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AS LEVEL

Examiners' report

FURTHER MATHEMATICS B (MEI)

H635

For first teaching in 2017

Y411/01 Summer 2022 series

Contents

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 are 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.

Advance Information for Summer 2022 assessments

To support student revision, advance information was published about the focus of exams for Summer 2022 assessments. Advance information was available for most GCSE, AS and A Level subjects, Core Maths, FSMQ, and Cambridge Nationals Information Technologies. You can find more information on our website.

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Paper Y411/01 series overview

Most candidates this summer demonstrated their knowledge and competence over a range of topics, notably in Questions 1 to 4. There were some challenging sections in the later questions, particularly Questions 5(c), 6(c), 6(d) and 7(c) and many candidates left these unanswered.

In this year's paper there are six places where an answer is given in the question ('Show that…' questions). This is intended to help candidates, giving them confidence that their work is correct, alerting them to mistakes and enabling them to continue with later parts of the question. However, it also means that they must show their methods clearly to earn the marks.

Candidates who did well on this paper generally did the following:	Candidates who did less well on this paper generally did the following:
• Produced substantially correct responses to the first four questions. • Attempted all parts of all the questions. • Set out their working clearly. • Explained their methods.	• Left unanswered multiple parts of questions (generally the later questions). • Produced work that was disorganised and difficult to follow. • Wrote down equations without explaining what methods they were using.

Assessment for learning

Candidates should be encouraged to set out their working clearly and to explain what they are doing (for example 'Taking moments about A', 'Resolving parallel to the slope', 'By the conservation of momentum' and so on).

This is particularly important when the answer is given in the question.

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

Question 1 (a)

1 (a) **Fig. 1.1** and **Fig. 1.2** show rigid rods with forces acting as marked. The diagrams are to scale, and in each figure the side length of a grid square is 1 metre.

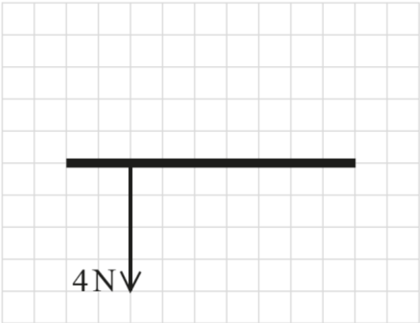


Fig. 1.1

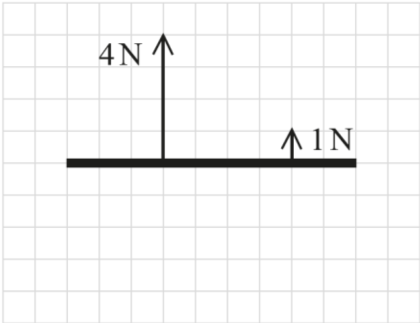


Fig. 1.2

- On the copy of **Fig. 1.1** in the Printed Answer Booklet, add, to scale, a force so that the overall system represents an anti-clockwise couple of magnitude 24 N m.
- On the copy of **Fig. 1.2** in the Printed Answer Booklet, add, to scale, a force so that the overall system represents a clockwise couple of magnitude 1 N m.

[3]

In the first case (Fig. 1.1) the couple consists of two forces, equal in magnitude, but in opposite directions. Most candidates completed the diagram correctly. The second case (Fig. 1.2) is a couple with three forces, where the net force must be zero. The extra force of 5 N downwards is then placed so as to give the required total moment. Only a minority of candidates answered this correctly. Very many put the extra force in the wrong place. Others added two more forces (usually 4 N and 1 N) and many gave a system in which the net force was not zero.

Question 1 (b) (i)

(b) **Fig. 1.3** shows a rectangular lamina with two coplanar forces acting as marked. Each grid square has side length 1 m.

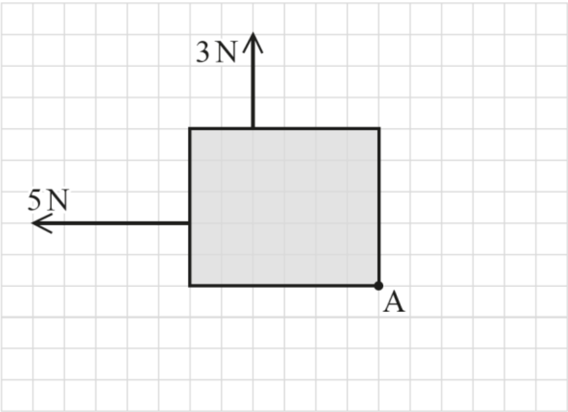


Fig. 1.3

A third coplanar force, of magnitude T N, acts at A so that the resultant force on the lamina is zero.

