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Examiners' report

AS LEVEL

FURTHER MATHEMATICS B (MEI)

OCR Level 3 Advanced Subsidiary GCE in Further Mathematics B (MEI)

H635

For first teaching in 2017

Y411/01 Summer 2025 series

Version 1

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Contents

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Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate responses is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from Teach Cambridge.

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Paper Y411/01 series overview

Most of the candidates demonstrated their knowledge and understanding of several topics, particularly in Questions 1 (dimensional analysis), 2 (triangle of forces) and 3 (work, power and energy). The later questions were found to be more difficult, and parts 4 (b), 5 (d) and 7 (a) were especially challenging for many candidates. The last two of these involved taking moments of forces about a point, and on this paper few candidates were able to write down a single fully correct moments equation.

The average mark was about the same as last year, although there were far fewer candidates with marks above 50 (out of 60).

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• attempted all parts of all the questions • set out their work clearly and in a logical order • explained where their equations came from • understood how to take moments • understood the concept of a couple.	• left several parts unattempted • produced work which was not well organised and difficult to follow • wrote down equations without explanation • did not understand how to take moments about a point.

Assessment for learning

Candidates should be encouraged to set out their work clearly, and to explain what they are doing, for example 'Using the work-energy principle', 'By the conservation of momentum', 'Taking moments about A' and so on.

This is particularly important when the answer is given on the question paper, or when **detailed reasoning** is required.

When the answer is wrong, or the answer is given on the question paper, method marks can only be given if the candidate's work is convincing.

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Question 1 (a)

1 A system consists of an object performing oscillations whilst suspended at the end of a spring S.

The period, t, is defined as the time taken for the object to complete one oscillation. The period is given by the formula

$$t = \lambda m^{\frac{1}{2}} k^{-\frac{1}{2}},$$

where

- λ is a constant,
- m is the mass of the object,
- k is the stiffness of S.

One possible unit which k can be measured in is $\mathrm{kg\,s^{-2}}$.

(a) Show that λ is dimensionless. **[3]**

Almost all candidates scored full marks on this part. A few did not state their conclusion (that λ is dimensionless) after an otherwise correct argument.

Question 1 (b)

For a given object P and S, the period of one oscillation is measured to be 1.48 seconds, correct to 3 significant figures. The object P is replaced with another object Q which has **three** times the mass of P.

(b) Find an estimate for the period of one oscillation of Q and S. **[1]**

This was less well answered, but most candidates correctly multiplied 1.48 by $\sqrt{3}$. Common errors were multiplying by 3 or dividing by $\sqrt{3}$.

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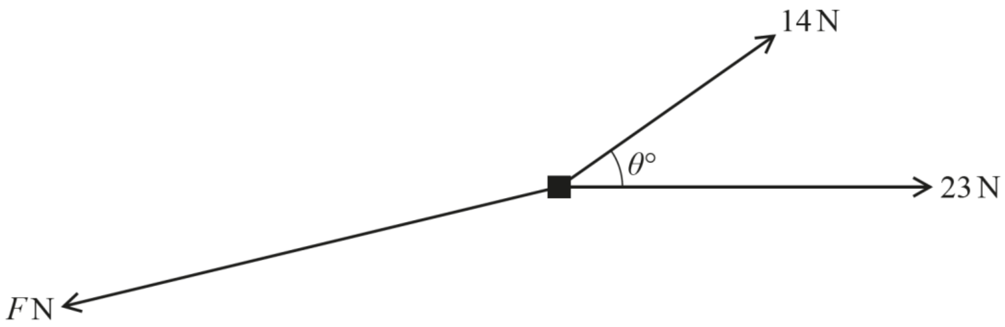
Question 2 (a)

2 A small block of mass 5 kg is placed on a rough horizontal surface. The coefficient of friction between the block and the surface is $\frac{5}{7}$.

