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Examiners' report

FURTHER MATHEMATICS B (MEI)

H645

For first teaching in 2017

Y431/01 Summer 2024 series

Version 1

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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 answers 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 OCR.

Paper 1 series overview

This is the Mechanics Minor component of the A Level specification H645: Further Mathematics B (MEI). It is a 1 hour 15-minute paper worth 60 marks.

This report will focus on areas of improvement based on the responses given by this year's cohort. However, this should not imply that the solutions seen were produced to a low standard. Very many scripts were produced to a very high standard and demonstrated candidates' mathematical understanding and their problem-solving abilities. There were candidates that scored full marks, with the median above half marks and a normal distribution showing negative skew.

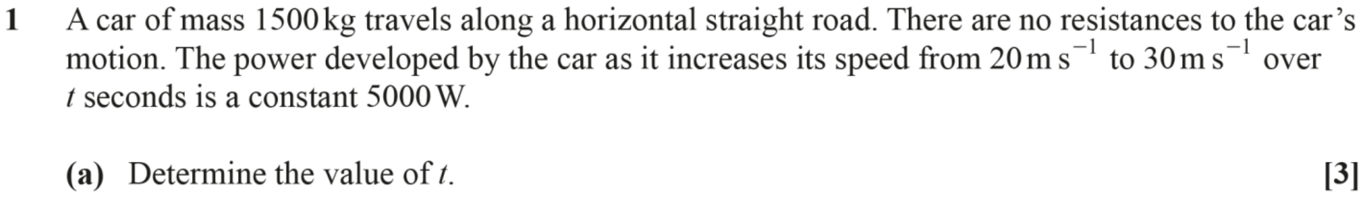
Most candidates exhibited excellent algebraic skills but some provided comparatively little written explanation to justify choices or show their understanding of physical situations. Not only would this secure additional marks, it would also support candidates' own understanding of the question context and focus their reasoning. Some questions made explicit request for clear working to be shown with the 'determine' and 'show that' commands. Those who provided consistently complete solutions for all questions, regardless of the command words used, were ultimately most successful in demonstrating their understanding of the problems and modelling them correctly. This was particularly noticeable for those candidates who produced and annotated their own diagrams and organised information in tables.

Candidates whose solutions commenced with full equations performed noticeably better than those who calculated separate numerical values which they then aggregated. This was especially apparent in calculations involving the work, energy and power equations when sign errors were introduced and some components the values of some terms were omitted.

Candidates used their calculators appropriately. However, there was evidence of unchecked solutions which could have been performed by a calculator and occasionally large numbers of written intermediate numerical results indicating that calculators had not been used in the most effective manner.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• started solutions with full equations, for example work energy and power equations • produced clear diagrams to support their understanding of physical situations • indicated to themselves and examiners the signing of the direction of vector quantities • used table to organise the components of their calculations • provided written explanations to interpret the results they calculated • understood what was expected by each of the given command words in the questions • produced structured solutions • used calculators to support their solutions appropriately • used concise technical vocabulary.	• calculated individual numerical terms rather than using complete equations • used fewer diagrams and tables • did not produce sufficient working to support their solutions particularly when dictated by the 'show that' or 'determine' command words • made errors transcribing information from the questions • did not consider all information from questions • did not consider the relationship between parts of questions.

Question 1 (a)



1 A car of mass 1500 kg travels along a horizontal straight road. There are no resistances to the car's motion. The power developed by the car as it increases its speed from 20 m s^{-1} to 30 m s^{-1} over t seconds is a constant 5000 W.

(a) Determine the value of t. **[3]**

Many candidates used considered the work done on the car to correctly answer this question. However, a significant number attempted to apply the equations of motion with constant acceleration.

Misconception

Misconception by some candidates that in this question acceleration is constant.

