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Examiners' Report
June 2014

GCE Physics 6PH01 01

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Introduction

This unit is designed to test the candidates' physics ability in the areas of mechanics and properties of matter. It tests their knowledge of physics, for instance asking for definitions of terms in question 12 and expecting them to know Newton's laws in question 15; it tests their understanding, in realising what the straight diagonal lines in question 16 indicate about the motion of a falling object; and it tests the ability of the candidates to apply the physics they know to applications which may or may not be familiar, such as the bouncing ball of question 16 (familiar) and the movement of solid carbon dioxide on water (unfamiliar).

The level of attainment on this paper demonstrated the ability of candidates to respond to questions set in an approximately real situation (like the bouncing ball) rather than in the abstract (e.g. "a body falls to the ground") is important. It was good to see that, on the whole, the candidates were very well able to apply the physics they had learnt to such contexts.

The marks obtained showed that the paper discriminated well. Less able candidates had sufficient material to demonstrate the understanding they had, while there were many opportunities for others to show their ability in the subject. The inability to express themselves clearly and concisely, as in the Newton's laws of question 15(a) or the force graphs of question 19(c), may have held back some candidates who otherwise probably fully understood the physics involved. It was surprising how many made errors in a simple mathematical requirement, such as the volume of the balloon in question 11(a), many using d^2 rather than d^3, or giving the volume of a cylinder. As is usual, many marks were lost due to missing units, with the N of question 19(a) being a particular problem. The candidates really need to understand that a value without a unit is not a correct physics quantity.

It is important that the candidates read the questions carefully so that they answer the question that is actually being asked. For instance, in question 15(b), many candidates tried to explain why the piece of solid carbon dioxide was spinning, often doing quite well, whereas the question asks why the solid piece remains in one place. Quantitative questions that were intended to be answered by correct use of algebra, rather than substituting given numbers, posed a particular problem. Few achieved the correct answer to 17(b), which asked for the factor by which a cyclist's power had to be increased when he doubled his speed, but had they been given numbers for the velocity, initial power, etc they might have coped well. The same applied to question 13(a), although as that was a "show that" question, where they were given the approximate answer, it caused fewer problems. The occasional use of algebra in this way is a higher level skill the candidates need to develop.

In this paper there were two questions that involved a two stage calculation, and sometimes slightly incorrect answers were given due to rounding at the intermediate stage. Although we try not to penalise correct rounding, wherever it occurs, the candidates need to be trained to do all calculations to a higher precision, to avoid these inaccuracies. There were occasions where a value was truncated rather than rounded, and such errors would be penalised.

There continue to be examples of careless scientific wording, which need to be discouraged. For instance, in question 16(a), words such as "the ball was accelerating at a constant speed" were seen, and in 16(e) the energy should be "transferred" or "dissipated".

Section A

Question	Subject	% correct	Correct response	Most common alternative
1	Vectors and scalars	92	B	Not significant
2	Velocity as a vector	48	B	
3	G.P.E. and power	66	B	A
4	G.P.E. transferred to K.E.	29	D	
5	Energy stored in a spring	48	D	B
6	Viscosity	92	A	Not significant
7	Terminal velocity	61	C	A
8	Components of a force	63	C	D
9	Force and energy	49	C	B
10	Experimental techniques	40	D	B

The multiple choice section scored quite highly. Each question being worth just one mark, candidates should be discouraged from spending too much time on any one question in this section.

Q1 was a straightforward question on vectors, which was very well answered.

Q2 was a question about the vector nature of velocity, but was answered surprisingly poorly. We hoped they would realise that the ball rebounded with a velocity of $-4\ \text{m s}^{-1}$. It was interesting that, of the 52% who gave the wrong response, all the other options were almost equally chosen, and also that the more able candidates were also quite likely to get this question wrong.

Q4 was a straightforward energy transfer question. It was hoped that the candidate would realise that the GPE is transferred in total to KE on the frictionless slide, so that the speed at the bottom of all four would be the same. However, just as many took the intuitive route, saying that the steeper slides produced a greater speed, showing a lack of understanding of energy conservation.

Q5 was fairly well answered, but as it required the use of two equations from the formula list, unless they had learnt $E=\frac{1}{2}kx^2$, it was a higher level calculation. The most common mistake was leaving out the square root.

Q7 was correctly answered by the majority of candidates. It would be quickly answered, and required no calculation. The most common incorrect response was A, with all the arrows in the right direction, but showing a resultant upward force so not at terminal velocity.

Q8 was also well answered, with C being the correct response, but some 22% giving the answer D. Perhaps they had forgotten the "not" in the question by the time they had worked down to D.

Q9 discriminated well. Their first idea may have been to use F=ma, and so F=mv/t, which would be correct but is not an option given, so some may have chosen the nearest which was response B (2mv/t), and this was the most popular incorrect response. However, the more able candidates would then go on to use $\frac{1}{2}mv^2$ or to substitute for t (=2d/v).

Q10 required an understanding of what is meant by a "reliable value", and responses were about equally divided between B and D.

Section B

Question 11

It was thought that this question would be a fair introduction to Section B of the examination paper, and it was for that reason that the question was broken down into a large number of steps. It required an understanding of some simple words: volume, mass, upthrust, weight, and the formulae involved with them. Many candidates did achieve full marks, and overall the full range of marks was achieved, so that the question did discriminate well. However, it was noted that a number of candidates did not know the formula for the volume of a sphere, or, more pertinently perhaps, did not realise it applied to the balloon.

For part (b), the answer we were originally expecting was that the required weight would be equal to the upthrust minus the weight of the helium. However, the majority of responses did not include the second term, the weight of the helium, and we made the assumption that they considered that weight to be included in the weight of the balloon. We therefore did not penalise those who said that the required weight was equal to the upthrust.

$\frac{4}{3}\pi\left(\frac{d}{2}\right)^3$ **(1)**

(ii) the mass of the helium inside the balloon

$\frac{4}{3}\pi\left(\frac{d}{2}\right)^3 \times \rho_h$ **(1)**

(iii) the mass of the air displaced by the balloon

$\frac{4}{3}\pi\left(\frac{d}{2}\right)^3 \times \rho_a$ **(1)**

(iv) the upthrust on the balloon.

$\frac{4}{3}\pi\left(\frac{d}{2}\right)^3 \times \rho_a \times g$ **(1)**

$\left[\frac{4}{3}\pi\left(\frac{d}{2}\right)^3 \times \rho_a \times g\right] - \left[\frac{4}{3}\pi\left(\frac{d}{2}\right)^3 \times \rho_h \times g\right]$ **(1)**

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Examiner Comments

This is an example of the ideal answer we were hoping for. The candidate has written the formulae using the symbols given in the question, and fully understood their meaning. Part (b) is the full statement we were expecting.

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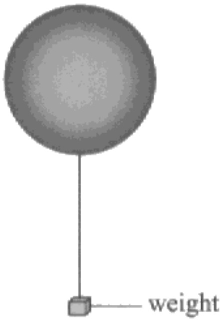
Examiner Tip

Where possible, use the symbols given in the question.

$\rho = \frac{m}{V}$

$V\rho = m$

$V = \frac{m}{\rho}$



The only measurement taken is the diameter d of the balloon. The student is given the values of the density of air ρ_a, the density of helium ρ_h and gravitational field strength g.

(a) Using the symbols given, write an expression for

(i) the volume V of the balloon **(1)**

$V = \frac{4}{3}\pi r^3$ $V = \frac{4}{3}\pi \frac{d}{2}^3$

(ii) the mass of the helium inside the balloon **(1)**

$m = V\rho_h$

(iii) the mass of the air displaced by the balloon **(1)**

$m = V\rho_a$

(iv) the upthrust on the balloon. = weight of fluid displaced **(1)**

Upthrust = $M_{air} \times g$.

Weight = $M_{air} \times g$.

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Examiner Comments

This response showed the minimum that could achieve full marks. In fact the first mark, for (a)(i), was not awarded as the equation showed ½mv^2 rather than $(d/2)^3$. This candidate did not use the given symbols all the way through the question, but was considered to fully understand the physics involved. We did insist on the use of d/2 and not r in (a)(i).

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Examiner Tip

Careless writing of mathematical equations is likely to be penalised as it leads to ambiguous answers.

(b) Assuming the weight of the balloon and string are negligible, write an expression for the magnitude of the required weight.

(1)

weight = drag + upthrust.

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Examiner Comments

There were various forms of response, like this one, which included viscous friction of some kind in the equation. It would be an equation remembered from terminal velocity situations. Any such mention, of course, lost the mark.

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Examiner Tip

Always consider the context in which the question is set. In this case the balloon is stationary.

Question 12 (a)

This is a question concerning the properties of materials, set in a context which would be easily understood and almost certainly experienced by the candidates. Part (i) was answered correctly by the great majority of candidates. Part (ii) required rather more thought, and often demonstrated an incomplete understanding of the physics involved. The expected answer was simply that "the broken ice had a greater surface area". However, many candidates said the opposite, that the surface area was reduced, presumably comparing the surface of a piece of the ice with that of the whole sheet. Others answered in term of the behaviour of the constituent atoms, either thinking that the molecules had been broken up by the hammering, or that the hammering had caused atomic vibration which raised the temperature of the ice. This type of response demonstrated a misunderstanding of both the question and the physics involved as there was no indication that the ice was melting as it was being broken, and so did not get the mark. However, most candidates answered both these questions correctly, achieving the 2 marks available.

12 (a) On a cold night ice forms over the surface of a small garden pond. The next day, the air temperature rises and the ice begins to melt slowly.

Melting can be speeded up by breaking the ice with a hammer.

(i) State the property of ice which means that it can be broken with a hammer.

(1)

Brittle

(ii) Suggest why the broken ice melts more quickly.

(1)

The surface area to volume ratio increases so it can melt quicker

ResultsPlus

Examiner Comments

This is an example of an ideal, succinct answer that goes straight to the point for both parts of the question.

The number of lines provided for the answer is intended as a good indication of the amount of writing required. If you are finding it difficult to say all you want to in the space provided you are probably writing too much.

12 (a) On a cold night ice forms over the surface of a small garden pond. The next day, the air temperature rises and the ice begins to melt slowly.

Melting can be speeded up by breaking the ice with a hammer.

(i) State the property of ice which means that it can be broken with a hammer.

(1)

Ice is brittle. It shows little or no plastic deformation before braking.

(ii) Suggest why the broken ice melts more quickly.

(1)

The Volume of pieces is smaller than the volume of the whole ice, then it melts more quickly.

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Examiner Comments

(i) After stating the property, the candidate went on to describe what brittle means. This was not asked for in the question even though it showed that the candidate had some knowledge of the subject, and so there was no extra credit given.

(ii) This is an example of a mistaken response. It might have been an intuitive thought that the volume decreases, but was clearly an elementary example of wrong physics.

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Examiner Tip

(i) There is no advantage in going beyond the question. It is intended to take a few seconds to answer.