(i) Calculate the value of T. **[1]**

Most candidates answered this correctly.

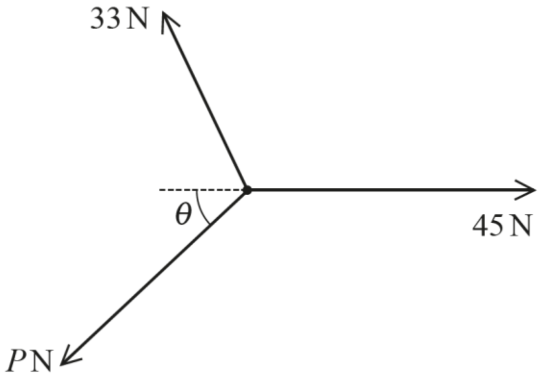
Question 1 (b) (ii)

(ii) Determine the magnitude and direction of the couple represented by this system of three forces. **[3]**

Many candidates found the magnitude of the couple successfully by taking moments about A, although some omitted to state its direction. Those who considered moments about a different point, such as the centre of the lamina, needed to include the third force T, and very few managed to do this accurately. Some candidates gave the magnitude and direction of a force, usually T.

Question 2 (a)

2 Three forces, of magnitudes 33 N, 45 N and P N, act at a point in the directions shown in the diagram. The system is in equilibrium.



(a) Draw a triangle of forces for the system shown above. Your diagram should include the magnitudes of the forces (33 N, 45 N and P N) and angle θ. **[2]**

Most candidates drew a correct triangle of forces, although some did not indicate the angle θ on their diagram.

Question 2 (b)

(b) If $P = 38$, find, in degrees, the value of θ. **[2]**

This was also answered well, with most candidates applying the cosine rule accurately to find the angle. Candidates who had not drawn a triangle of forces often attempted a solution by resolving forces, but this was never completed successfully.

Question 2 (c)

(c) If $\theta = 40°$, determine the possible values for P. **[3]**

Most candidates used the cosine rule again. When applied correctly using the angle 40° this gives a quadratic equation for P, leading to the two solutions. Other candidates used the sine rule, although most of these gave just one of the answers (the question does indicate that there is more than one possible value).

Question 3 (a)

3 **Fig. 3.1** shows a thin rectangular frame ABCD, with part of it filled by a triangular lamina ABD. AD = 30 cm and AB = x cm. Together they form the composite structure S.

The centre of mass of S lies at a point M, 16.5 cm from AD and 11.7 cm from AB.

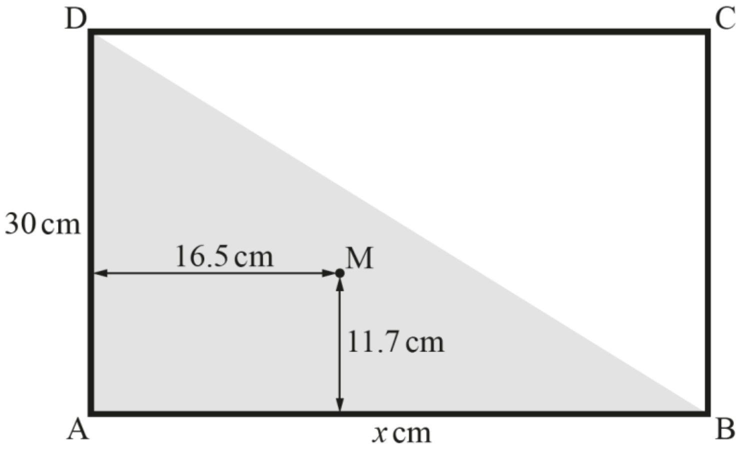


Fig. 3.1

The frame and the triangular lamina are both uniform but made of different materials. The mass of the frame is 1.7 kg.

(a) Show that the triangular lamina has a mass of 3.3 kg. **[3]**

Candidates who produced confident and efficient solutions to this part and part (b) very often began by clearly setting out what they knew about the masses and centres of mass of the two components (see the exemplar below). Candidates who began by writing down an equation for *m* often became confused about how to use the given information. Some candidates used the area of the triangle (15*x*) as its mass and produced work that was difficult to follow. Candidates should remember that when the answer is given in a question, it is important that their argument is clear.