Question 1 (b)

(b) Find the acceleration of the car when its speed is 25 m s^{-1}. **[2]**

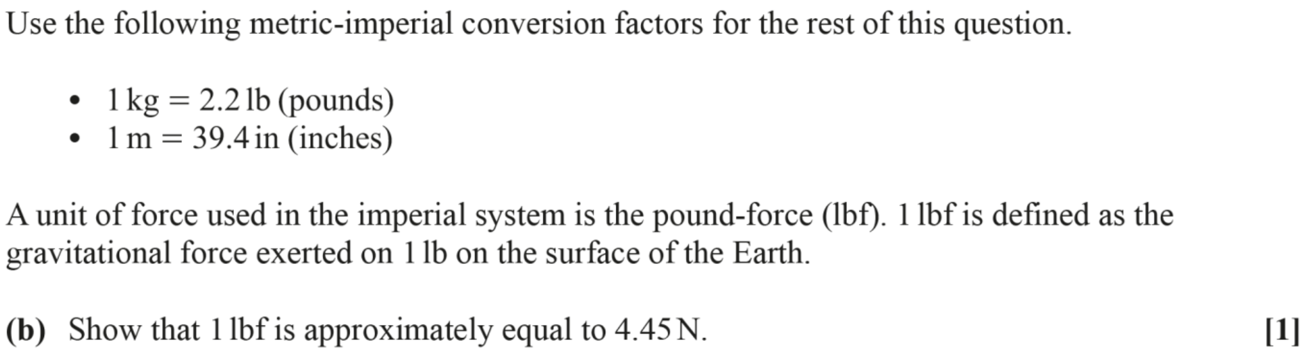
This was generally well answered with the majority using the power to correctly find the driving force and hence acceleration.

Question 2 (a)

2 **(a)** State the dimensions of force. **[1]**

Most candidates correctly gave answers using dimensions, only a very small number responded with fundamental SI units.

Question 2 (b)



Use the following metric-imperial conversion factors for the rest of this question.

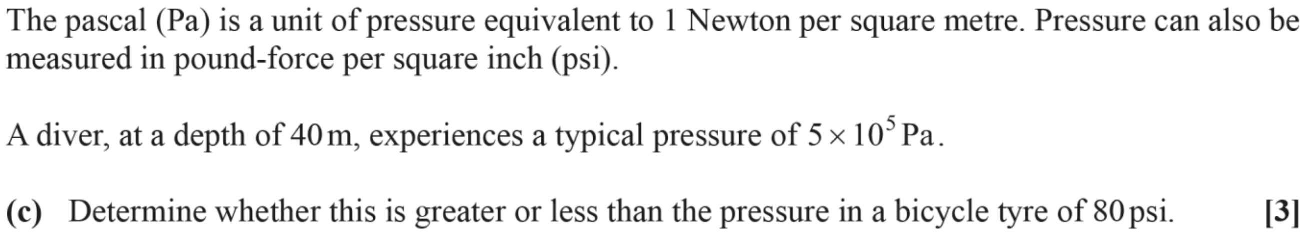
- 1 kg = 2.2 lb (pounds)
- 1 m = 39.4 in (inches)

A unit of force used in the imperial system is the pound-force (lbf). 1 lbf is defined as the gravitational force exerted on 1 lb on the surface of the Earth.

(b) Show that 1 lbf is approximately equal to 4.45 N. **[1]**

This was shown clearly by the majority of candidates, a small number neglected to include gravitational acceleration in their calculations.

Question 2 (c)



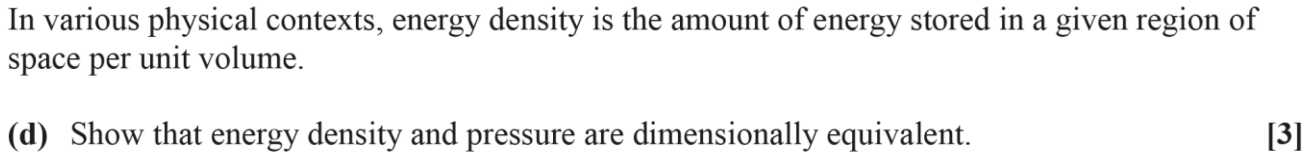
The pascal (Pa) is a unit of pressure equivalent to 1 Newton per square metre. Pressure can also be measured in pound-force per square inch (psi).