(ii) Suggest why the broken ice melts more quickly.

(1)

The broken ice has atoms which are already split and have broken away from their usual positions, so it is easier for them to gain energy from heat and move, causing the ice to melt.

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Examiner Comments

This is an example of a response where a candidate has tried to explain the faster melting by describing what happened with the constituent atoms. No responses of this type gained any credit.

Question 12 (b) (i)

As with (a)(i), the term "hard" was understood by most candidates, and a correct answer, such as "resistant to indentation or scratching" was given. An occasional mistake was to define the term "hardness" which did not get the mark, and some candidates confused "hard" with "tough", saying that it could absorb a lot of energy, or was difficult to break. Candidates need to beware of giving more than one answer, e.g. "difficult to scratch or break", as that is likely to be denied the mark.

(b) Ice is a hard material.

(i) Define the term hard.

(1)

Not easily scratched or indented

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Examiner Comments

This response is an example of a simple and correct answer.

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Examiner Tip

Note that writing more than is required can lead to contradictory physics which might lose the mark that was initially gained.

(b) Ice is a hard material.

(i) Define the term hard.

(1)

It cannot be scratched or indented (plastically deformed).

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Examiner Comments

There are two points here. Firstly, hard materials can be scratched, just not very easily, so this response would not get the mark. Secondly, it would come very close to losing the mark anyway because of the comment about plastic deformation. We would allow that the surface is resistant to plastic deformation, but candidates should not confuse “hard” with “not plastic”. Although most hard materials are not plastic, the two terms refer to different properties.

Question 12 (b) (ii)

This is an interesting application of hardness to a situation with which the candidates would probably not be familiar, although just about all the candidates understood the fact that fast and slow ice referred to the speed at which the skaters could move on the ice. The question clearly asked for a comparison between colder and warmer ice, and most candidates did produce a comparative response. The actual physics involved in knowing what makes ice slippery is extremely complicated, but it should be, and generally was, obvious to the candidates that it involved the hardness of the ice, as the first part of the question, "define hard", leads to that understanding. We were hoping for two parts to the response: firstly that there was less scratching on cold ice; secondly that there would therefore be less friction. Some candidates, ignored the lead we gave about hardness and branched out into viscosity or melting of the ice, both of which are incorrect in this situation.

Almost half of the candidates scored the full 2 marks and roughly a quarter scored zero, so the question did discriminate well.

The colder ice will be harder to scratch so there will be less friction so they can skate faster and the warmer ice wont be as hard so it will have more friction causing the skaters to skate slower.

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Examiner Comments

This was a good, clear answer. The candidate followed the lead through question 12(b), discussed the way the hardness of the ice varies with temperature, related it to the difference in friction and then to the speed of the skater. The cold ice was compared to the warm ice unambiguously.

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Examiner Tip

Always look for a lead given earlier in the same part of the question, in this case part (b). Beware of going back to a previous part which might be about a different aspect of the context.

Less resistive frictional forces, Skate falter
less force transfered from kinetic
to frictional.

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Examiner Comments

This was a less able response and gained no credit, but it is a pity that the candidate did not say whether the cold or warm ice is intended, which would have gained a mark.

As the hardness increases, it makes scratches less likely. This makes it faster to skate on as it is smooth, hence, fast ice. As the temperature increases, ice scratches more easily as it becomes less hard. For this reason it is harder and slower to skate on due to the scratches.

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Examiner Comments

This response gained just 1 of the 2 marks. It is a pity that, despite the clarity of the answer, friction was not mentioned.

As the temperature of the ice decreases the viscosity ~~decreases~~ increases so it doesn't flow that much making it faster to skate on and warmer ice has less viscosity so it travels faster and is very liquid which makes it harder for skaters to skate fast.

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Examiner Comments

This candidate has gone outside the terms of the question and attempted to give an answer in terms of the viscosity of the ice. Clearly, a really good answer could be given which involves viscosity, but there was nothing in the question to indicate that we were expecting that in this case.

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Examiner Tip

Always first try to answer within the parameters of the question. This question is about hardness so consider what effect different hardness would have on the speed of the skater.

Question 13 (a)

This question is a fairly standard format used to test the candidates' understanding of the Young modulus equation beyond the simple substitution into stress and strain. In this case, with the copper and steel wires joined end to end, they had to combine the equations for stress, strain and Young modulus (all given in the formula list on the paper), and to realise that both wires would be subject to the same tension.

In part (i), the candidates made some errors in combining the formulae, but most marks were lost because the answer was left incomplete. Often, the values of E × A were calculated for the copper and the steel, but then the candidate was unsure what to do with them. Marks were regularly lost when the candidate, having done all the correct working, did not give the final answer but just said, from the final equation, that the result would be about 2 (as given in the question). It is important to realise that if the question asks the candidate to show that the answer is about a certain value then they are expected to calculate the actual resulting value. In addition, many left the answer as a ratio (9:4 or 9/4) without calculating it as 2.25, which lost the third mark. We did particularly want to see the candidate's working for this question, and an answer of just 2.25 with little working was unlikely to score highly. Overall, for this part, those candidates with a reasonable understanding of Young modulus scored 2 marks, with the third mark less usual for the reasons stated above.

In part (ii), most candidates failed to achieve the correct answer of 6.9mm. The idea was to divide the total extension (0.01m) in the ratio of 2.25:1, but not many seemed to understand the use of a ratio. Those who achieved the mark usually used the value of 2 for the ratio as given in part (i), which they are quite entitled to do, particularly if they think that their answer to part (i) is wide off the mark. Incorrect rounding was often evident in the answer.

We were looking for an answer of 2.2 or 2.3 with the working shown for part (i) and 6.9mm for part (ii).

(a) (i) Show that the extension of the copper wire is about twice the extension of the steel wire.

(3)

$E = \frac{\sigma}{\varepsilon}$

$E = \frac{F}{A} \times \frac{x}{\Delta x}$

$1.3 \times 10^{11} = \frac{F}{0.80 \times 10^{-6}} \times \frac{l}{\Delta x}$ $\quad 1.8 \times 10^{11} = \frac{F}{1.3 \times 10^{-6}} \times \frac{l}{\Delta x}$

$104000 = \frac{Fl}{\Delta x_c}$ $\quad 234000 = \frac{Fl}{\Delta x_s}$

$\Delta x_c = \frac{Fl}{104000}$ $\quad \Delta x_s = \frac{Fl}{234000}$

$\frac{\Delta x_c}{\Delta x_s} = \frac{Fl}{104000} \times \frac{234000}{Fl}$

$\frac{\Delta x_c}{\Delta x_s} = \frac{234000}{104000} = \frac{234}{104}$

$\frac{\Delta x_c}{\Delta x_s} = 2.25$

$\frac{\Delta x_c}{\Delta x_s} \approx 2$

(ii) Hence calculate the extension of the copper wire.

(2)

~~$Fl = 234000\Delta x_s$~~ ~~$Fl =$~~

~~$\Delta x_c + 2\Delta s = 0.010$~~ ~~$\Delta x_c = 2.25\Delta s$~~

~~$104000 = Fl \div \frac{2Fl}{104000}$~~ ~~$\Delta x_c = 2.25\left(\frac{Fl}{234000}\right)$~~

~~$104000 = \frac{Fl(104000)}{2Fl}$~~ ~~$\Delta x_c = \frac{Fl}{104000}$~~

$\Delta x_c + \Delta x_s = 0.01$

$\Delta x_c = 0.01 - \Delta x_s$

$\Delta x_c = 0.01 - \frac{\Delta x_c}{2.25}$

$2.25\Delta x_c = 0.0225 - \Delta x_c$

$3.25\Delta x_c = 0.0225$

$\Delta x_c = \frac{0.0225}{3.25}$

$\Delta x_c = 6.9 \times 10^{-3}$

Extension = 6.9×10^{-3} m

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Examiner Comments

This is the kind of response we saw from more able candidates and it gained full marks. The formulae for stress and strain were clearly combined; the values given were substitutes for copper and steel separately and the equations rearranged to make Δx the subject; the ratio was then taken and the constant values cancelled; finally the answer was stated. It would have been good to see a statement that F and l were the same for both wires. Part (ii) was also clearly worked through to the correct answer.

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Examiner Tip

In a "show that" question, clear working is particularly important.

(a) (i) Show that the extension of the copper wire is about twice the extension of the steel wire.

(3)

Copper wire → $E = \frac{\text{stress}}{\text{strain}} = \frac{FL}{A\Delta L}$ Steel → $1.8\times10^{11} = \frac{FL}{1.3\times10^{-6}\Delta L}$

$1.3\times10^{11} = \frac{FL}{0.8\times10^{-6}\Delta L}$

$234000\,\Delta L = FL$

$104000\Delta L = FL$

$104000\,\Delta L = 234000\Delta L$

$\therefore \approx 1$ copper extension = 2 steel extension

ResultsPlus
Examiner Comments

This was a more typical response where the equations and substitutions are correct, but the candidate did not work it through to a final answer.

(ii) Hence calculate the extension of the copper wire.

(2)

total extension = 0.01 m

~~$\frac{0.01}{3.25} \times 2.25$~~ = $\frac{0.01}{3.25} \times 2.25$ = 0.007m

Extension = 0.007m

ResultsPlus
Examiner Comments

This is a case where the candidate correctly worked through to a numerically correct answer, but quoted that answer to one significant figure. While we might sometimes allow that, it is not good practice, and answers should be given to the same precision as the data in the question. For this question 0.007 m was not considered sufficiently precise, and we were expecting at least 2 significant figures.

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Examiner Tip

It is not normally good practice to give answers to one significant figure.

Question 13 (b)

A simple question that was answered correctly by most candidates. The only answers credited were "ductile" or "ductility". Some confused ductile with malleable, but only a small number.

Ductile

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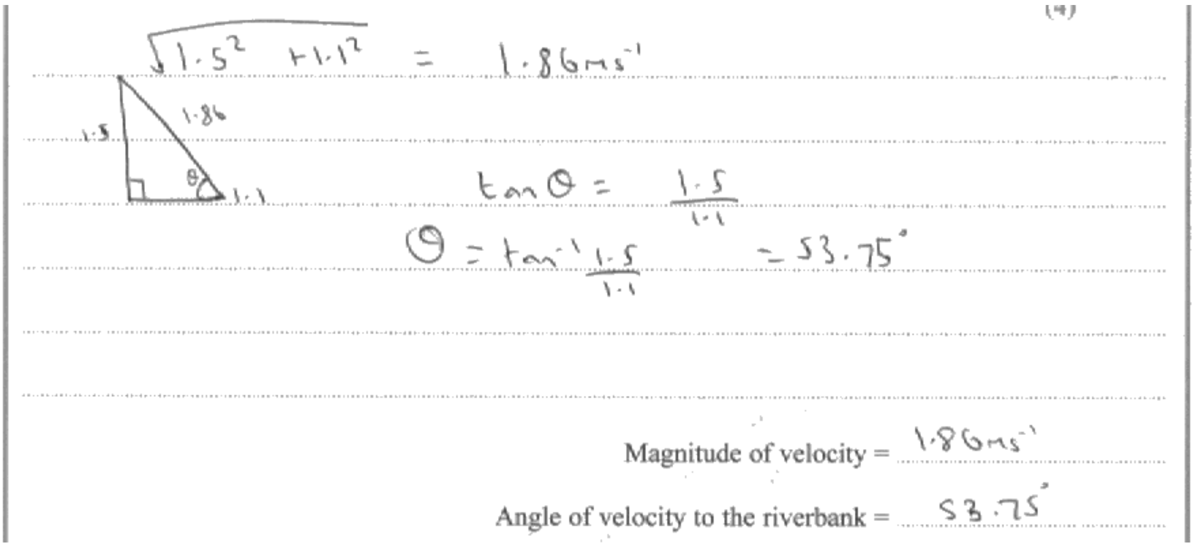
Examiner Comments

This was the response normally given. A single word is sufficient.