Two **horizontal** pulling forces act on the block. One pulling force has a magnitude of 14 N, and the other pulling force has a magnitude of 23 N. The **plan-view** diagram shows these two forces, along with the frictional force of magnitude F N, exerted by the surface on the block. The angle between the two horizontal forces acting on the block is $\theta°$. There are **no** other horizontal forces acting on the block. The block is in limiting equilibrium.



(a) Show that $F = 35$. **[1]**

Most candidates realised that they should use the coefficient of friction and the normal reaction to calculate the limiting frictional force. There were some attempts to use the 14 and 23.

Question 2 (b)

(b) Draw a triangle of forces to represent the system shown in the diagram. **[2]**

Many candidates drew a correct diagram. The triangle of forces should indicate the magnitudes and directions of all three forces, and should show the angle θ; the most common error was the omission or misplacement of θ. Some diagrams showed the subtraction of the two pulling forces instead of addition.

Question 2 (c)

(c) Determine the value of θ. Give your answer correct to **3** significant figures. **[2]**

Most candidates applied the cosine rule to find an angle of the triangle, although it was often not the appropriate one for finding θ. A few candidates did not follow the instruction to give their answer correct to 3 significant figures. This risks not gaining a mark, but on this occasion any value rounding to 39.1° was accepted for full marks.

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Question 2 (d)

The value of θ is now increased slightly.

(d) Explain what happens to the block. **[1]**

Most candidates stated that the block would move. Some suggested that the block would lift off the surface, presumably misunderstanding that the pulling forces were horizontal. The reality is that increasing the angle between the pulling forces will reduce the magnitude of their resultant, and so the block will not move. Very few candidates earned this mark, which required a statement that the block remains at rest, supported by a valid explanation such as 'it is no longer in limiting equilibrium'.

Question 3 (a)

3 In parts (a) and (b) of this question you should assume that the car experiences no resistances to motion.

A car of mass 1200 kg is moving on a straight road.

At first the car travels **up** a section of the road inclined at 3° to the horizontal.

(a) Determine the power developed by the car at the instant when it has a speed of $22\,\mathrm{m\,s^{-1}}$ and is accelerating at $0.4\,\mathrm{m\,s^{-2}}$. **[3]**

Almost all candidates understood the relationship between power, driving force and speed, and most answered this correctly. Many candidates omitted the component of weight from their equation of motion, and worked with a driving force of 480 N.

Question 3 (b)

The maximum power that can be developed by the car is 40 kW.

(b) Calculate the greatest speed that can be maintained by the car when travelling up the road. **[2]**

About half the candidates answered this correctly. The most common error was to assume that the driving force was the same as in part (a).

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Question 3 (c)

The car now moves **down** a section of the road inclined at 5° to the horizontal.

The car passes a signpost as it is travelling at $28\,\mathrm{m\,s^{-1}}$. At that instant, the driver applies the brakes, so that 600 m later, when it passes a second signpost, the car has slowed down to $15\,\mathrm{m\,s^{-1}}$. You should assume that the car experiences no other resistances to motion.

(c) Determine the work done by the braking force of the car as it travels between the two signposts. **[4]**

About a third of the candidates scored full marks on this part, usually by applying the work-energy principle. The gravitational potential energy was sometimes omitted and sometimes doubled (by also including the work done by the weight), and there were often sign errors in the equation. After finding the work done, several candidates went on to divide this by 600 (obtaining the average braking force), as in the following exemplar.

Exemplar 1

3(c)	$\frac{1}{2} \times 1200 \times 28^2 = 470400$ ←	$135000 = 0.5 \times 1200 \times 15^2$ $1200 \times 9.8 \times \sin(5) \times 600 = 614970$
	$470400 + 614970 - 135000 = 950370$ J	
	$\frac{950370}{600} = \underline{1583.95\ \mathrm{N}}$ W F = Fd	

Here the energy terms are not identified (as kinetic energy and potential energy) but are put together correctly into an energy equation, giving the work done as 950370 J (which is the correct answer). However, it is not clear that this is the candidate's intended answer, and their final underlined answer of 1583.95 N will be marked, so they lose the final mark. If they had written '= work done' next to 950370 J they would have scored the mark even with the additional working.