A diver, at a depth of 40 m, experiences a typical pressure of 5×10^5 Pa.

(c) Determine whether this is greater or less than the pressure in a bicycle tyre of 80 psi. **[3]**

Candidates generally understood that the number of square inches in a square metre was required along with the answer to Question 2 (b). The most common error was to divide or multiply incorrectly by one of the conversion factors while applying the other correctly.

Question 2 (d)



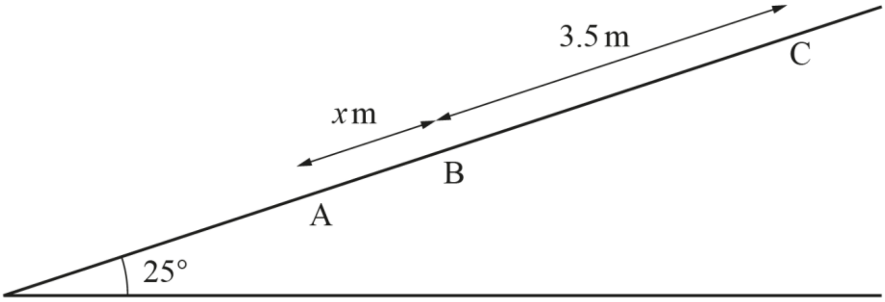
In various physical contexts, energy density is the amount of energy stored in a given region of space per unit volume.

(d) Show that energy density and pressure are dimensionally equivalent. **[3]**

Candidates almost universally used standard methods to show these quantities are dimensionally equivalent.

Question 3 (a) (i)

3 The diagram shows the three points A, B and C that lie along a line of greatest slope on a rough plane which is inclined at an angle of 25° to the horizontal.



A block of mass 6 kg is placed at B and is projected up the plane towards C with an initial speed of $u\,\mathrm{m\,s^{-1}}$. The block travels 3.5 m before coming instantaneously to rest at C, before sliding back down the plane. When the block is sliding back down the plane it attains its initial speed at A, which lies x m down the plane from B.

It is given that the work done against resistance throughout the motion is 4 joules per metre.

(a) Use an energy method to determine the following.

(i) The value of u **[3]**

The vast majority of candidates attempted this question using energy methods as requested. A very small number used the constant acceleration equations for both parts of the question. In addition to algebraic errors the most common errors were to sign the work done and gravitational potential energy incorrectly.

Assessment for learning

Candidates need to follow commands in questions including requirements to use specific methods.

Question 3 (a) (ii)

(ii) The value of x **[3]**

This was well answered by most candidates, and even those who calculated an incorrect velocity in part (a) calculated a correct value of x for their velocity.

Question 3 (b)

A student claims that half of the energy lost due to resistances is accounted for by friction between the block and the plane, and the other half by air resistance.

(b) Assuming that the student's claim is correct, determine the coefficient of friction between the block and the plane. **[3]**

The most common error in this part was to not halve the total resistance to give the resistance due to friction.

Assessment for learning

Reinforce the need for candidates to scrutinise the introductions to sub parts of questions for additional information and instructions.

Question 4 (a)

4 **Fig. 4.1** shows two spheres, A and B, on a smooth horizontal surface. Their masses are 3 kg and 1 kg respectively.

Fig. 4.1

Initially, sphere A travels at a speed of $1\,\mathrm{m\,s^{-1}}$ in a straight line towards B, which is at rest. The spheres collide and the coefficient of restitution between A and B is e.