Question 14 (a)

This question was well answered. The candidates were clearly happy with combining two vectors at 90° to one another, using Pythagoras and tan. The drawing of an appropriate triangle or rectangle would help them get the right answer. Over half of the candidates scored the full 4 marks on this question, and only 11% scored less than half marks.

The responses required were 1.9ms^{-1} for the magnitude of the velocity, and 54° for the angle to the riverbank.



$\sqrt{1.5^2 + 1.1^2} = 1.86\,ms^{-1}$

$\tan\theta = \frac{1.5}{1.1}$

$\theta = \tan^{-1}\frac{1.5}{1.1} = 53.75°$

Magnitude of velocity = 1.86ms^{-1}

Angle of velocity to the riverbank = 53.75°

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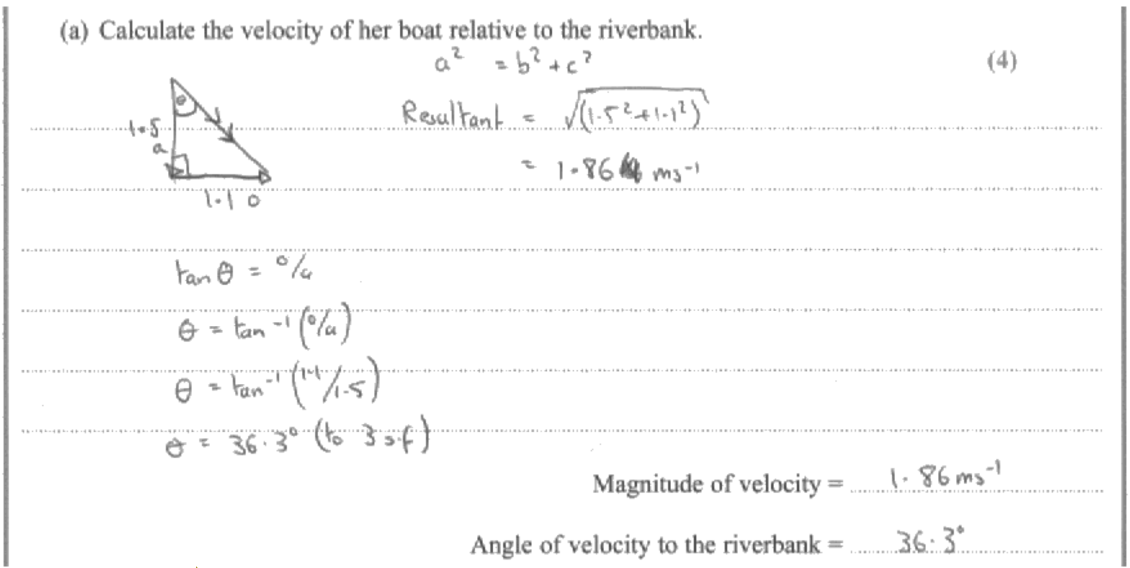
Examiner Comments

This was a fully correct response in its simplest form.



(a) Calculate the velocity of her boat relative to the riverbank. (4)

$a^2 = b^2 + c^2$

Resultant $= \sqrt{(1.5^2 + 1.1^2)}$

$= 1.86\,ms^{-1}$

$\tan\theta = o/a$

$\theta = \tan^{-1}(o/a)$

$\theta = \tan^{-1}(1.1/1.5)$

$\theta = 36.3°$ (to 3 s.f)

Magnitude of velocity = 1.86 ms^{-1}

Angle of velocity to the riverbank = 36.3°

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Examiner Comments

This was the common mistake, giving an incorrect angle.

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Examiner Tip

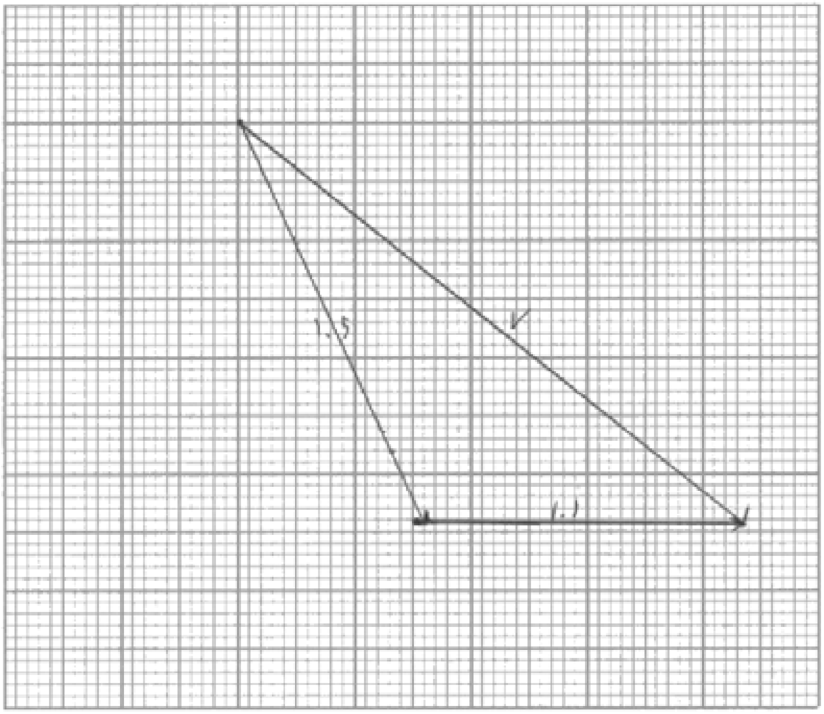
Where an angle is needed in a vector question, make sure you understand what the angle is relative to.

Question 14 (b)

This question was very poorly answered and there was a significant number of blank responses. It was surprising how many candidates failed to utilise an appropriate amount of graph paper, thus rendering their answers too far out of range. It was evident that a large percentage of candidates did not really understand the use of a vector triangle, an essential skill which should be well practiced since most of those candidates who knew how to draw a vector diagram were able to score marks for the two correct values.

In general, providing the candidate had drawn a correct construction for the vector diagram, they then went on to get maximum marks. This implied that too many candidates are unfamiliar with the drawing of scaled vector diagrams, probably preferring to answer questions using trigonometry. In this question, the use of trigonometry to calculate the values for the velocity was credited for 2 marks, but to gain full credit a correct vector diagram had to be seen, as that was how they were instructed to approach the problem. In addition, the calculations here were not straightforward, and those who took measurements from a vector diagram were more likely to gain the credit even if the answers were less accurate. One of the intentions behind the question was to force the use of a scale drawing in order to test that skill in the candidates.

The correct answer was $2.2 ms^{-1}$ for the magnitude of the velocity and 38° for the angle to the riverbank.



Magnitude of velocity = 2.2 ms^{-1}

Angle of velocity to the riverbank = 39°

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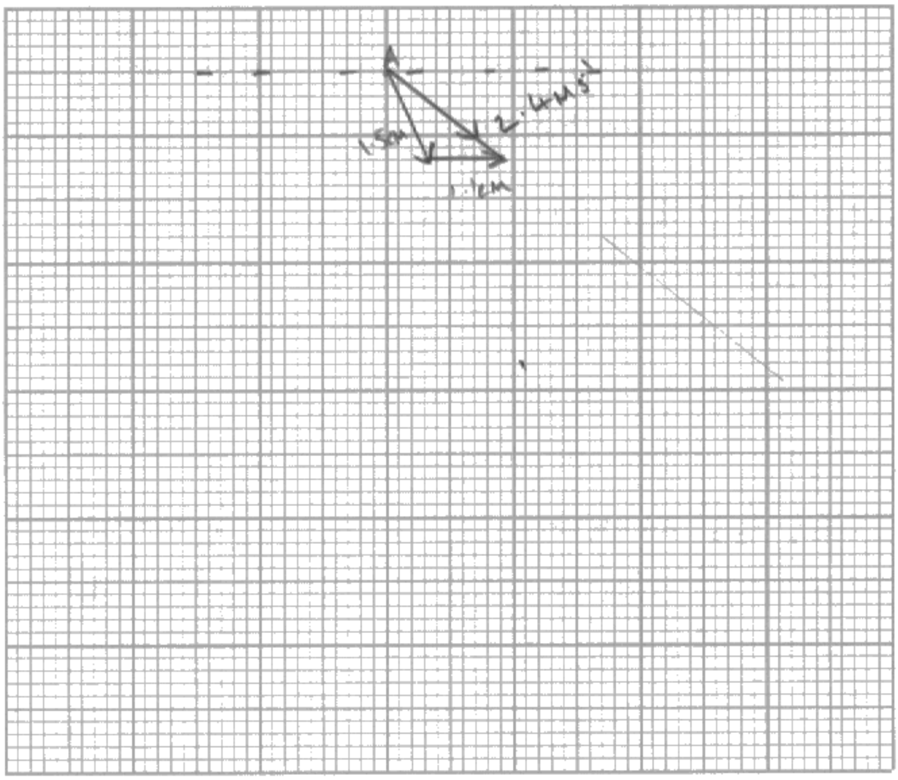
Examiner Comments

This response shows a clearly drawn vector diagram, of a good size, and with the sides labelled. An indication of the scale used would have helped but was not penalised. Measurements from the diagram gave exactly the correct answers, showing that a good scale diagram can be accurate.



Magnitude of velocity = 2.4 ms-1

Angle of velocity to the riverbank = 32°

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Examiner Comments

This response, which scored 1 out of 3 marks, was typical of those who used the simplest scale of 1 cm ≡ 1 m s-1. Although correctly drawn, and gained that mark, the values for magnitude and angle of the velocity were so inaccurate as to be out of the allowed range and so did not score.

