Examiners' Report

Principal Examiner Feedback

Summer 2024

Pearson Edexcel GCE

In A Level Further Mathematics (9FM0)

Paper 3C Mechanics 1

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General

Overall candidates were able to access all seven questions on this paper and time did not appear to be a limiting factor. Candidates were able to recall and use standard formulae and were familiar with the context given in all questions.

Although the presentation was generally good, candidates are advised to present solutions vertically down the page, using all the space available, and to avoid using arrows to direct examiners around their solution. When candidates use informal columns for working, it can be difficult for examiners to determine which part of the question the working belongs to.

If there is a printed answer to show, as in 2(a), 4(a), 7(a), 7(b) and 7(c), candidates need to ensure that they show sufficient detail in their working to warrant being awarded all of the marks available and that they end up with *exactly* what is printed on the question paper with no errors in the working. It is evident that many understand these requirements, clearly establishing necessary equations, including at least one line of working and re-arranging their final answer, when necessary, to match the printed answer.

In all cases, as stated on the front of the question paper, candidates should show sufficient working to make their methods clear to the examiner and correct answers without working may not score all, or indeed, any of the marks available.

If a candidate runs out of space in which to give their answer then they are advised to use a supplementary sheet – if a centre is reluctant to supply extra paper then it is crucial for the candidate to say whereabouts in the script the extra working is going to be done. Some candidates appeared to abandon their response to question 5 only for a different examiner to discover the completed working at the end of question 4, 6 or 7. Individual examiners do not have access to a full script so it is very poor exam practice, and puts marks at risk, if candidates do not indicate where a question is completed.

In calculations the numerical value of g which should be used is 9.8. Final answers should then be given to 2 (or 3) significant figures – more accurate answers will be penalised, including fractions but exact multiples of g are usually accepted.

Question 1

Providing an accessible start to the paper, this question was a good source of marks for candidates at all levels. Although solutions were often fully correct, even high attainers lost marks and made errors that could have been avoided with careful checking.

In part (a) the question asked for the total KE and therefore those who found KE terms but did not add them together were unable to gain any marks. Pythagoras was almost always used correctly to find the speed from the velocity vectors. However, some candidates forgot to square the speed when calculating KE. Unfortunately, without evidence of a correct KE formula, marks were unavailable. It is good exam technique to state a correct formula before its use, providing evidence of a correct method if computational errors occur.

The vast majority chose to use column vectors in parts (b) and (c) with great success. Column vectors are always acceptable throughout working but candidates are advised to double check the required format of the final answer. In this question, candidates were asked to give their final answers to parts (b) and (c) in terms of **i** and **j** and those who forgot or ignored the instruction, lost one mark.

Question 2

This question tested candidates on the work-energy principle, and it was incredibly rare to see an attempt using *suvat*, for which no marks were available. The scaffolded parts ensured that candidates considered friction from the outset and were using a correct expression moving into part (b).

Although most, at this level, are capable of writing down a correct expression for friction immediately, it was pleasing to see that candidates understood 'show that' requirements, resolving R correctly and using both $\frac{1}{7}$ and $\frac{4}{5}$ in their working before reaching the given answer.

Most made a confident start to part (b), establishing a work-energy equation with all required terms: GPE, KE and work-done against friction. Mistakes were rarely seen with signs or sin/cos confusion and candidates were clearly well-rehearsed, immediately stating the vertical height in terms of *d*. The most common error was to produce an equation with inconsistent units, using friction (newtons) instead of work-done against friction (joules). This is a costly mistake as there are no marks available for an equation that is dimensionally incorrect.

Question 3

The vast majority were able to demonstrate a good understanding of the relationship between the driving force and the power of an engine as they worked through this question.

Errors were most likely to occur in (a) and usually arose from a failure to convert the speed in the question from km h^{-1} to m s^{-1} which led to an incorrect answer of 64.8kW. Others forgot to give their final answer in kilowatts. Candidates should always check that they have answered the question fully and given their final answer in the required form.