(a) Show that, after the collision, A has a speed of $\frac{1}{4}(3-e)\,\mathrm{m\,s^{-1}}$, and find an expression for the speed of B in terms of e. **[4]**

In the main candidates successfully applied the principle of the conservation of momentum and Newton's law successfully to find both the speed of A and B.

Question 4 (b)

During the collision, the kinetic energy of the system decreases by 21%.

(b) Determine the value of e. **[3]**

This was a generally well answered question apart from small algebraic slips. The only conceptual error was applying the factor (0.79) to reduce the kinetic energy incorrectly.

Question 4 (c)

(c) State why in part **(a)** it was necessary to assume that A and B have equal radii. **[1]**

Very few candidates stated that this would ensure the impact was direct but many described the situation in suitable depth.

Assessment for learning

Candidates' descriptions of physical situations would be clearer if the correct technical vocabulary was used.

Question 4 (d)

Fig. 4.2 shows two spheres, C and D, of equal radii on a smooth horizontal surface. Their masses are 1 kg and 2 kg respectively.

Fig. 4.2

Spheres C and D travel towards each other along the same straight line, C with a speed of $u\,\mathrm{m\,s^{-1}}$ and D with a speed of $1\,\mathrm{m\,s^{-1}}$. The spheres collide and during the collision C exerts an impulse on D of magnitude $\frac{2}{3}(u+1)\,\mathrm{N\,s}$.

(d) Show that C and D have the same velocity after the collision. **[4]**

Incorrect answers inevitably arose from incorrect signs of the impulse and/or initial velocities.

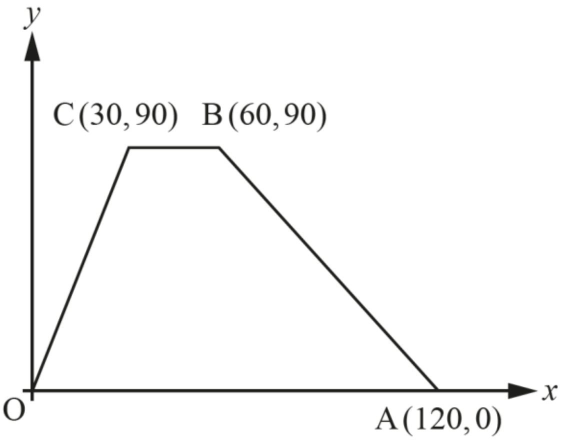
Question 4 (e)

(e) Determine the fraction of kinetic energy lost due to the collision between C and D as $u \to \infty$. **[3]**

Those that created a fractional expression invariably calculated the correct final value. Unfortunately, many candidates only produced an expression for the absolute change in kinetic energy.

Question 5 (a)

5 A uniform lamina OABC is in the shape of a trapezium where O is the origin of the coordinate system in which the points A, B and C have coordinates (120, 0), (60, 90) and (30, 90) respectively (see diagram). The units of the axes are centimetres.