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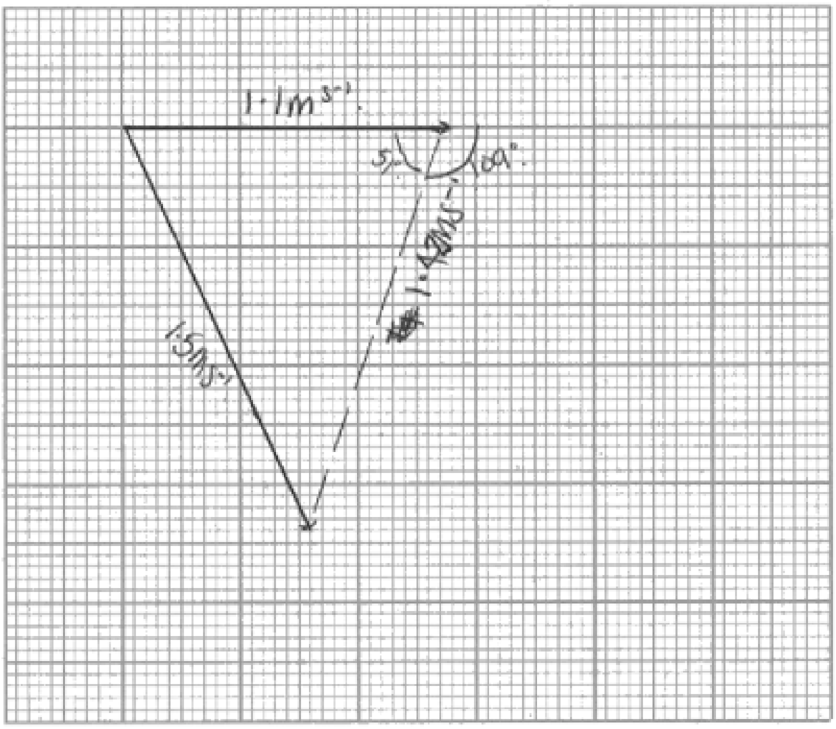
Examiner Tip

With scale diagrams and graphs, always use as much of the graph paper as possible, consistent with a simple scale.



Magnitude of velocity = 1·42ms^{-1}.

Angle of velocity to the riverbank = 51°.

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Examiner Comments

This was also a very commonly seen response. The candidate correctly drew the two vectors, but the resultant should have been the diagonal of the parallelogram for this diagram. The difference between a parallelogram and a triangle of vectors was misunderstood, and perhaps the drawing of vector diagrams needs more practice.

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Examiner Tip

Understand the difference between a triangle and a parallelogram of vectors.

Question 15 (a)

As seen in previous examinations, many candidates struggled with applying Newton's laws in "real" situations. The situation described in this paper was not one with which the candidates were expected to be familiar, but was well within their understanding. They were told clearly what was observed, that piece X began to move rapidly in a single direction, and that the cause was jets of ejected gas. Overall, the question discriminated well, with the full range of marks being seen, although the mean mark for the question was less than 2. The responses to the question showed a number of common problems:

- Candidates had a good knowledge of Newton's laws of motion, but they were often quoted verbatim without any application to the question posed. These candidates wasted a lot of time and space, and did not get any credit unless the laws were applied to the situation described.
- The pair of forces involved was clearly between the solid and ejected gas. However many, possibly the majority, saw the water or the air as applying the force to the CO2 in which case they would only get one mark of the three available for noting the opposite direction of the force.
- Many quoted the third law but applied it to the solid floating on the water, i.e. weight and upthrust. The less able candidates wrongly interpreted the context in this case.
- There was a mark for saying that there was a resultant force on the solid, or a word similar to resultant, but not "external force" or just "force" as there were many external forces which did not cause the movement, such as the weight. However, the majority of candidates gained a mark for saying that the force would cause an acceleration due to Newton's second law.
- Very few candidates attempted to explain the rapid movement of X, and many who did suggested that it was due to the mass of the solid reducing as it sublimed, rather than due to the small mass.

As it ejects jets of gas it creates a newtons
third law pair so the gas ejected puts a force
on x while x puts an equal and opposite force
on the gas. As the gas is ejected one side the
force put on x is in the opposite direction of
the expelled gas. This force on the object x
kreates a resultant force in its direction of travel which allows the
object to accelerete due to newtons
second law stating F=ma. This means a
Force on an object with mass will result
in an acceleration in the direction of the
resultant force.

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Examiner Comments

This response clearly applied Newton's third law to the solid/gas interface, and applied the second law to explain the acceleration. As the candidate realised, there was no need to give a full statement of each law. Many responses of this type were seen, and gained full credit.

ResultsPlus
Examiner Tip

Make sure the context of the question is understood as well as possible, so that time is not wasted and no essential points are missed.

Newton's 3rd law of motion states that if body A exerts a force on body B, then body B will exert an equal and opposite force on body A. In this situation, the ejected exerts a force on the solid carbon dioxide and the carbon dioxide exerts an equal and opposite force on the gas.

The solid carbon dioxide will move rapidly in the direction shown as there is a net resultant force acting towards that direction. Due to the Newton's second law: F=ma, a net resultant force will cause the piece X to accelerate towards the direction shown, and thus move rapidly.

ResultsPlus
Examiner Comments

Often the candidate prefers to quote the law first and then to apply it, as here for the third law. That was not a problem and the response gained 5 marks.

- when first placed, there is no resultant force on the piece x so due to F=ma, there will be no acceleration (remains at rest)
- when the ~~sol~~ solid carbon dioxide reacts and begins to changes from solid to liquid, jets of ejected gas are released, causing a resultant force in the direction of the arrow.
- This resultant force due to F=ma, the resultant force (F) causes an acceleration as F is proportional to a.
- This acceleration causes x to move rapidly in the direction shown.

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Examiner Comments

We were expecting the candidate to state which law was being applied to the particular explanation being described. This candidate did not mention "Newton's second law" so got no credit for saying there was an acceleration.

Newton's law questions are common on this paper, and do require a reference to the law being applied. The response needs to use a form such as "Due to Newton's second law ...."

According to Newton's third law the ejected gas has force on the water so the water has a, and equal magnitude of force but in the opposite direction, on the object x which is ejecting the gas.
~~The causes~~ The initial force of the ejected gas on the water proves Newton's second law. This is that force is proportional to acceleration when the mass of object x is constant

ResultsPlus
Examiner Comments

A very common response was where the candidate thought the water was pushing the solid CO_2. This response just gained a single mark for the direction of the force.

Question 15 (b)

The discussion of the movement of piece Y caused the candidates a considerable problem, but again the question did discriminate well. The first point to note is that, while the context of the question did describe two aspects of the motion of the piece, remaining in one position and spinning, the question itself was just about the former, the latter being there to indicate that there were forces acting on the piece due to jets of gas. The candidates did not have to attempt to give a reason for the rotation, which many did using a "Catherine Wheel" idea, or a force from a tangential jet. In explaining why it remained in one position, most gave the "zero resultant force" but only the more able stated that there must be more than one jet.

> There must be ejected gas being released from both sides of Y meaning that there is no resultant force so stays in one place.

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Examiner Comments

This is a correct response, which scores both marks. The candidate focused on the actual question about why the piece Y remained in one place. The response indicated that there was more than one jet of gas, and that the forces from the jets cancel to give zero resultant force.

The three responses that follow are examples of incorrect answers that were commonly seen but did not get any credit.

because the Jet on y is not at the Center of the mass Causing ~~the~~ the rock to spin

ResultsPlus

Examiner Comments

This response focused on the spinning of the solid piece of CO_2, which was explained in terms of off-centre jets. The physics described was correct, but it did not answer the question that had been asked.

Piece Y remains in the same position due to turbulent flow. This makes the piece eddy in circles causing a resultant force from all sides which makes it spin.

ResultsPlus

Examiner Comments

This time the lack of translational movement was explained in term of the water's movement, another common response. This also did not answer the question asked, and, in addition, there was very little water movement involved in the apparatus described.

Piece Y has a larger mass which means it would need a larger force to push it off into a certain direction as the force is proportional to the mass of an object.

ResultsPlus

Examiner Comments

This response incorrectly attempted to explain the lack of movement of Y in terms of its greater mass. While this response indicated that the candidate thought through and largely understood the physics of the movement involved, it ignored the fact that Y is placed on water where friction will be very low.

Question 16 (a)

The context of this question was intended to be one with which candidates would be familiar, the bouncing of a ball on hard ground, and they will almost certainly have seen the velocity-time graph for a falling object during their physics teaching time, and learnt how to interpret and analyse such a graph.

The m

Gradient of these lines represents g (acceleration due to gravity) which is constant.

ResultsPlus
Examiner Comments

This was a well-expressed and correct answer. The candidate has said that the gradient represents the acceleration, in this case due to gravity, and that the acceleration is constant.

The ball is travelling the same distance.

ResultsPlus
Examiner Comments

This was a fairly rare response, but indicated a clear, but very elementary misunderstanding of velocity-time graphs. There was no reference to the areas under the graphs, which are in any case quite different, and the candidate who wrote it is unlikely to achieve a grade E.

As it drops with the same velocity due to gravitional force $= 9.81\ ms^{-1}$. but time decreases

ResultsPlus
Examiner Comments

This response represents a more common, but still elementary error, where the candidate seems to confuse velocity with acceleration.

Question 16 (b) (i)

This question was marked, with any indication that the dotted lines represented the points at which the ball bounced getting the mark. We would have liked to have seen something about its being the short time for which the ball is in contact with the floor, but few responses were that detailed.

The ball remains on the ground during this time, while compressing and uncompressing

ResultsPlus
Examiner Comments

This response was a very good description of what was happening, and went well beyond the grade E response we were looking for. This was the kind of response the more able candidates were likely to give.

ResultsPlus
Examiner Tip

Try to describe exactly what is happening, rather than giving a vague answer.

The ball bounces and goes straight from a negative velocity to a positive one this is shown by the lines.

ResultsPlus
Examiner Comments

In this instance, the word "bounces" was sufficient to gain the mark, but it was not a very complete response.

This is a change in direction of the balls velocity.

ResultsPlus
Examiner Comments

This response did not gain the mark. Although there was a change in direction, there was also a change in direction at the top of the path where the solid line went through zero. The candidate has just read the change in velocity from the graph without giving a reason.

Question 16 (b) (ii)

The candidates found this question much harder to answer, and it required a deeper understanding about what was happening. It was also asking how the graph would change, rather than interpreting the graph as it was drawn. The question did not ask for an explanation of why the graph changed as it did, just a description of the change that would be seen. All we were looking for was that the dotted lines on the graph would be less steep.

If not fully inflated, the basketball wouldn't change directions as quicky, meaning the gradient would decrease.

ResultsPlus
Examiner Comments

This good response described the decrease in gradient, and also went on to give a simple explanation.

If the basketball was not fully inflated the dotted lines would decrease to a lower velocity.

ResultsPlus
Examiner Comments

This candidate gave an intuitive response which did not answer the question. The velocity of the ball would certainly be less after the bounce if the ball were not fully inflated, but the question asked about the change in the gradient.