Some candidates did not use energy, but found the deceleration, used Newton's second law to find the braking force, then multiplied by the distance to calculate the work done. This method requires the additional assumption that the braking force (and hence the deceleration) is constant, which is not given. However, this is a reasonable assumption, and, on this occasion, it was accepted for full marks.

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Question 3 (d)

(d) State **one** way in which the modelling of the car's motion in this question could be refined. **[1]**

Most candidates earned this mark, usually by mentioning air resistance or other possible resistances. Some suggested friction between the tyres and the road. This is what produces the driving force and so is already included in the model; it was not accepted if it was the only feature mentioned.

Question 4 (a)

4 Two small trucks, A and B, are at rest on a smooth horizontal track. The mass of A is 2 kg, and the mass of B is 3 kg. At one end of the track there is a fixed bumper, as shown in the diagram. When the trucks touch, they become permanently attached to each other and form a single object AB.

Truck A is set in motion towards the bumper with speed $8\,\mathrm{m\,s^{-1}}$. At the same instant, truck B is also set in motion towards the bumper with speed $4\,\mathrm{m\,s^{-1}}$.

(a) State the initial impulse required to set A in motion. **[2]**

Almost all candidates calculated the magnitude of the impulse correctly. Impulse also has a direction, and in this series, there was a mark specifically for stating its direction. Very few candidates earned this mark.

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Question 4 (b)

You are given the following information.

- The coefficient of restitution between B and the bumper is e.
- If A collides with B **before** B reaches the bumper, the speed of AB after it hits the bumper is $v\,\mathrm{m\,s^{-1}}$.
- If B collides with the bumper first and then collides with A, after this second collision AB moves towards the bumper with speed $v\,\mathrm{m\,s^{-1}}$.
- All impacts are direct.

(b) Determine the following in either order.

- The value of e
- The value of v

[7]

This was found by many candidates to be difficult, and few candidates were completely successful. Although the principles of conservation of momentum, and restitution, appeared to be understood, equations were very often written down without any explanation of which scenario was being considered. This made the work hard to follow and often prevented the candidate from making progress. In the first scenario, many candidates used *v* for the speed of the attached trucks AB before hitting the bumper, which then became confused with the *v* defined in the question, which is the speed after hitting the bumper. This often led to $e = 1$ and $v = 5.6$. In the following exemplar (which is the first part of the candidate's response) the work is organised and presented well.

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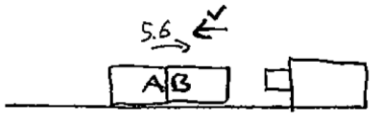
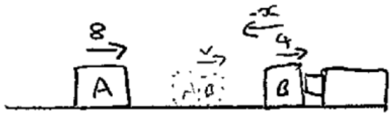
Exemplar 2

4(b)

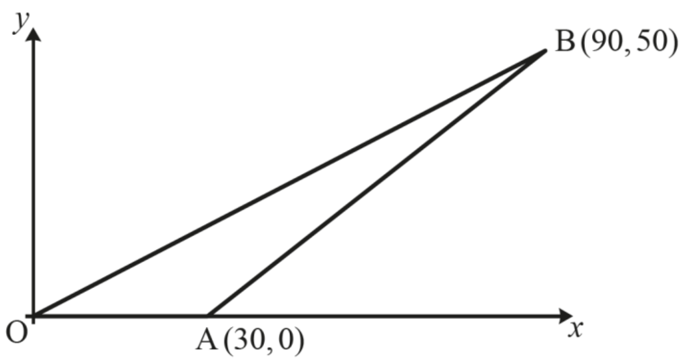
Senario 1	Senario 2
	
Senario 1: Momentum before AB collide = (2x8)+(3x4)	Senario 2: Speed of B after hitting bumper. $\frac{v_2 - v_1}{u_1 - u_2} = e = \frac{0-x}{4-0}$
16+12=28	$e = \frac{-x}{4}$ $4e=-x$
Speed of AB after collision is 28 ÷ (3+2) = 5.6 ms⁻¹	Momentum is conserved - collision between A and B. $(8\times2)+(x\times3) = (v\times5)$
$\frac{0-v}{5.6} = e$ $-v = 5.6e$	$16+3x = 5v$ $-x = 4e$
$v = -5.6e$	$16+12e = 5v$ $x = -4e$ $3x = -12e$

