the resu beomes~~ becomes zero.

ResultsPlus
Examiner Comments

Both marks were awarded for the diagram. The weight arrow was just about considered to be close enough in length to the drag arrow. A ruler should have been used to draw and measure these lines.

MP2 has been awarded but again, the candidate has not explained what is meant by terminal velocity, ie a maximum or constant velocity, so no MP1.

This response scored 2 marks.



As the rain drop falls down due to the weight acting on it, it gains velocity however as velocity increases the drag force also increases thus at one point weight = drag and it reaches terminal velocity.

ResultsPlus
Examiner Comments

According to the lengths of the arrows, this object is either decelerating or moving upwards, hence MP4 could not be awarded for correct arrow lengths.

The explanation does not explain that the velocity is constant or maximum at the terminal velocity, hence MP1 could not be awarded either.

ResultsPlus
Examiner Tip

The relative arrow lengths must be correct in relation to the motion of the object when drawing a free-body force diagram.

Question 18 (a) (ii)

Q18(a)(ii) was the last of the long calculations on the paper. Candidates found this challenging for the wrong reasons in that they knew which equations to use to determine the weight of the raindrop and then mostly knew to equate the weight of the raindrop to the given equation for the air resistance. However, many candidates lost marks as they were unable to calculate the area of a circle, ie the cross-sectional area of the raindrop and the volume of the raindrop correctly, skills they would have used many times before.

It was not uncommon to see answers using the equation for the surface area of a sphere ($4\pi r^2$) in place of the cross-sectional area and other mistakes made included halving the radius (assuming that the question had given the diameter and not the radius) and forgetting to square or cube the radius as appropriate. The most common error when calculating the weight was to forget to multiply the mass by *g*. Some incorrectly used Stoke's equation for air resistance instead of the given equation.

Candidates were quite often awarded the second and third marks as they could use the equations to attempt to calculate the weight and equate it to the expression for air resistance. However, for a variety of small mathematical errors, the final mark was not awarded much. Candidates should be encouraged to check their calculations carefully and show all working clearly.

This response scored 3 marks.

(ii) The air resistance F acting on a raindrop travelling at a velocity v, can be determined using the expression

$$F = 0.45\rho A v^2$$

where A is the cross-sectional area of the raindrop and ρ is the density of the air.

Calculate the terminal velocity of a spherical raindrop of radius 2.0×10^{-3} m.

density of air = $1.2\,\text{kg}\,\text{m}^{-3}$
density of rainwater = $1.0 \times 10^{3}\,\text{kg}\,\text{m}^{-3}$

(4)

$F = 0.45 \rho A v^2$

$v^2 = \dfrac{3.29 \times 10^{-4}}{0.45 \times 1.2 \times \pi \times (2\times10^{-3})^2}$

$v = 0.129\ \text{ms}^{-1}$

$F = ma$

$m = \text{density} \times \text{Volume}$

$= 1.0 \times 10^{3} \times \frac{4}{3}\pi (2 \times 10^{-3})^3$

$= 3.35 \times 10^{-5}$ kg

$F = 3.35 \times 10^{-5} \times 9.81$

$= 3.29 \times 10^{-4}$ N

Terminal velocity = $0.129\ \text{m s}^{-1}$

ResultsPlus
Examiner Comments

The volume, mass and hence weight have all been calculated correctly. The weight was then equated to the air resistance equation and rearranged in one step which is something to be avoided. Therefore MPs 1, 2 and 3 could be awarded.

Then, in the process of calculating the final answer, an arithmetic error must have been made as the final answer quoted is incorrect.

ResultsPlus
Examiner Tip

Always show your working out so interim method marks, 3 in this case, can be awarded.

This response scored 1 mark.