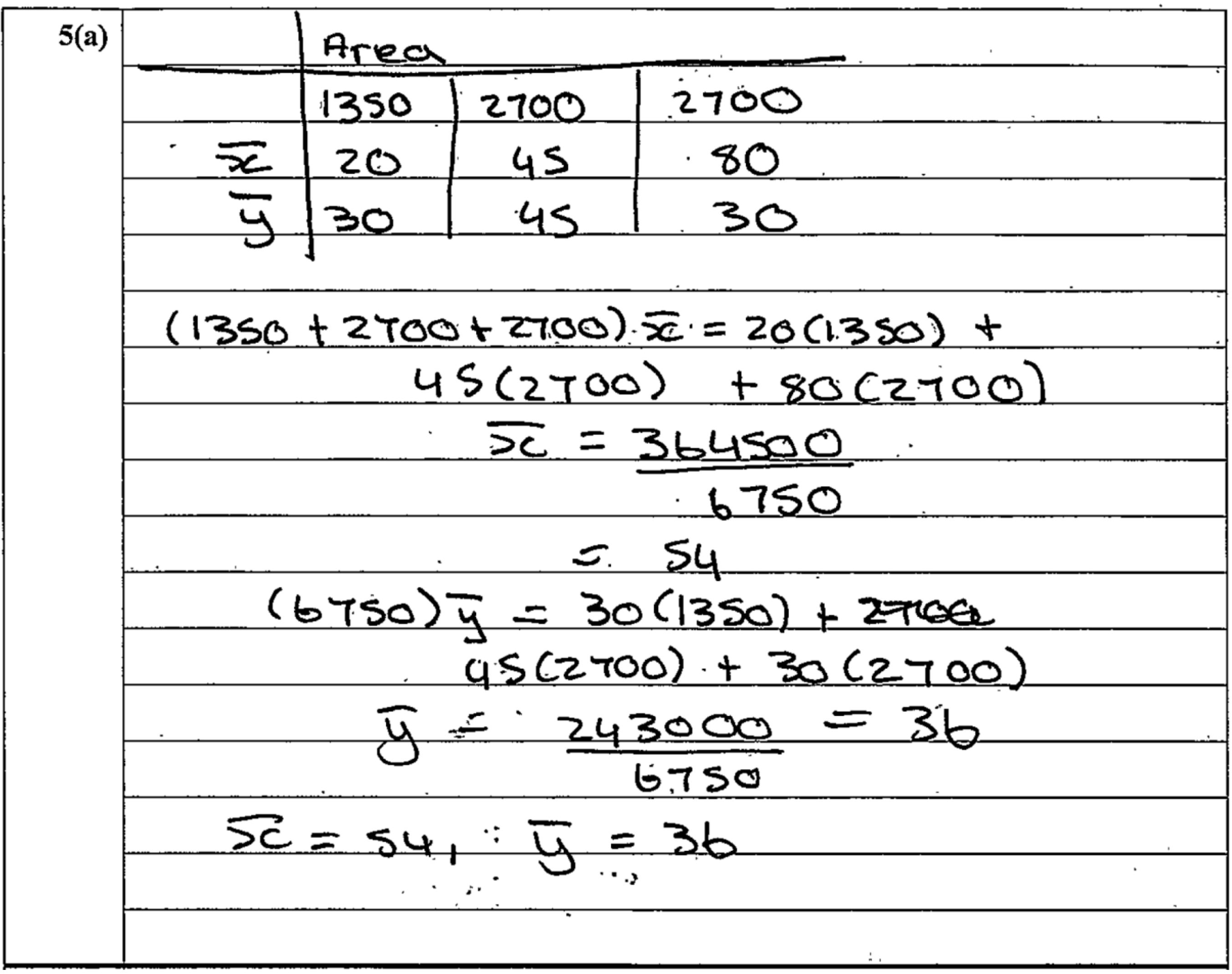


The centre of mass of the lamina lies at $(\overline{x}, \overline{y})$.

(a) Show that $\overline{x} = 54$ and determine the value of $\overline{y}$. **[5]**

Candidates appeared confident with answering this question. Many candidates used the vector notation shown in the mark scheme. However, those candidates that set out their initial working as a table, before forming separate equations for *x* and *y* components, were generally less likely to have arithmetic mistakes.

Exemplar 1



5(a)

	Area		
	1350	2700	2700
$\bar{x}$	20	45	80
$\bar{y}$	30	45	30

$(1350 + 2700 + 2700)\bar{x} = 20(1350) + 45(2700) + 80(2700)$

$\bar{x} = \frac{364500}{6750}$

$= 54$

$(6750)\bar{y} = 30(1350) + 2700$
$45(2700) + 30(2700)$

$\bar{y} = \frac{243000}{6750} = 36$

$\bar{x} = 54, \bar{y} = 36$

This exemplar shows a typical approach using a table to record the coordinates for the two triangles and one rectangle that make up the composite body. Separate equations have then been formed in the *x* and *y* directions which can then be solved accurately.