There are diagrams for each scenario, and all the workings are clearly explained. This candidate has made some sign errors (the equations resulting from the two scenarios should be $v = 5.6e$ and $16 - 12e = 5v$), but they did score 5 marks out of 7.

Question 5 (a)

5 **Fig 5.1** shows a uniform triangular lamina OAB where O is the origin of the coordinate system in which the points A and B have coordinates (30, 0) and (90, 50) respectively.

Fig 5.1



(a) Calculate the coordinates of the centre of mass of OAB. **[2]**

Most candidates answered this correctly.

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Question 5 (b)

The lamina OAB is the cross-section through the centre of mass of a uniform solid prism S.

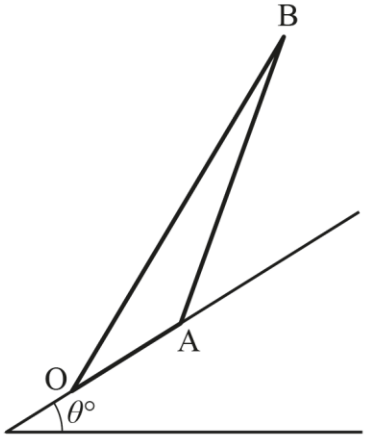
(b) Explain why S can **not** rest in equilibrium if OA is placed on a horizontal surface. **[1]**

Candidates were expected to use the *x*-coordinate to explain that the centre of mass is to the right of A, and about one third of them earned the mark. Many made a general statement such as 'the centre of mass is not above the base', which, by itself, was insufficient.

Question 5 (c)

The prism S now rests in equilibrium on a rough plane inclined at an angle of $\theta°$ to the horizontal, as shown in **Fig. 5.2**. The line OA lies along a line of greatest slope of the plane.

Fig. 5.2



(c) Assuming that S does not slide, calculate the least possible value of θ. **[2]**

Most candidates understood that the centre of mass was vertically above A, but only about one fifth of them used this correctly to find the angle θ. Common errors were $\tan^{-1}(\frac{\bar{y}}{\bar{x}-30})$ or $\tan^{-1}(\frac{\bar{x}}{\bar{y}})$ instead of $\tan^{-1}(\frac{\bar{x}-30}{\bar{y}})$.

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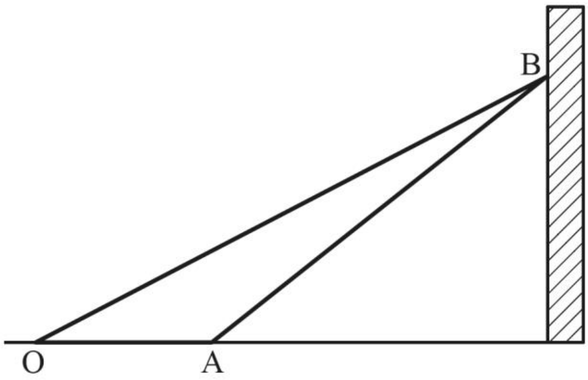
Question 5 (d)

Prism S is now placed on rough horizontal ground so that OA is horizontal, but with B in contact with a smooth vertical wall, as shown in **Fig. 5.3**. The vertical plane containing O, A and B is perpendicular to the wall.

Fig. 5.3



The coefficient of friction between S and the ground is μ. You are given that S is in limiting equilibrium with the total contact force exerted by the ground on S acting at A.