$m = \rho \times V$ **(4)**

~~We~~ $W = mg$

$= \rho \times V \times g$

$= 1.0 \times 10^3 \times 4/3 \times \pi \times (2.0 \times 10^{-3})^3 \times 9.81$

$= 3.29 \times 10^{-4}$ kg

Weight = F

$\Rightarrow 3.29 \times 10^{-4} = 0.45 \times 1.2 \times 4\pi (2.0 \times 10^{-3}) \times v^2$

$\Rightarrow v = \sqrt{\dfrac{3.29 \times 10^{-4}}{0.45 \times 1.2 \times 4\pi (2.0 \times 10^{-3})}}$

$\Rightarrow v = 0.156$

$\Rightarrow v \approx 0.16$ m/s

Terminal velocity = 0.16 m/s

ResultsPlus
Examiner Comments

MP2 was awarded for use of $\rho = m/V$ and $W = mg$.

To score MP1, both the volume and cross-sectional area equations had to be correctly used. This candidate has used the equation for the surface area of a sphere rather than the cross-sectional area of a sphere so MP1 could not be awarded. In addition to this they did not square the radius when using the equation.

As the candidate has used the correct equation for F incorrectly and has not made it clear earlier on in their response that they think $4\pi r$ represents the area, credit was not given for use of $W = F$ as they have effectively not used the equation for F correctly.

ResultsPlus
Examiner Tip

Again, show all interim steps and try not to substitute everything into an equation in one step.

This last example scored all 4 marks.

$$v^2 = \frac{F}{0.45\rho A}$$

$$\Rightarrow v^2 = \frac{mg}{0.45\rho A}$$

$$\Rightarrow v^2 = \frac{1\times10^3 \times \frac{4}{3}\pi(2\times10^{-3})^3 \times 9.81}{0.45(1.2)(\pi(2\times10^{-3})^2)}$$

$$\Rightarrow v^2 = 48.44$$

$$\therefore v = 6.96\ ms^{-1}$$

Terminal velocity = $6.96\ ms^{-1}$

ResultsPlus
Examiner Comments

Not to be encouraged but the substitution into the combined equations for *W* = *F* was made in one step. This candidate however has used the correct equations for the volume of the sphere, the cross-sectional area of the raindrop, the mass and the weight correctly giving an answer in range with units.

Question 18 (b) (i)

Question 18(b)(i) examined specification point 7: 'understand how to make use of the independence of vertical and horizontal motion of a projectile moving freely under gravity'. This question required candidates to realise that the drops followed a projectile trajectory so that the vertical displacement increased while the horizontal displacement was constant. Few managed to consider both aspects of the motion with sufficient accuracy to score both marks, even if the motion was known (and sometimes even stated above the diagram). More often than not, if the motion in one direction was drawn with sufficient accuracy, the other direction was neglected. Therefore, for those that scored on this question, it was far more common to award 1 and not 2 marks.

It was more common for candidates to draw the increasing displacement between the vertical drops although this was often accompanied with a decreasing horizontal displacement between the drops.

Questions that require candidates to demonstrate their knowledge and understanding by sketching of graphs and completing diagrams are often more demanding than those that examine the same specification points and skills in written form, even if on first glance the question appears to be quite straightforward. The level of accuracy required does not allow for the ambiguity that written responses permit. Therefore, it is essential that candidates are given the opportunity to practice these skills wherever opportunity arises during the delivery of the course.

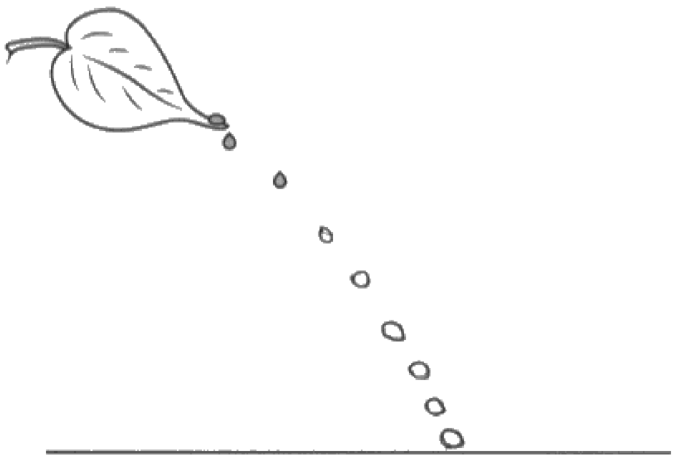
A very typical response that scored 0 marks.