ResultsPlus
Examiner Tip

Make sure the question asked has been answered.

Question 16 (c)

Most candidates scored highly on this question, which involved taking readings from the graph as well as a calculation. Most candidates used the area under the graph approach here, but a disappointing percentage failed to score marks through using area = base x height rather than ½ base x height. If a candidate used an equation of motion only one reading needed taking from the graph, either the maximum velocity or the time of fall, and the equation tended to be applied correctly. Very few candidates used a GPE = KE approach. Because readings from the graph were involved, a range of possible answers was allowed. A few candidates made the rather critical mistake of assuming the velocity was constant during the fall, and using d = v × t.

The correct answer to this question would be about 1.2 m.

$h = \text{Area} = \frac{1}{2} \times 0.52 \times 4.8 = 1.248 \cong 1.25\,m$

ResultsPlus
Examiner Comments

Here is the straightforward, and correct answer from a candidate who has read velocity and time from the graph in order to calculate the area.

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

$0 \quad \frac{1}{2} \times 9.81 \times 0.5^2 = 1.23\ m$

ResultsPlus
Examiner Comments

This was the most common form of response where a candidate has read a time of about 0.5 s from the graph and substituted into s=½gt2. Candidates who took this approach usually scored both marks.

(c) Calculate the initial height through which the basketball fell.

(2)

s = v x t

s = 4.7 x 0.5 = 2.35 m

Height = 2.35 m

ResultsPlus

Examiner Comments

This was the most common mistake, forgetting that the ball would be accelerating.

Question 16 (d)

This question was a test in the use of the equations for kinetic energy, and in most cases for gravitational potential energy. Reading the velocity from the graph was straightforward as candidates were told the position X to use, and candidates were well-practised in the use of ½mv2. As the approximate answer of 1J was given, they were expected to show some working. The responses to part (i) were almost 100% correct, and those to part (ii) were only a little less. The question for part (ii) started "Hence calculate ...." and so we did expect the candidates to use their answer to part (i) as the starting point for the second part, using GPE = mgh to complete the calculation.

(c) Calculate the initial height through which the basketball fell.

(2)

h = Area = ½ x 0.52 x 4.8 = 1.248 ≅ 1.25 m

Height = ...

ResultsPlus

Examiner Comments

This response showed a typical answer, which scored full marks. The candidate has written down the equation used in each part, substituted values into it and then done the calculation. All the working is therefore clearly shown.

ResultsPlus

Examiner Tip

It is best to write any equation used, and to clearly show the substitution before calculating the answer.

Question 16 (e)

In this situation, the majority of the transfer of energy away from the KE and GPE pair occurred when the ball was compressed in contact with the ground, and very little was lost through friction with the air. However, very few candidates gave a correct response about where the energy transfer occurred, this being something they would have to deduce themselves rather than repeating a fact they had been taught, and so a statement about what happened to the energy was accepted. Some candidates did incorrectly refer to friction with the air, but for this question such a reference was treated as neutral and did not deny them the mark. We were expecting candidates to tell us that the energy was transferred to thermal energy, or words to that effect.

One concern was that the majority of responses involved "loss" of energy which was surprising at the end of their first year of A level studies. A significant number mentioned energy transfer but did not say into what type of energy. The terms "converted", "transformed" and "dissipated" were quite commonly and correctly used as well.

We were expecting an answer that energy had been transferred to thermal energy.

energy has been ~~lost~~ dissipated as heat and sound so ball has less kinetic energy

ResultsPlus

Examiner Comments

This response gained the mark as the candidate stated that energy had been transferred (dissipated is a good alternative as it is changing to thermal), and had stated that the energy had become heat. The comment about sound was ignored, but by itself would not get the mark as the amount of energy converted to sound was very small.

ResultsPlus

Examiner Tip

This is a clear energy transfer statement.

The following were common responses that did not gain the mark.

> Ball bounces less as kinetic energy is lost in each bounce

ResultsPlus
Examiner Comments

There are two reasons that this response was not given the mark:

- We were not told what becomes of the KE that is "lost".
- 'Lost' is not a good word to use when discussing energy transfer, but was extremely common, possibly 50% of the otherwise correct responses we saw. The energy was not in fact lost, it had just changed its form.

ResultsPlus
Examiner Tip

Avoid the word "lost" when discussing energy transfer.

Due to Air resistance opposing the motion of the ball.

ResultsPlus
Examiner Comments

Many candidates gave answers in terms of friction with the air, probably because that is a standard response for a question of this type. As that friction is very small, such answers were not given credit.

ResultsPlus
Examiner Tip

Think carefully before giving a “standard response”.

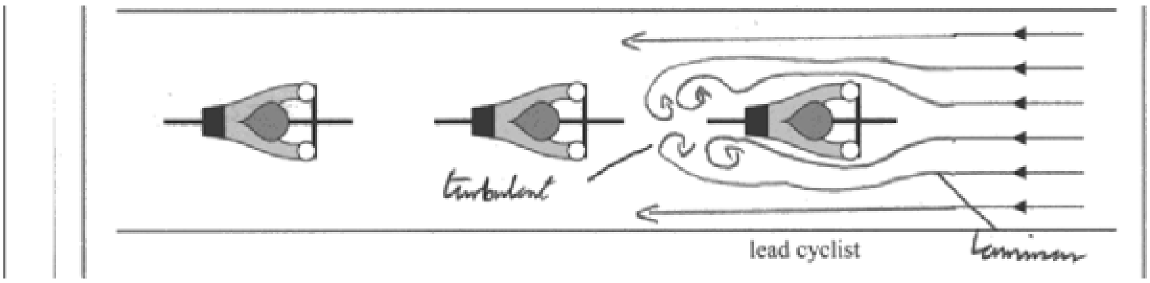
Question 17 (a) (i)

The use of the context of cyclists racing at the London velodrome enabled us to test three aspects of the candidates' ability: their understanding of viscosity and air flow, work and power, and forces; their ability to apply their knowledge to solve numerical problems using the given formulae; and their ability to apply the physics they know to explain what the cyclists experience in a real situation. The latter would test the more able candidates, but all the candidates would be able to access most of the questions set.

Question (a)(i) concerns the meaning of laminar and turbulent air flow, and the candidates are asked to add lines to the diagram to show how the air flows around the moving cyclist, and to label the regions of laminar and turbulent flow. They were given one mark for drawing the flow, and one for labelling. As intended, the candidates recognised that the arrows drawn in front of the lead cyclist represented laminar flow, and they were told in the question that the flow becomes turbulent behind the lead cyclist. Those candidates who drew turbulent flow in front of the cyclist would certainly therefore not get the mark. The great majority of candidates answered this question well, continuing the six lines given and taking them smoothly, and without touching or crossing, around the cyclist. The lines then ended up in eddies behind the cyclist, although it was interesting to see the many different ways the candidates represented turbulent flow, including sharp changes in direction of the lines, lines crossing, and just random movement of the lines, although the presence of eddies was most popular and probably easiest for the candidates to pick up on. A number of responses mistakenly showed a sudden change of direction of the air flow just before the handlebars, which denied them the mark. A few candidates lost the mark for taking the laminar air flow passed all three cyclists, becoming turbulent only after all three had passed.

A surprisingly high number of candidates lost the second mark for failing to label the regions, despite it clearly being requested in the question. This second mark could be obtained even if the diagram of air flow was completely mistaken.

We were looking for smooth lines passing around the lead cyclist, with eddies behind, for mark 1, and correct labelling of "laminar" and "turbulent" for mark 2.



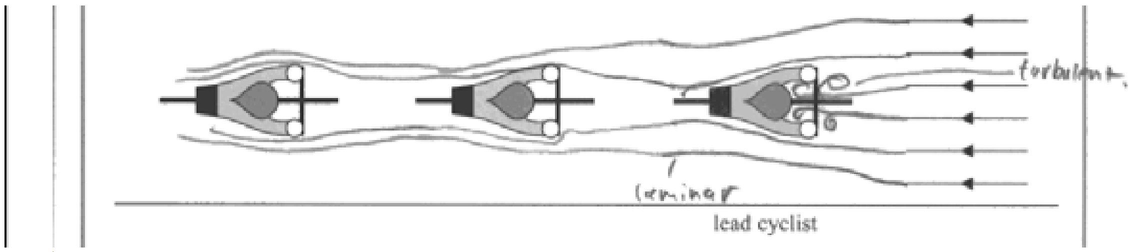
ResultsPlus
Examiner Comments

This candidate continued the given lines smoothly around the lead cyclist, without any breaks, sharp direction changes, or touching or crossing of the lines. Both regions were correctly labelled and indicate the precise position of the flow specified. As the diagram was clear there was no ambiguity and the examiner would not hesitate to award the marks

ResultsPlus
Examiner Tip

Make sure diagrams are clear and unambiguous.

The following two responses show commonly seen ways in which candidates lost marks.

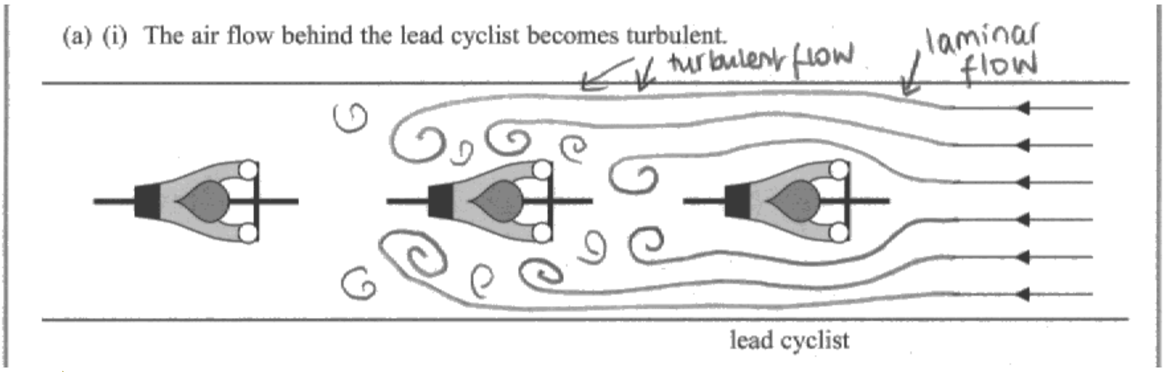


ResultsPlus
Examiner Comments

This response shows turbulent flow in front of the lead cyclist. Reading the line immediately above the diagram would have put the error right. The candidate clearly understands the meaning of laminar and turbulent flow, and gained the mark for correct labelling.

ResultsPlus
Examiner Tip

A lot of marks can be lost through only half reading the question.



ResultsPlus
Examiner Comments

In this case, the candidate correctly drew all the lines, but the labelling of "turbulent" was imprecise. This response therefore gained 1 mark.