Parts (b) and (c) were routine power problems based on a car travelling up an inclined plane. The power equation and N2L were used together successfully to find the acceleration in part (b) and the speed in part (c). It was very pleasing to see that the negative value for speed was either clearly rejected or never written down, demonstrating good exam technique.

In part (b) weak candidates were more likely to calculate the resultant force separately and then divide by mass to find the acceleration. The method mark is awarded when the relevant forces, mass and acceleration are correctly combined in one equation; delaying this puts marks at risk because any error made simplifying the resultant force, will bring an error into the equation of motion. High attainers are more likely to set up an equation of motion with all the force terms present and unsimplified on the LHS, and with mass $\times$ acceleration on the RHS, before processing.

For success in part (c), both the power and the resistance to motion were required in terms of *U*. Errors were rare but often the result of continuing to use 200 newtons from part (b) as the resistive force in part (c). Using an incorrect force in an equation of motion is a method error which can result in a significant loss of marks.

Question 4

This was a very popular question with candidates at all levels achieving most of the marks available.

In part (a) candidates confidently established equations for the conservation of linear momentum and Newton's Experimental Law. This routine process was well-rehearsed and candidates who made sign errors were able to use the given answer to identify the error and often made a full recovery by returning to their initial equations to follow the correction through. There was other evidence of good exam technique with candidates re-writing their velocity of *B* to match the printed answer *exactly*.

Candidates who were successful in part (a) usually earned the first two marks in part (b) for finding the velocity of *A*. However, the final mark required clear reasoning and precise language which presented more of a challenge and distinguished between the grades. Centres should advise candidates to avoid describing the direction of motion as 'to the left' or 'to the right'. It is much better to use phrases such as 'continues in the direction of motion' or 'reverses the direction of motion' or to describe the motion relative to an object defined in the question, in this case, a fixed wall.

Most candidates quickly identified the speed of *B* after colliding with the wall and used it successfully in part (b) to find the magnitude of the impulse, and in part (c) to find the loss in KE. The most common error in part (b) was a sign error in the rebound velocity which led to an incorrect impulse. Those who subtracted terms the wrong way round in parts (b) and (c) were more likely to recognise and correct the error.

Question 5

This question presented candidates with the first major challenge of the paper and whilst there were many excellent solutions, scores of 0 and 1 were not unusual. The unstructured format of this elasticity problem, and lack of a given answer, discriminated between the grades.

Well-prepared candidates successfully produced a clear diagram and presented energy terms in a table. This approach would usually avoid mistakes with lengths and prompted the need for two EPE terms. The conservation of energy could lead quickly to a quadratic equation in an unknown length and the required EPE could follow in just a few lines of working.

When solving problems involving EPE, it is recommended to state the EPE formula and show the full substitution. When candidates form an energy equation with simplified expressions, it can be very difficult for examiners to determine a valid method if mistakes are made.

Errors in energy terms were frequent amongst weaker candidates; the initial EPE was often forgotten, the GPE term was not in terms of an unknown distance and the final EPE was written as 'E' rather than in terms of an unknown length.

Despite the difficulties, candidates were reluctant to leave this question, instead producing pages of incorrect and crossed out working. Many appeared determined to complete the problem showing a confidence in the topic despite being unable to identify their error.

This 7-mark question gave two pages for working and some re-attempts were made elsewhere in the script rather than on additional sheets. A surprising number did so without any direction to the examiner. Examiners must be alerted to working elsewhere in the script otherwise candidates are at risk of losing marks.

Question 6

For many, the first part of this question on oblique impact, was the most challenging on the paper and candidates attempted a variety of approaches. The most successful, shown on the main mark scheme, used $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$ followed by $e = \dfrac{\mathbf{v}\cdot\hat{\mathbf{I}}}{-\mathbf{u}\cdot\hat{\mathbf{I}}}$. Well-prepared candidates used this approach with ease to obtain the correct answer.