(b) Some plants have adapted to high rainfall by having a specialised shape and waxy leaves. This allows rain to slide down a leaf and off the end as a series of drops.

(i) A drop of water slides off a leaf as shown.

Add to the diagram to show the position of the drop at regular intervals of time. The first two positions have been drawn for you.

(2)



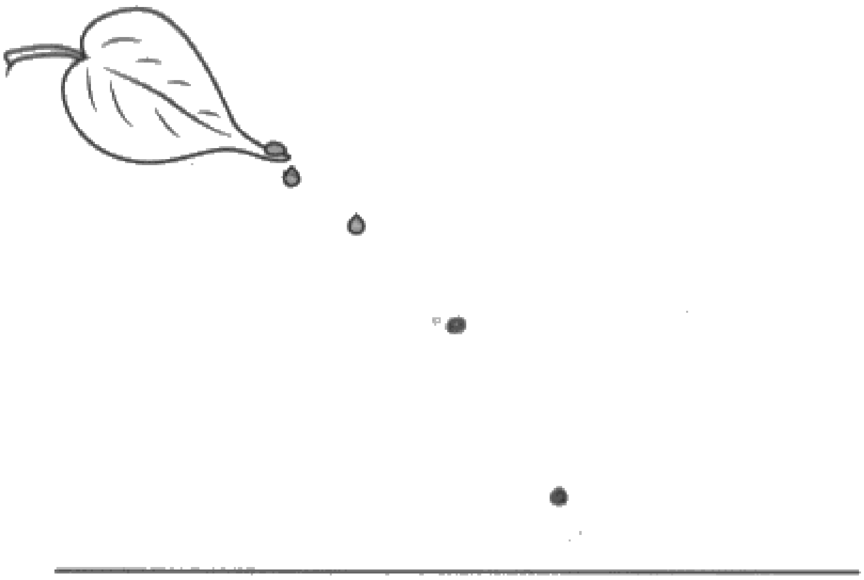
ResultsPlus
Examiner Comments

The candidate has a curved trajectory but it can be seen that both the horizontal and vertical displacements are decreasing.

ResultsPlus
Examiner Tip

In such questions, without the help of graph paper or a printed grid, it may be helpful to mark out a very basic grid on which to sketch the positions.

This response scored 1 mark.



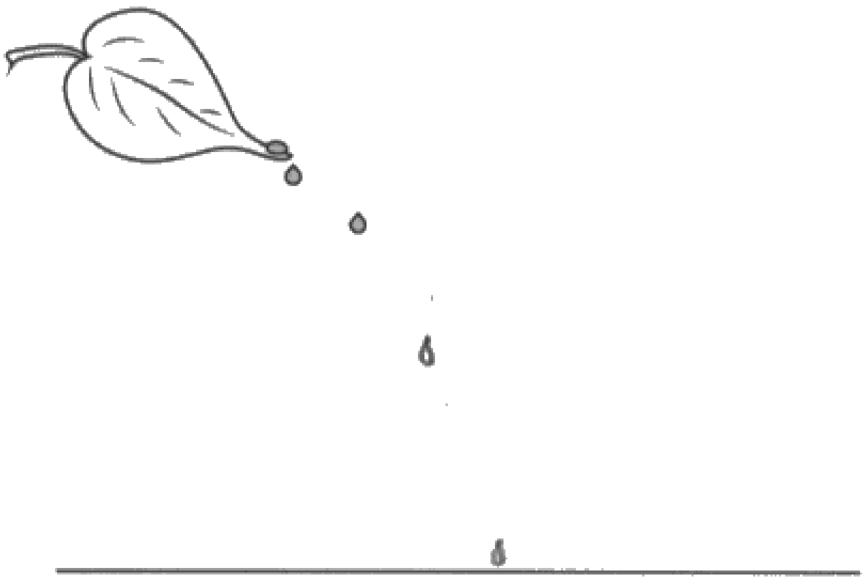
ResultsPlus
Examiner Comments

By eye, you can see clearly that the vertical displacement between each drop is increasing. In comparison to the displacement between the first two printed drops, the horizontal displacement is increasing so no MP2.