Question 17 (a) (ii)

Many candidates struggled with this question, and it did give the higher ability candidates the opportunity to gain marks that others did not. However, one of the two marks ought to have been accessible to all. It should have been clear from the question that all three cyclists were travelling at the same speed. The photograph shows them close together with no indication of overtaking, so any idea that the lead cyclist is travelling faster did not get credit. Also, the candidates were told to use the idea of the relative velocity between the cyclist and the air, but this indication was largely ignored.

One of the marks was for the simple statement that the lead cyclist faced a greater air resistance. Since the first line of the question tells them it is all about air resistance, it was expected that most would gain the mark. However, there were a number who thought that the lead cyclist would face less air resistance, possibly because they only faced laminar flow, which showed a misunderstanding of the physics as well as a misreading of the question, and these candidates were unlikely to score the marks.

The other mark was for an explanation in terms of the velocity of the air relative to the cyclists. It was clear that most candidates had a poor appreciation of relative velocity, or perhaps did not understand the meaning of the term. All that was needed for this mark was an indication that the air was travelling past the first cyclist at a greater speed than past the second, but not because the lead cyclist was travelling faster. A lot of candidates ignored the idea of relative velocity, and gave their own alternative explanation, usually saying that the cyclist would find it easier to travel through turbulent air than through laminar. This may be true, but as it did not answer the question set it did not get the mark.

Having said all that, it was pleasing to see that the more able candidates could give good and clear answers to the question, demonstrating their sound grasp of the situation and the physics involved.

We were looking for the lead cyclist having a greater velocity relative to the air than those behind, and that the drag on the lead cyclist was therefore greater.

The relative velocity of the air around him is greater so there's more ~~drag~~ frictional force. Therefore cyclist has to do more work ~~agains~~ against the larger frictional force to travel at same speed as the others

ResultsPlus
Examiner Comments

This response clearly stated that the relative velocity round the first cyclist was the greater, and that there would be a greater frictional force, requiring the greater use of energy than the other cyclists. It therefore gained both marks.

The relative velocity between lead cyclist and air creates viscous drag between him and passing air causing resistance against his movement meaning more energy needed to maintain speed.

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Examiner Comments

This candidate has stated the physics involved correctly, but at no point was the situation of the lead cyclist compared with that of the others, and so the response could not be given credit.

ResultsPlus
Examiner Tip

Very often a comparison between two situations is required.

(2)

The ~~The~~ lead cyclist ~~is~~ has a far greater relative velocity between himself and the air around him than the cyclists behind him who are riding through the air that was sped up by the lead cyclist.

ResultsPlus

Examiner Comments

This was a very good response concerning the relative velocity of the air, but did not mention the consequence being greater air resistance. It was awarded 1 mark only.

The air around the lead cyclist is laminar so he has to do less work where as the air around the other cyclist behind him is turbulent so they have to do more work is they maintain the same velocity as the lead cyclist

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Examiner Comments

This was an example of the many responses that tried to explain the extra energy needed in terms of the type of air flow. In this particular case, the candidate stated that the lead cyclist did less work, and so misread the question, but in any case it would not get the mark. Had the candidate gone on to discuss air resistance, then 1 mark could have been given.

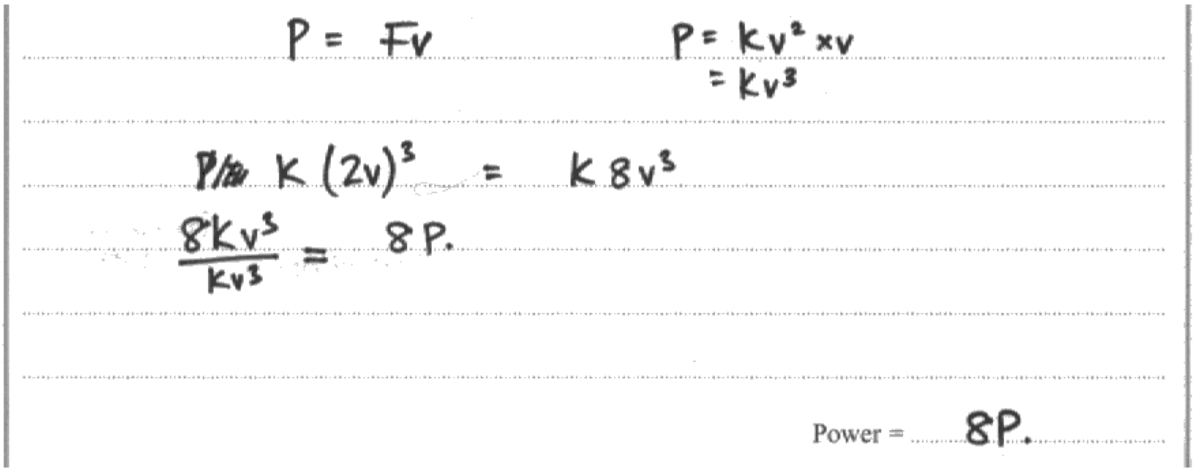
Question 17 (b)

The number of correct answers to this question was fairly small. This was a two stage calculation, a situation that was missed by the majority of candidates who did not appreciate the fact that the cyclist travelling at twice the speed would take half the time to cover the distance.

The first mark was for realising that at twice the speed the cyclist would experience four times the air resistance. Many candidates missed this step out and went straight to the statement that there would be four times the power, an incorrect statement which therefore gained no credit unless a statement about the 4× air resistance could be seen.

The second mark was for seeing $P = F \times v$ or $P = F \times d/t$. The majority of candidates did gain this mark.

The third mark was for combining these two together to get the correct answer of $8 \times P$.



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Examiner Comments

This response was typical of the fully correct answers. The candidate has combined the equation for power with that for the force to show that power is proportional to v^3.

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

$$\frac{m(2v)^2}{2t} = \frac{4mv^2}{2t} = \frac{2mv^2}{t} = 4P$$

Power = 4P

ResultsPlus
Examiner Comments

This response showed an error in understanding the physics of the situation that was commonly observed, and it scored zero marks. The candidate knew that power was the rate of conversion of energy, but the only type of energy recognised was kinetic energy.

Question 17 (c) (i)

For one mark, the candidate had to recognise that to achieve the highest cycling speed, the amount of air friction was more important than the comfort of the cyclists. The graph given shows that the drag was lower at 30°C than at 20°C, and so the correct answer had to be 30°C. For the single mark, we expected the correct temperature and the explanation.

Temperature = 30 °C

results in less drag at any given velocity

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Examiner Comments

This response stated the correct temperature and gave the reason. "At any given velocity" did make the response more precise, but was not required.

Temperature = 30°C

30°C is the most suitable temperature because it allows the cyclist to reach a higher velocity before experiencing the ~~same~~ same magnitude of drag in 20°C

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Examiner Comments

This alternative way of expressing the explanation was commonly seen, and gained the mark.

Temperature = 30°

This means there is ~~less~~ less viscosity and less drag.

ResultsPlus

Examiner Comments

Any reference to the viscosity of the air was ignored in the marking as we were not looking for that amount of detail, so this response gained the mark. However, it would not do so without the comment on drag, particularly as the viscosity would, in fact, increase at the higher temperature.

Question 17 (c) (ii)

To achieve the 2 marks for this question, the candidate had to simply multiply the two given forces by the given distance (in metres) and find the difference. The question was answered well by candidates of all abilities. The most common mistake was to take the distance as 4 m.

We were looking for an answer of 8800 J, although 9000 J would be accepted as the response that would be obtained if the intermediate calculations were done to 3 significant figures.

WD = F x s

20°C : 66·4 x (4x10³) = 265600J   30°C : 64·2 x (4x10³) = 256800J

265600 − 256800 = 8800J 8·8kJ

Difference = 8·8kJ

(Total for Question 17 = 10 marks)

ResultsPlus

Examiner Comments

In this fully correct response, the candidate calculated the two values of work done and found the difference, correctly converting km to m.

(ii) The table shows the drag forces acting on a cyclist travelling at a speed of 21 m s^{-1}.

Wd = F x d

Drag force at 20 °C	Drag force at 30 °C
66.4 N	64.2 N

The cyclist travels 4 km at 21 m s^{-1}.

Calculate the difference between the work the cyclist must do when cycling the 4 km at 20 °C and at 30 °C.

(2)

66.4 − 64.2 = 2.2N

F x d = E

2.2 x 4,000 = 8800J

Difference = 8800J

(Total for Question 17 = 10 marks)

ResultsPlus
Examiner Comments

This response showed a better method for calculating the difference in work as it did not involve finding the two values of work to 4 significant figures.

(ii) The table shows the drag forces acting on a cyclist travelling at a speed of 21 m s^{-1}.

Drag force at 20 °C	Drag force at 30 °C
66.4 N	64.2 N

$V = F \times d$

The cyclist travels 4 km at 21 m s^{-1}.

Calculate the difference between the work the cyclist must do when cycling the 4 km at 20 °C and at 30 °C.

(2)

~~[illegible]~~ $\Delta W = (4 \times 66.4) - (4 \times 64.2) = 8.8$ J

Difference = 8.8 J

(Total for Question 17 = 10 marks)

ResultsPlus
Examiner Comments

In this response the distance was not converted to metres, so lost one of the marks.

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Examiner Tip

Always read the units with the value of a variable.

66·4 x 21 = 1394.4 J

64·2 x 21 = 1348·2 J

Difference = 46·2 J

ResultsPlus

Examiner Comments

This incorrect response was very common. The candidate substituted the speed rather than the distance and so calculated the power. The speed was included in the question so that the candidate had to make a decision about what to substitute and so demonstrate an understanding of the meaning of work.

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Examiner Tip

Watch out for redundant information in a question.

Question 18 (a)

This question was a projectile problem, involving an appreciation that the motions in the vertical and horizontal directions are independent. In part (i) the candidates were expected to use the equation $s=ut+½gt^2$ to determine the time of fall, and in part (ii) to use this time, and the equation $d=vt$ to calculate the horizontal distance.

Part (i) was answered very well. Most candidates used the correct equation, but a few lost a mark for incorrect rounding of their answer to 0.22 m s^{-1} rather than the correct 0.23 m s^{-1}, the more precise answer being 0.226 m s^{-1}.

Part (ii) was also generally well answered, the most common error being the use of $s=ut+½at^2$, using $a=g$ rather than $a=0$, or using $s=t(u+v)/2$, with $v=0$.

Over half of the candidates achieved the full 4 marks for this question.

Note that the expected answers were 0.23 s for part (i) and 0.59 or 0.60 m for part (ii).

u = 0   a = g   s = ~~0.28~~ 0.25   t = ?

0.25 = ½ g t²   t² = 50/981   t = 0.226s

(ii) The ball is projected with a horizontal velocity of 2.6 m s^{-1}.

Calculate the horizontal distance that the ball should travel if the ball is to hit the monkey as it reaches the bench.

(2)

s = d/t   2.6 × 0.226 = d

d = 0.588m

Horizontal distance = 0.588m

ResultsPlus
Examiner Comments

This response was a fully correct calculation, in which the candidate calculated the time correctly and then used that time in part (ii).