(d) Determine the value of μ. **[4]**

This part was found to be challenging, and only a few candidates scored full marks. Most candidates showed forces on the diagram, although the normal reactions were often omitted or misplaced. Horizontal and vertical equilibrium, and $F = \mu R$, were well understood, but few candidates wrote down a correct moments equation. There was confusion over the perpendicular distances and, especially when taking moments about O or B, some of the forces were often omitted. Many candidates made no attempt to take moments.

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Question 6 (a)

6 Throughout this question you should assume that there is no air resistance.

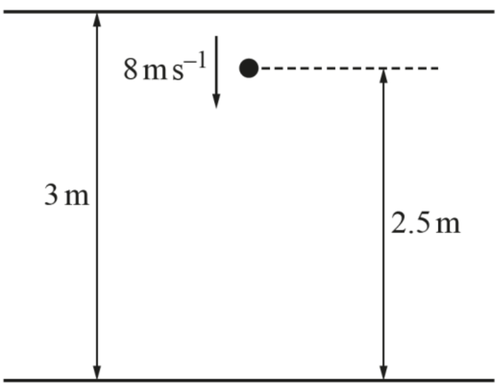
A particle is projected vertically upwards with speed $u\,\mathrm{m\,s^{-1}}$.

(a) Show that the particle will reach a height of 3 m above the point of projection if $u^2 \geqslant 58.8$. **[2]**

Those who considered energy and started with $\frac{1}{2}mu^2 \geq mg(3)$ could obtain the required result almost immediately. Most candidates used the constant acceleration formulae to show that the particle will reach a maximum height of 3 m when $u^2 = 58.8$, and many did not explain where the inequality comes from. A statement such as 'this is the minimum speed to reach 3 m' or 'to reach a height of 3 m or more…' was needed to earn the final mark.

Question 6 (b)

The diagram shows a horizontal floor and a horizontal ceiling. The vertical distance between the floor and ceiling is 3 m. A particle is held 2.5 m above the floor and is projected vertically downwards with speed $8\,\mathrm{m\,s^{-1}}$. The coefficient of restitution between the particle and the floor is 0.95. The coefficient of restitution between the particle and the ceiling is 1.



(b) Show that the particle will have a speed of $10.1\,\mathrm{m\,s^{-1}}$ immediately after the first impact with the floor, correct to **3** significant figures. **[3]**

Most candidates answered this correctly.

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Question 6 (c)

(c) Hence, using part **(a)**, show that the particle will reach the ceiling after the first impact with the floor. **[1]**

The question requires the use of part (a), and the result follows immediately when the given answer to part (b) is tested in the given inequality in part (a). Many candidates worked independently of part (a), for example finding the speed when the particle reaches the ceiling or finding the potential height (which the particle would reach if the ceiling were not there). On this occasion, correct explanations independent of part (a) were accepted, and most candidates earned the mark.

Assessment for learning

A question sometimes specifies the method which should be used.

A candidate may not gain marks if they use an alternative method, even when it is correct.

Question 6 (d)

(d) Explain why the speed of the particle immediately before the second impact with the floor is the same as the speed of the particle immediately after the first impact with the floor. **[1]**

Most candidates answered this correctly. The crucial point is that the coefficient of restitution with the ceiling is 1, and so no energy is lost in that collision.

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Question 6 (e)

(e) In this question you must show detailed reasoning.

Find the number of times the particle hits the ceiling. **[4]**

This question asks for detailed reasoning, and so all steps and calculations should be fully explained. In the standard approach, the speed on reaching the floor for the first time is $\sqrt{113}\ \mathrm{ms^{-1}}$ and so the condition for the particle to hit the ceiling for the *n*th time is $\sqrt{113} \times 0.95^n \geq \sqrt{58.8}$. Solving this gives $n \leq 6.37$ and so the particle hits the ceiling 6 times. Candidates often did not gain marks for the following reasons: not explaining what *n* was or what their inequality or equation meant (reaching or not reaching the ceiling); not showing the use of logarithms or the results of trials when solving; not explaining how their final answer follows from their working (especially when they used an equation rather than an inequality).