Exemplar 1

3(a)

~~COM of frame=~~

COM of frame = $\begin{pmatrix} \frac{x}{2} \\ 15 \end{pmatrix}$

COM of triangle = $\begin{pmatrix} x/3 \\ 10 \end{pmatrix}$

$1.7+m\begin{pmatrix} 16.5 \\ 11.7 \end{pmatrix} = 1.7\begin{pmatrix} x/2 \\ 15 \end{pmatrix} + m\begin{pmatrix} x/3 \\ 10 \end{pmatrix}$

$19.89 + 11.7m = 25.5 + 10m$

$19.89 + 1.7m = 25.5 \Rightarrow 1.7m = 5.61 \Rightarrow m = 3.3$

This exemplar shows an exceptionally good response, including a single vector equation.

Question 3 (b)

(b) Determine the value of x, correct to **3** significant figures. **[2]**

Most candidates considered the distances of the centres of mass from AD to find the value of *x*. A few realised that it could also be found using similar triangles, since the centre of mass M lies on AC.

Question 3 (c)

One end of a light inextensible string is attached to S at D. The other end is attached to a fixed point on a vertical wall. For S to hang in equilibrium with AD vertical, a force of magnitude Q N is applied to S as shown in **Fig. 3.2**. The line of action of this force lies in the same plane as S. The string is taut and lies in the same plane as S at an angle ϕ to the downward vertical.

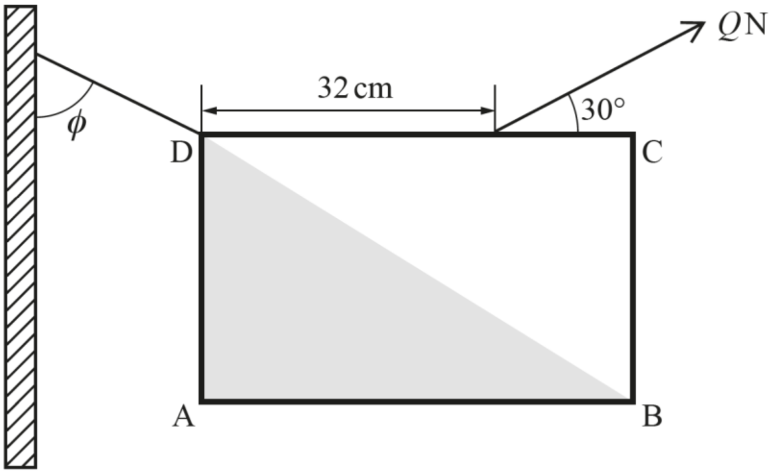


Fig. 3.2

(c) By taking moments about D, show that $Q = 50.5$, correct to **3** significant figures. **[2]**

Almost all candidates obtained the given answer, with clear working.

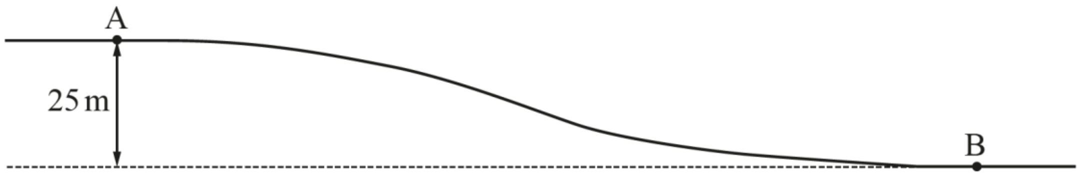
Question 3 (d)

(d) Determine, in degrees, the value of ϕ. **[3]**

This was often answered correctly, usually by resolving to find the horizontal and vertical components of the tension in the string. Candidates who chose to take moments to find one or both components instead of resolving, tended to be less successful.

Question 4 (a)

4 The diagram shows two points A and B on a snowy slope. A is a vertical distance of 25 m above B.



A rider and snowmobile, with a combined mass of 240 kg, start at the top of the slope, heading in the direction of B. As the snowmobile passes A, with a speed of $3\,\mathrm{m\,s^{-1}}$, the rider switches off the engine so that the snowmobile coasts freely. When the snowmobile passes B, it has a speed of $18\,\mathrm{m\,s^{-1}}$.

The resistances to motion can be modelled as a single, constant force of magnitude 120 N.