Question 18 (b)

Situations in which a projectile has an initial velocity at an angle to the horizontal are much harder to deal with than those, as in part (a), which are projected horizontally, dealing as they do with both positive and negative displacements and velocities in the vertical direction. Although the question here was written in such a way that only the downward (and horizontal) values were required in the calculation, it was a higher level concept for the candidates and their mean mark (3 out of 5) was lower than the mean for part (a) (3 out of 4). In fact, grade A candidates scored well, with a mean mark of 4, while grade E candidates still averaged a mark of 2, generally on the diagram.

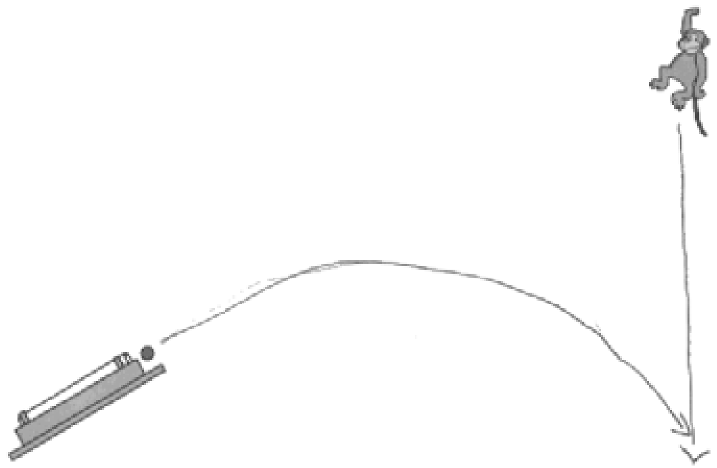
In part (i), the candidates were expected to draw the parabolic path of the ball intersecting with the vertically downward path of the monkey. We were not specific about the exact shape of the ball's path, any initially upward path curving down would do whether or not it passed the peak, but, as always, it was a concern to see a very large number of very carelessly drawn diagrams. For the 2 marks, we expected to see a path for the monkey that was vertical, a downward curving path for the ball, a ball's path that was initially parallel to the launcher, and the ball and monkey paths intersecting. Many lost marks because the ball did not start parallel to the launcher, and a few drew a path for the ball that was straight, or did not reach the monkey's path. Questions like this one can quickly gain full credit, but there was a danger of even the more able candidates losing marks if the drawing was rushed or done without thought.

Part (ii) was answered less well. Unlike part (a), this was a two stage calculation that had not been divided to lead the candidate through. Using the horizontal velocity of the ball, the candidates had to find the time to the collision, and then substitute that into an equation of uniformly accelerated motion for the monkey to determine the distance fallen. This process confused many candidates, who tried to use $s=ut+½at^2$ to find the time of fall, or to give the monkey an initial speed u equal to the initial vertical speed of the ball.

On the diagram, the ball's path should start parallel with the launcher and curve downwards, intersecting the vertically downward path of the monkey.

For the calculation, the time to the collision is 0.177s and the monkey falls 0.15 or 0.16m.

(b) A variation of this experiment is where the monkey is initially higher so that the ball has to be projected upwards towards the monkey. The two objects will still always meet.



(i) Complete the diagram above to show the paths of the ball and the monkey.

(2)

(ii) The ball is projected with a velocity of 3.0 m s^{-1} at an angle of 20° to the horizontal. If the monkey is at a horizontal distance of 0.50 m, how far will it have fallen when it meets the ball?

(3)

3×cos20 s=ut+½at²
s=0.5 0.5=3cos20×t
a=0 t=0.177s

a=9.81 s=ut+½at²
t=0.177s s=½×9.81×0.177²
u=0 =0.154m

Distance fallen = 0.154m

(Total for Question 18 = 9 marks)

ResultsPlus
Examiner Comments

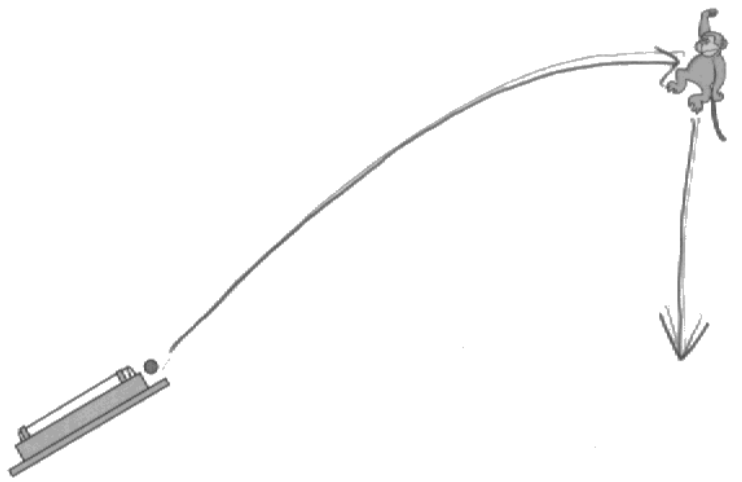
This response scored all 5 marks. The paths of the ball and monkey are correct. The time to the collision was calculated using $s=ut+\frac{1}{2}at^2$, with $u=3\cos20°$. The equation was unnecessarily complicated but as $a=0$ it was a perfectly good solution. The distance fallen was then calculated using the same equation but with $u=0$.

ResultsPlus

Examiner Tip

A carefully drawn diagram need not take long but quickly gains marks.

(b) A variation of this experiment is where the monkey is initially higher so that the ball has to be projected upwards towards the monkey. The two objects will still always meet.

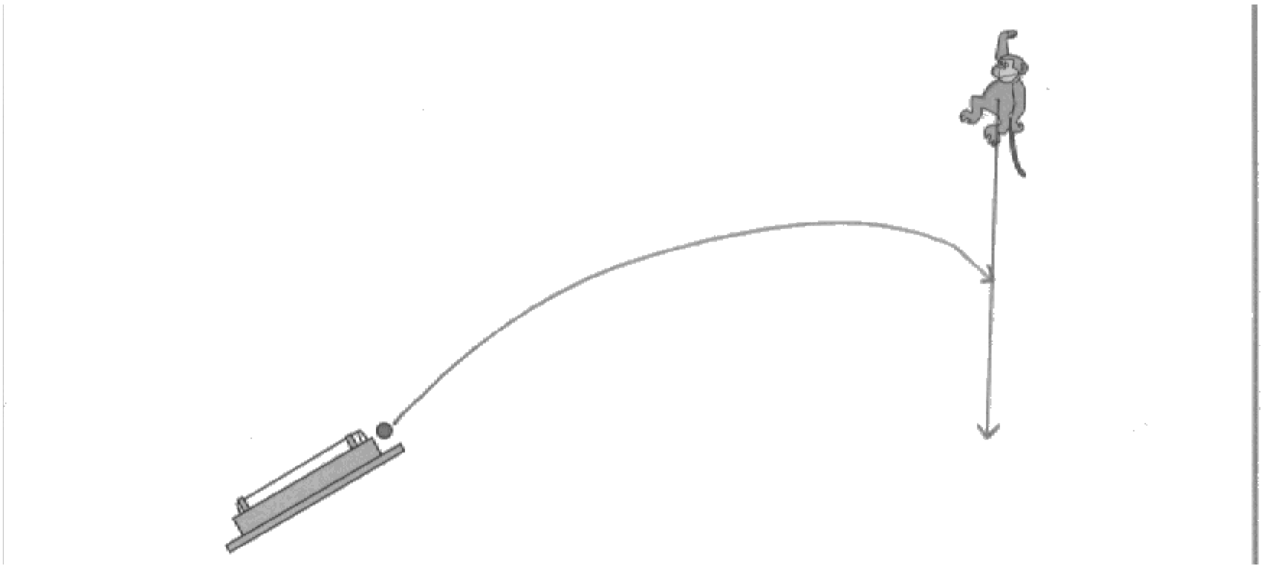


(i) Complete the diagram above to show the paths of the ball and the monkey.

ResultsPlus

Examiner Comments

This candidate did not understand the situation. A bit of thought would have made it clear that the ball could not hit the monkey. The ball's initial path was not parallel to the launcher.



ResultsPlus
Examiner Comments

The ball's initial path was not parallel to the launcher, otherwise this would have gained the marks.

Ball

R↑ $3 \sin 20 = 1 \text{ ms}^{-1} = u$ R→ $3 \cos 20 = 2.8 \text{ ms}^{-1}$

$u = 1$, $a = -9.8$ $t = 0.2s$ $t = \frac{0.5}{2.8} = 0.2s$

~~$v = u + at$~~ $v = s/t$

$s = vt$

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

$= 0.2 + \frac{1}{2} 0.2^2 \times 9.81 = 0.39m$

Distance fallen = 0.40m

ResultsPlus
Examiner Comments

This response shows the time to the collision being correctly calculated, although to insufficient precision. The candidate then used the correct equation for the vertical displacement of the monkey but omitted to put the initial velocity of the monkey to zero. This error lost two marks, for the physics error in missing u=0 and for the wrong answer that results.

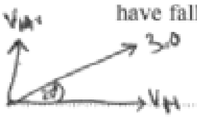
ResultsPlus

Examiner Tip

Try to do intermediate calculations to a higher precision than you need for the answer.

have fallen when it meets the ball?

(3)



$t = \frac{2a}{}$ vertical velocity = $3.0\ ms^{-1} \times \sin 20°$

$= 1.03\ ms^{-1}$

$t = \frac{2u}{a} = \frac{2 \times 1.03\ ms^{-1}}{9.81\ ms^{-2}} = 0.210\ s$

Horizontal velocity = $3\ ms^{-1} \times \cos 20° = 2.82\ ms^{-1}$

Range = $H_v \times t = 2.82\ ms^{-1} \times 0.21\ s = 0.592\ m$

distance fallen = $(0.592 - 0.50)\ m$

$= 0.092\ m$

Distance fallen = 0.092 m

ResultsPlus

Examiner Comments

This response was typical of the responses we saw. The candidate was confused about the way through the problem. The horizontal velocity of the ball had been calculated, but not used to find the time to the collision. Instead, the candidate attempted to use the vertical component of velocity of the ball, and calculated quite a different time. The horizontal velocity of the ball was then used to calculate the vertical displacement of the monkey.

Question 19 (a)

This question was about using a spring, the properties of which will be very familiar to the candidates, to model the forces between atoms. The concept of modelling at this level is very difficult for the candidates, and they became confused about whether they should be answering in term of a spring or in terms of the forces between atoms. However, the majority of the marks were actually about the properties of a spring, and it was only in part (c) that very low marks were seen.

For part (a) the great majority of candidates scored full marks. They had to calculate the actual distance between the nuclei using the equation on the diagram, use that to find the "extension" and therefore be able to calculate the force using F=kΔx. The most common error was in the calculation of the "extension".