A second popular and fairly successful, technique was to state the wall direction as $\mathbf{d} = x\mathbf{i} + y\mathbf{j}$ and the impulse direction as $\mathbf{I} = -y\mathbf{i} + x\mathbf{j}$. Those with strong algebraic skills produced simultaneous equations from $\mathbf{u}\cdot\mathbf{d} = \mathbf{v}\cdot\mathbf{d}$ and $e = \dfrac{\mathbf{v}\cdot\hat{\mathbf{I}}}{-\mathbf{u}\cdot\hat{\mathbf{I}}}$ processing them to obtain e.

It was very rare for candidates to use a matrix approach but those who did, demonstrated a solid understanding and usually did so successfully. Those who attempted to use trigonometry produced cumbersome algebra and were usually unsuccessful.

Many who struggled with part (a) made no attempt at part (b) despite it being more accessible. Those who produced a diagram usually found the required velocity successfully and progressed to find the angle of deflection using the scalar product. The inverse tan alternative was less popular but well-executed when accompanied by a diagram.

Question 7

The final question on the paper contained three parts, each with a given answer, providing an appropriate level of challenge to stretch high attainers. Whilst part (a) was routine bookwork, parts (b) and (c) demanded clear reasoning and precise language, providing candidates with an opportunity to demonstrate their knowledge and understanding of mechanics.

Many candidates at all levels made a confident start to part (a), labelling components on the given figure and making use of the directions of motion of A. Most assigned v as the speed of A after impact and w as the speed of B after impact. The majority recognised that the velocity component of A perpendicular to the line of centres remained unchanged, that B would move parallel to the line of centres and labelled the angle α appropriately for the motion of A after impact. Well-prepared candidates produced fluent solutions, forming equations for the conservation of linear momentum and Newton's Experimental Law and combined them to reach the given answer. It was rare for sign errors to occur, and these were easily rectified. Good exam technique was demonstrated with at least one line of working shown before reaching the given answer and the final answer re-written, if necessary, to ensure it was *exactly* as printed in the question.

Errors in part (a) were more likely to occur in solutions where candidates chose to draw their own diagram. These candidates were more likely to ignore the angle of deflection, producing a generic solution with additional angles for both particles after impact. With additional angles and sign differences, some solutions lacked fluency and failed to obtain the given answer from fully correct working. Candidates are advised to annotate a Figure when one is provided in the question, as it is usually in place to support understanding and aid progression.

Those who were well-prepared and successful in part (a) were quick to earn the first two marks in (b) by completing their simultaneous equations and finding an expression for the velocity component of *A* parallel to the line of centres after impact. The subsequent method mark was for establishing an appropriate inequality based on the direction of motion of *A* and high attainers showed confidence using mathematical notation. Weaker candidates were more likely to attempt an explanation using phrases such as ‘to the left’ which are not acceptable. To achieve the final mark in part (b), candidates were required to provide correct and complete reasoning to obtain the given answer, $e > \frac{1}{3}$, including justification of why dividing by $\cos\alpha$ did not change the inequality sign. Only the best candidates produced a fully correct solution.

Some candidates attempted part (b) without considering the context and proceeded along a path of trigonometric identities and algebraic manipulation. Solutions became very chaotic, and it was rare for any marks to be awarded.

The first mark in part (c) was given for recognising that the velocity component of *A* perpendicular to the line of centres is unchanged after impact. Although many candidates had abandoned the question by this point, the mark was often achieved by those who had clearly labelled the Figure provided. To reach the given inequality for $\tan\alpha$, candidates were required to consider the context of the question, in particular the perpendicular deflection of *A*. Those who were able to produce a correct equation in $\tan\alpha$ and e were usually able to justify the upper limit by stating $e \leq 1$ and processing correctly to reach $\tan\alpha \leq \frac{1}{\sqrt{2}}$. However, it was common for candidates to incorrectly use $e > \frac{1}{3}$, rather than the range of values of α, in an attempt to justify the lower limit.

Despite the level of challenge in this question, it was pleasing to see many well-presented and efficient solutions.

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