ResultsPlus
Examiner Tip

Please remember that when falling solely under gravity, the horizontal velocity of an object is constant and the object accelerates vertically.

This response scored both marks.



ResultsPlus
Examiner Comments

With such large distance between drops 2 and 3, there was only space to draw 2 additional drops. The candidates did not have to work out the relative spacing vertically so as long as the displacement increased, MP1 could be awarded.

It was quite tricky to gauge by eye, but with a ruler it can be seen that the horizontal displacement remained constant, scoring MP2.

Question 18 (b) (ii)

While most candidates appreciated that the equation $s = ut + ½at^2$ was required, with $u = 0$, few could select the appropriate time taken for the drop to reach the ground. As has been seen in previous exam questions (on legacy specifications), using ticker tape or frame rates, extracting the time of an event from the dot/frame rate can be challenging for candidates.

Hence only the best candidates scored both marks with most that attained an E or above being awarded MP1 for use of the above equation of motion using a time of 0.2s, 0.25s, 0.75s, 1s or the correct time of 0.38s. 1s and 0.2s were the most common incorrect times used.

With a drop rate of 5 per second, the time between drops was 0.2s. With 4 drops above the lowest drop, there are 4 time periods or 4 x 0.2s = 0.8s.

This response scored all 3 marks.

(ii) Water falls from a leaf at a steady rate of five drops per second.

As each drop reaches the ground, there are four drops above it in the air.

Calculate the height of the leaf from the ground. It can be assumed that the drop at the highest position has just left the leaf.

(3)

$time = \frac{1}{5} = 0.2 secs$

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

$= 0 + \frac{1}{2} \times 9.81 \times (0.2 \times 4)^2$

~~= 0.1962m~~ = 3.14 m

~~= 0.20m~~

Height of leaf = ~~0.20m~~ 3.14m

ResultsPlus
Examiner Comments

The candidate has identified that the time between drops is 0.2s and multiplied this by 4 to get the time taken for the first drop to reach the ground. They have used this in the correct equation of motion to reach the correct answer of 3.14m.

ResultsPlus
Examiner Tip

When given an event rate, try to identify the time between events and look at the number of events (distances between drops) in order to work out the total time.

This response scored 1 mark.

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

$s = 0.5 \cdot 9.81\,m/s^2\; 0.2^2\,s$

$s = 0.19\ m$

Height of leaf = 0.19 m

ResultsPlus
Examiner Comments

The correct equation of motion with *u* = 0 has been used but with an incorrect time of 0.2s. Just MP1 awarded.

Paper Summary

This paper provided candidates with a wide range of contexts from which their knowledge and understanding of the physics contained within this unit could be tested.

A greater understanding of the context and question being asked would have helped many candidates. A sound knowledge of the subject was evident for many, but the responses seen did not reflect this as the specific question was not always answered as intended.

Based on their performance on this paper, some candidates could benefit from more teaching time and extra practice on the following concepts and skills:

- Make sure that the core practicals are covered thoroughly; there are usually recall questions asking for details of these practicals.
- Practise using equations to determine the area of a circle and the volume of a sphere and extend this practice to correct use of the density equation and for upthrust calculations.
- Practise longer explanations paying particular attention to the structure and making sure that the points mentioned link together wherever possible.
- Invest time when a large amount of information is presented in a question; read the question so that the context is fully understood before answering the question.
- Make sure that all working out is shown in higher mark calculations so that credit for interim working can be given if arithmetic or power of ten errors are made.

Grade Boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link:

http://www.edexcel.com/iwantto/Pages/grade-boundaries.aspx

Pearson Education Limited. Registered company number 872828
with its registered office at 80 Strand, London WC2R 0RL.