$F = k\Delta x$ $\Delta x = (1.12 \times 1.06\times10^{-10}) - (1.06\times10^{-10})$

$= 1.272\times10^{-11}$

$F = 1130 \times 1.272\times10^{-11}$

$= 1.43736\times10^{-8}$ N

1.44×10^{-8} N (3sf)

Force =

ResultsPlus

Examiner Comments

This was a good response. The candidate calculated the "extension", showing clear working, and giving it to a good precision. That was then substituted into F=kΔx to calculate the force. This response gained all 3 marks.

Calculate the force *F*. $F = k\Delta x$

spring constant for hydrogen = 1130 N m^{-1}

diameter of an atom of hydrogen = 1.06 × 10^{-10} m

(3)

$1.12\times(1.06\times10^{-10}) = 1.187\times10^{-10} = 1.19\times10^{-10}$ m.

$(1.19\times10^{-10}) - (1.06\times10^{-10}) = 1.3\times10^{-11}$ m $= \Delta x$

2 forces: $2F = k\Delta x$ $= 2F = 1130 \times 1.3\times10^{-11}$

$F = \frac{1130 \times 1.3\times10^{-11}}{2}$

$F = 7.345\times10^{-9}$ N $= 7.35\times10^{-9}$ N.

Force = 7.35×10^{-9} N

ResultsPlus

Examiner Comments

This candidate started well, correctly calculating Δx although to a rather insufficient precision. However, it was then assumed that the two forces at the two ends of the spring were separate and add up to a total force of 2F, a quite common mistake with springs which are not supported from above.

Question 19 (b)

This question tested whether the candidates could explain the shape of the graph using their knowledge about the way that springs extend. The unfamiliar aspect of the graph was that it included both extension and compression, and the first two marks of the mark scheme were for noting that the negative forces represented compression and the positive forces represented tension. Few candidates noted this, however. For the other three marks, the candidates had to refer to particular parts of the graph, specifying them using values of extension or force, and many responses either lacked these numerical values or the values were inaccurate. This was the last question on the paper, and was designed to test the candidates beyond simple Hooke's law ideas, which it did very well.

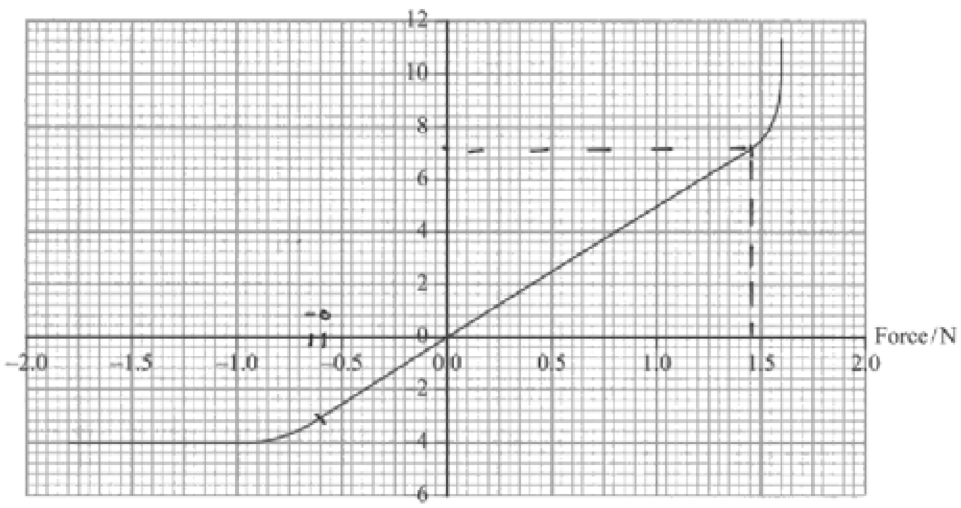
Part (ii) of the question was well answered, the most common errors being in calculating 1/k rather than k or taking inaccurate readings from the graph.

Overall, the question discriminated well. The most common mark was 3 out of 5, but many scored either 2 or 4.

(b) A student carries out an experiment to model the forces between atoms.

A varying force is applied to the end of a spring. The student measures the length of the spring and calculates the extension for each force applied.

The student plots the following graph.



(i) Explain the shape of the graph.

(3)

~~Between~~ When the force is positive, the string undergoes tensile strain and extends,
~~hence~~ why when the force it is negative, the spring undergoes compression and the extension is negative
Between when the force is ~~0F~~ −0.6 and 2N, the gradient is constant and therefore
the ~~string~~ spring is still obeying Hooke's Law at that point. This is elastic deformation
However past 1.5, the gradient curves because it has passed the elastic limit. A small
increase results in a large extension and the spring undergoes plastic deformation. It would
not return to original position if force is removed. At F = 1.6N, the force is too great and the spring breaks

(ii) Use the graph to calculate the spring constant.

(2)

$F = ke \qquad k = \frac{F}{e} = \frac{1.45}{0.072} = 20\,\mathrm{N\,m^{-1}}$

Spring constant = $20\,\mathrm{N\,m^{-1}}$

ResultsPlus
Examiner Comments

This response gained full marks. In part (i) the negative and positive extensions were explained as compression and tension. The Hooke's law range was incorrect, but the third mark was collected for giving the elastic limit at 1.5N. k was correctly calculated for 2 marks in part (ii), and helpfully the part of the line used was indicated on the graph.

$F = k\Delta x$

$k = \frac{F}{\Delta x}$ = gradient of graph $\frac{7.5}{1.5} = 5$ ~~Ncm~~

Spring constant = 1/5 ~~Ncm~~ Ncm

Spring constant = ~~5~~ $\frac{1}{5}$ Ncm^{-1}

ResultsPlus

Examiner Comments

This was a good response, with the gradient points clearly indicated on the graph. The gradient was calculated and its reciprocal taken. However, this candidate lost a mark for not calculating the final value of $0.20Ncm^{-1}$.

ResultsPlus

Examiner Tip

Do not leave answers as a fraction.

(ii) Use the graph to calculate the spring constant. (2)

Spring constant = $\frac{1}{grad}$

~~F~~ = $kx = f$

$k = \frac{f}{x}$ $\left(\frac{7.8}{1.5}\right)^{-1} = 0.1\dot{9} = 0.2$

Spring constant = 0.2

ResultsPlus

Examiner Comments

Another fully correct calculation, but the answer is left without a unit, so 1 mark out of 2.

ResultsPlus

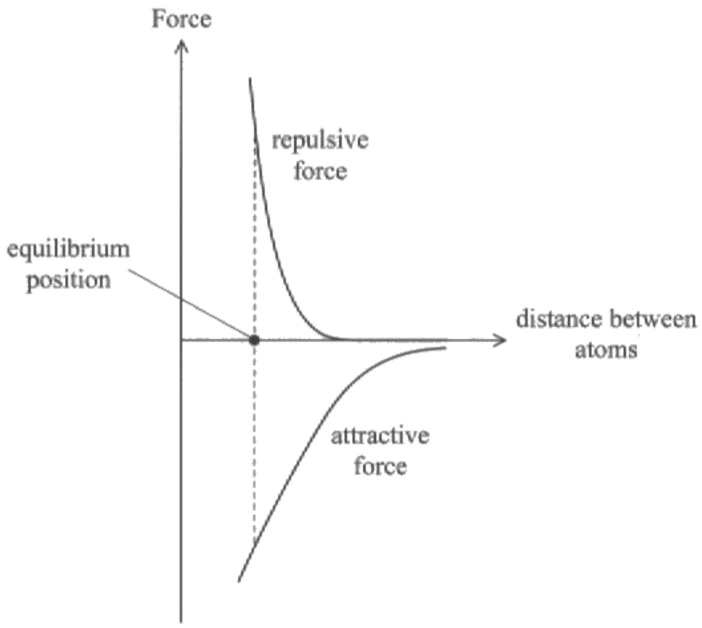
Examiner Tip

Do not forget the unit. You can lose a lot of marks on the paper as a whole.

Question 19 (c)

This question on the forces between atoms scored very badly. Most did not understand the graph, or realise that the two separate forces could act together. For 2 marks, we were expecting the candidate to say that before the equilibrium separation the repulsive force was greater than the attractive force, and that for separations greater than equilibrium the attractive force was greater than the repulsive force. For the third mark they had to give an explanation in terms of the relative gradients of the graph. A lot of candidates gave a response stating that the atoms wanted to be in equilibrium and therefore the forces had to be attractive at a large distance and visa-versa. Others tried to give an answer in terms of the electrostatic forces between the constituents of the atoms. Neither of these approaches used the graph given, and both scored zero marks.

*(c) The graph below shows how the forces acting between two atoms consist of a repulsive force and an attractive force. At the equilibrium position, the sum of these forces is zero.



Use the graph to explain why the forces between atoms are attractive when they are pulled apart and repulsive when pushed together.

(3)

as distance increases attractive force is still at play and affecting the material, however repulsive force stops repelling at a lower distance, so as pulled far apart attractive force is stronger than repulsive force. however when the distance is smaller, repulsive force has a much higher gradient before the equilibrium, and so faster, repulsive force is greater at smaller distances than attractive force, so are repelling overall

(Total for Question 19 = 11 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

ResultsPlus

Examiner Comments

This was an example of an excellent response, very clearly explained, that gained all three marks.

they want to be at the equilibrium position ~~so~~ due to the forces in the atoms. This means if they are pushed together the subatomic forces repel it to try and stay at equilibrium. This is the same when pulled apart except the atoms want to be closer the the forces are opposing the force seperating them and are attractive.

(Total for Question 19 = 11 marks)

ResultsPlus

Examiner Comments

This response tried to apply the "wish" of the atoms to be at equilibrium. It did not attempt to use the graphs given.

~~To~~ when they are pulled apart, ~~then~~ their attractive force is greater because ~~as~~ the positively charged nuclei is attracted to the negative charged ~~of~~ electron on the outer shell of the another atom. when they are pushed together, the positive ~~neutrons~~ nucleus are closer and ~~like charge~~ same charges repel, therefore they are repulsive.

ResultsPlus

Examiner Comments

In this response, the charges on the nucleus and the electrons were being used in the explanation. This might explain the graphs given, but does not use them to answer the question.

Paper Summary

Overall, the average mark on this paper was 42/80, with a standard deviation of 13, and it therefore gave candidates of all abilities the opportunity to show what they knew.

Based on their performance on this paper, candidates are offered the following advice

- If a question is set in a context that you find hard to understand, remember that the majority of the questions within it will be set on physics that is generally applicable, and that can therefore be answered without reference to the context.
- It is important that candidates are able to apply the physics they have learnt to real situations.
- It is clear from this examination that candidates would benefit from more teaching time on vector diagrams, including relative velocity.
- Read the question carefully and answer just what is asked.
- Show all working in calculations, and beware of incorrect rounding of the answer.
- Not all the data given in a question needs to be used.

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

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