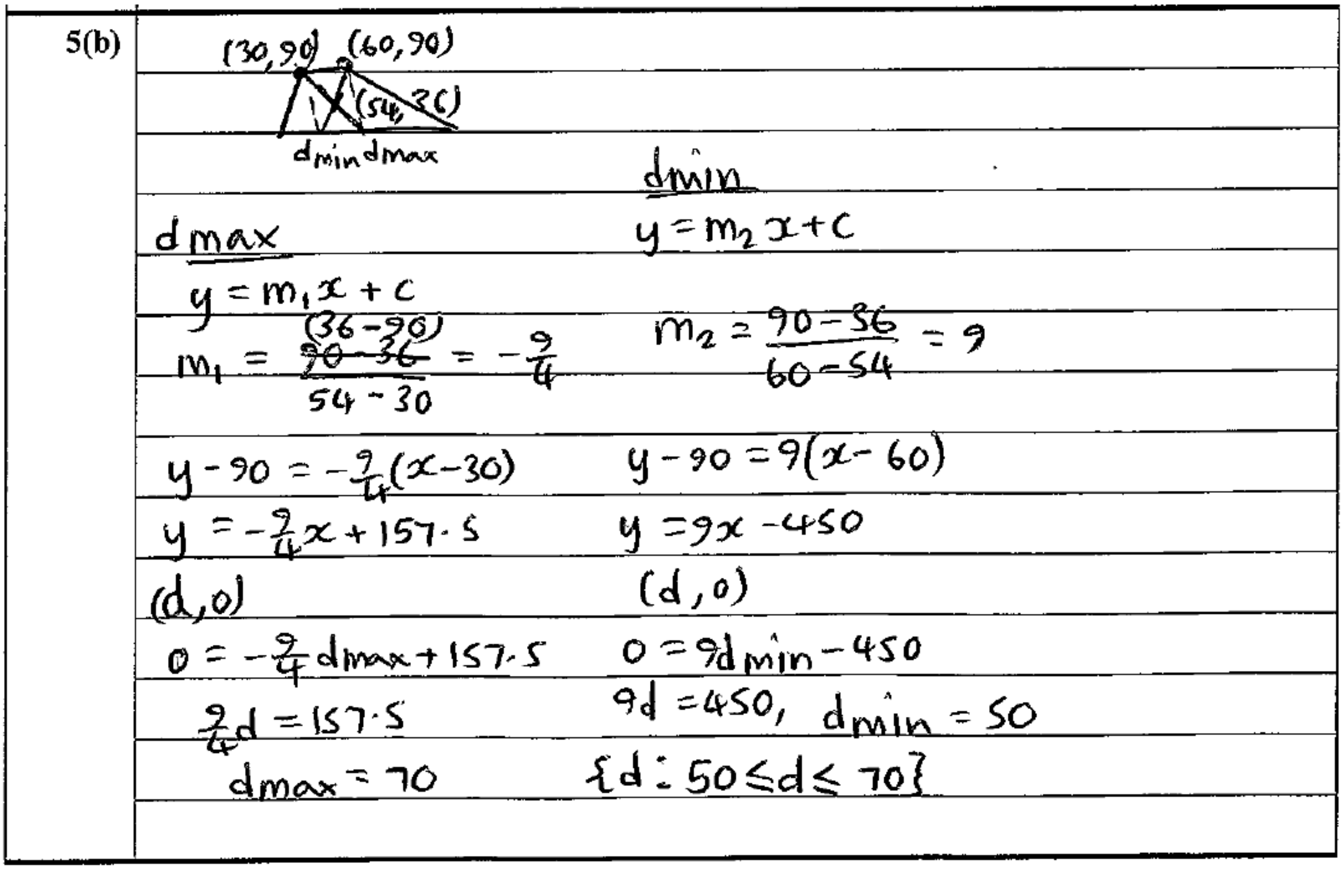
Question 5 (b)

The lamina is placed horizontally so that it rests on three supports, whose points of contact are at B, C and D, where D lies on the edge OA and has coordinates (d, 0).