About one third of candidates used a step-by-step approach, calculating values of the launch speed after successive bounces, until the speed became lower than $\sqrt{58.8}$. Marks were often lost for not giving full details of the calculations being done, or for not explaining clearly how their answer follows from their values.

With both approaches there were several variations, such as working with the potential heights, or energy, or considering the speed when the particle reaches the ceiling. In the case of the heights, some candidates knew that successive heights were in the ratio $1: 0.95^2$, but others incorrectly multiplied by 0.95.

Many candidates made good progress in this part, but only few scored full marks.

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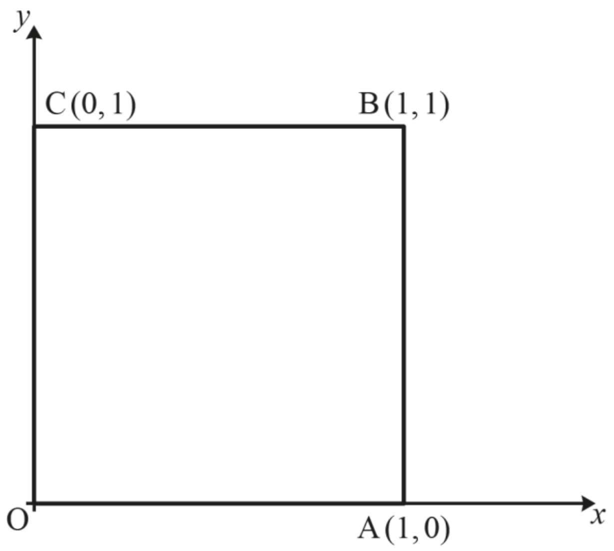
Question 7 (a)

7 The diagram shows a light square lamina OABC where O is the origin of the coordinate system in which the points A, B and C have coordinates (1, 0), (1, 1) and (0, 1) respectively. Coordinates refer to the axes shown and the units are metres.



The following three forces are applied to the lamina.

$\begin{pmatrix} p \\ 2q \end{pmatrix}$ N at the point $(1, 0.5)$

$\begin{pmatrix} -3q \\ p \end{pmatrix}$ N at the point C

$\begin{pmatrix} 10 \\ -50 \end{pmatrix}$ N at the point $(r, 0)$, where $0 \leqslant r \leqslant 1$

The three forces form a couple of magnitude 13 N m in the anticlockwise direction.

(a) Determine the values of p, q and r. **[5]**

Many candidates used the fact that the resultant force was zero to find the values of *p* and *q* correctly, although some set one of the forces equal to the sum of the other two. Most attempted to take moments, but taking account of all six force components, with their associated distances and directions, proved to be challenging, and very few candidates wrote down a fully correct moments equation. The total moment of all the forces was sometimes equated to zero, instead of the given moment of the couple.

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Question 7 (b)

The three forces are removed. The lamina is in the same position as shown in the diagram.

Three particles are now attached to certain points on the lamina as follows.

- A particle of mass 2 kg at the point (λ, λ^2), where $0 \leqslant \lambda \leqslant 1$
- A particle of mass 3 kg at the point A
- A particle of mass 1 kg at the point C

(b) Find the coordinates of the composite body's centre of mass. Give your answer in terms of λ. **[3]**

This was quite well understood, and about half the candidates answered it correctly. Although the lamina is described as 'light', some candidates included a mass for the lamina in their calculations.

Question 7 (c)

(c) Show that, as λ varies, the centre of mass of the combined object lies on the curve

$$y = 3x^2 - 3x + k ,$$

where k is a constant to be determined. **[3]**

This part was often omitted or poorly attempted (equating the *x* and *y* coordinates of the centre of mass was fairly common). Correct responses used one of two possible approaches, which occurred with approximately equal frequency. One was to eliminate λ to obtain the given equation; the other was to verify that the coordinates satisfy the equation for all λ. Many candidates took one particular centre of mass (usually the one corresponding to $\lambda = 0$) and substituted it into the given equation; this finds the value of *k* but does not show that the centre of mass always lies on the curve.

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