(b) Determine the range of values of d for the lamina to rest in equilibrium. **[3]**

The most successful solutions were often accompanied by a drawing indicated the lines denoting the limiting values as shown in Exemplar 1.

Exemplar 2



5(b)

(30,90) (60,90)

(54,36)

dmin dmax

dmax

$y = m_1 x + c$

$m_1 = \frac{\cancel{90-36}\ (36-90)}{54-30} = -\frac{9}{4}$

$y - 90 = -\frac{9}{4}(x - 30)$

$y = -\frac{9}{4}x + 157.5$

$(d, 0)$

$0 = -\frac{9}{4}d_{max} + 157.5$

$\frac{9}{4}d = 157.5$

$d_{max} = 70$

dmin

$y = m_2 x + c$

$m_2 = \frac{90-36}{60-54} = 9$

$y - 90 = 9(x - 60)$

$y = 9x - 450$

$(d, 0)$

$0 = 9d_{min} - 450$

$9d = 450,\ d_{min} = 50$

$\{d : 50 \leq d \leq 70\}$

The diagram in this exemplar, although quite small, is neat and supports a clear solution via the equations of the lines. Some candidates produced untidy diagrams with subsequent arithmetic errors that suggest that they struggled to read their own values.

Question 5 (c)

It is now given that $d = 63$, and that the lamina has a weight of 100 N.

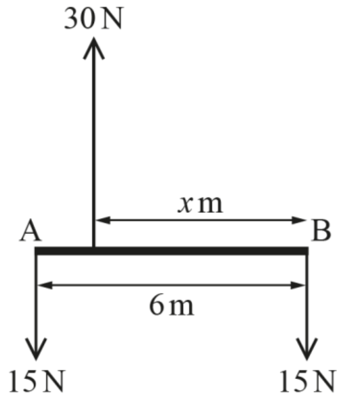
(c) Determine the forces exerted on the lamina by each of the supports at B, C and D. **[4]**

The most common error was to take moments about two parallel lines which gave an inconsistent set of equations. A significant number of candidates did not appreciate that the lamina was horizontal and attempted to consider it 'vertically' as drawn.

Question 6 (a)

6 **Fig. 6.1** shows three forces of magnitude 15 N, 15 N and 30 N acting on a rigid beam AB of length 6 m. One of the forces of magnitude 15 N acts at A, and the other force of magnitude 15 N acts at B. The force of magnitude 30 N acts at distance of x m from B. All three forces act in a direction perpendicular to the beam as shown in **Fig. 6.1**. The beam and the three forces all lie in the same horizontal plane. The three forces form a couple of magnitude 42 N m in the clockwise direction.

Fig. 6.1



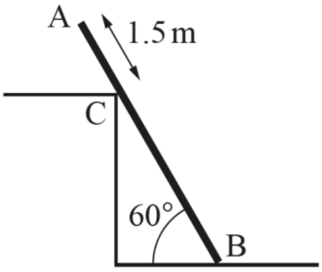
(a) Determine the value of x. **[2]**

Candidates took moments about both A and B and the point that 30N force acts through but were able to equate to the couple. The most common errors consisted or incorrect signs or finding $6 - x$ rather than x.

Question 6 (b)

Fig. 6.2 shows the same beam, without the three forces from **Fig. 6.1**, resting in limiting equilibrium against a step. The point of contact, C, between the beam and the edge of the step lies 1.5 m from A. The other end of the beam rests on a horizontal floor. The contacts between the beam and both the step and the floor are rough.

Fig. 6.2

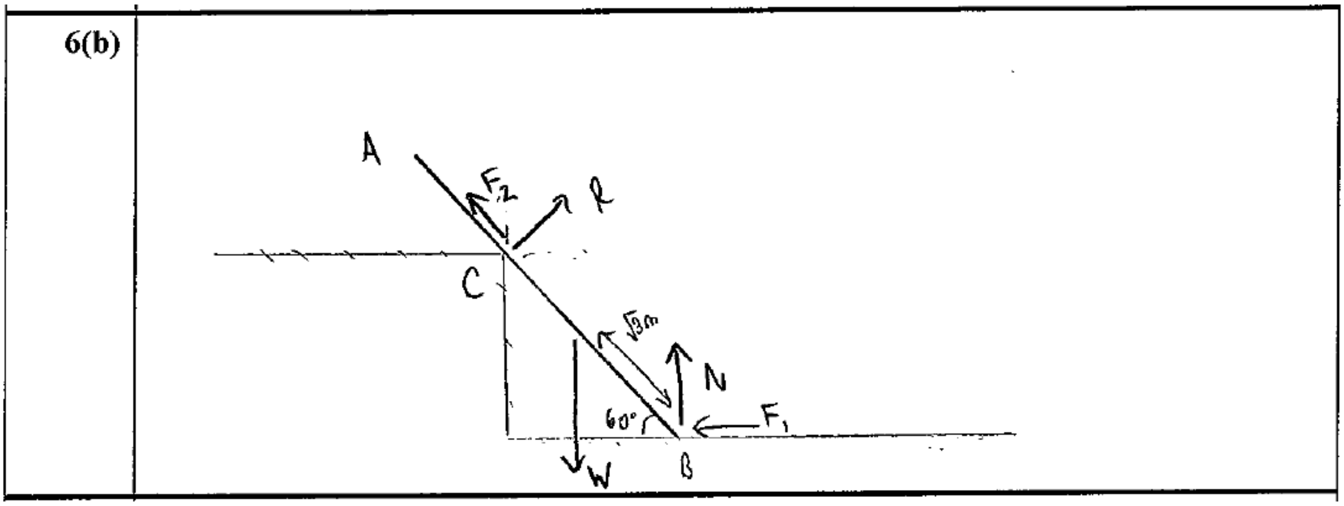


It is given that the beam is non-uniform, and that its centre of mass lies $\sqrt{3}$ m from B.

(b) Draw a diagram to show all the forces acting on the beam. **[2]**

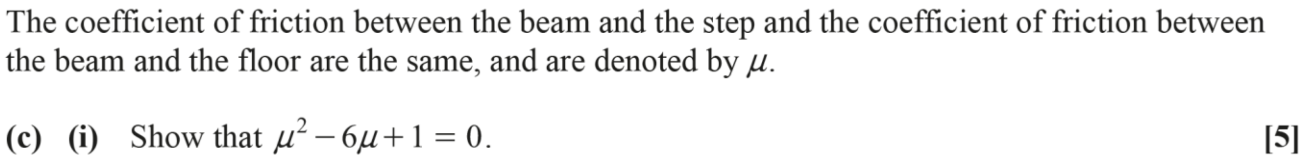
The forces acting at B were correctly shown in most cases but those at C were often drawn as being vertical and horizontal rather than parallel and perpendicular to the beam. The weight was usually correctly located with a label of the distance to B for clarity.

Exemplar 3



Forces clearly shown and label used to make position of centre of mass clear.

Question 6 (c) (i)



The coefficient of friction between the beam and the step and the coefficient of friction between the beam and the floor are the same, and are denoted by μ.

(c) **(i)** Show that $\mu^2 - 6\mu + 1 = 0$. **[5]**

Equations for the moment and resolution of forces were often completed successfully and then usually led to the given equation.

Question 6 (c) (ii)

(ii) Hence determine the value of μ. **[2]**

Many candidates correctly identified $3 - 2\sqrt{2}$ as the correct value of μ but most justified this by stating the generic $\mu < 1$ rather than referring to the context of the question and a value of the reaction at B.

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