(a) Calculate the distance the snowmobile travels from A to B. **[3]**

This was well answered, with most candidates obtaining the correct distance. Some however omitted one of the energy terms and some made sign errors.

Question 4 (b)

The rider now turns the snowmobile around and brings it back to B, so that it faces up the slope. Starting from rest, the snowmobile ascends the slope so that it passes A with a speed of $7\,\mathrm{m\,s^{-1}}$. It takes 30 seconds for the snowmobile to travel from B to A. The resistances to motion can still be modelled as a single, constant force of magnitude 120 N.

(b) Show that the snowmobile develops an average power of 2856 W during this time. **[2]**

Here the three terms (kinetic energy, potential energy and work done against the resistances) need to be added together. Most candidates showed this clearly (as they need to do, since the power developed is a given answer). The potential energy was sometimes omitted, as was the work done.

Question 4 (c)

The snowmobile can develop a maximum power of 6000 W. At a later point in the journey, the rider and snowmobile reach a different slope inclined at 12° to the horizontal. The resistances to motion can still be modelled as a single, constant force of magnitude 120 N.

(c) Determine the maximum speed with which the rider and snowmobile can ascend. **[3]**

This part was answered well, with most candidates understanding the relationship between power, driving force and speed.

Question 4 (d)

The power developed by a vehicle is sometimes given in the non-SI unit *mechanical horsepower* (hp). 1 hp is the power required to lift 550 pounds against gravity, starting and ending at rest, by 1 foot in 1 second.

(d) Given that 1 metre ≈ 3.28 feet and 1 kg ≈ 2.2 pounds, determine the number of watts that are equivalent to 1 hp. **[2]**

Most candidates answered this correctly. Some made errors when converting 550 pounds to kilograms or 1 foot to metres. Others omitted *g* from the potential energy *mgh*.

Question 5 (a)

5 **Fig. 5.1** shows a small smooth sphere A at rest on a smooth horizontal surface. At both ends of the surface is a smooth vertical wall.

Fig. 5.1

Sphere A is projected directly towards the left-hand wall at a speed of $5\,\mathrm{m\,s^{-1}}$. Sphere A collides directly with the left-hand wall, rebounds, then collides directly with the right-hand wall. After this second collision A has a speed of $3.2\,\mathrm{m\,s^{-1}}$.

(a) Explain how it can be deduced that the collision between A and the left-hand wall was **not** inelastic. **[1]**

Most candidates explained this by saying that the ball bounces away from the wall. There was some confusion however, with many references to a loss of kinetic energy. The specification defines an inelastic collision to be one in which the coefficient of restitution is zero.

Question 5 (b)

The coefficient of restitution between A and each wall is e.

(b) Calculate the value of e. **[2]**

Most candidates considered the two collisions to obtain the correct equation $5e^2 = 3.2$. A very common error was to treat it as one collision, leading to $5e = 3.2$.

Question 5 (c)

Sphere A is now brought to rest and a second identical sphere B is placed on the surface. The surface is 1 m long, and A and B are positioned so that they are both 0.5 m from each wall, as shown in **Fig. 5.2**.

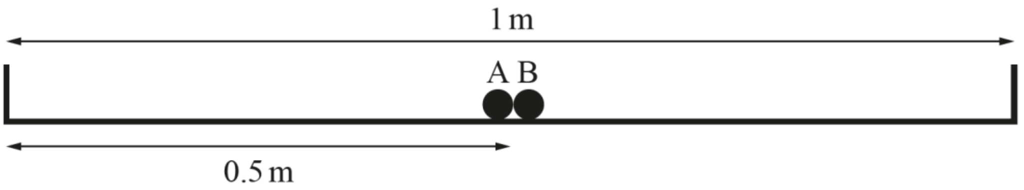


Fig. 5.2

Sphere A is projected directly towards the left-hand wall at a speed of $0.2\,\mathrm{m\,s^{-1}}$. At the same time, B is projected directly towards the right-hand wall at a speed of $0.3\,\mathrm{m\,s^{-1}}$. You may assume that the duration of impact of a sphere and a wall is negligible.

(c) Calculate the distance of A and B from the left-hand wall when they meet again. **[3]**

Many candidates found this a challenge. To make any worthwhile progress, it is essential to realise that the two spheres take different times to reach the walls before rebounding at lower speeds. Almost all candidates who attempted this part found the speeds after rebound, but not very many took these different times into account.

Question 6 (a)

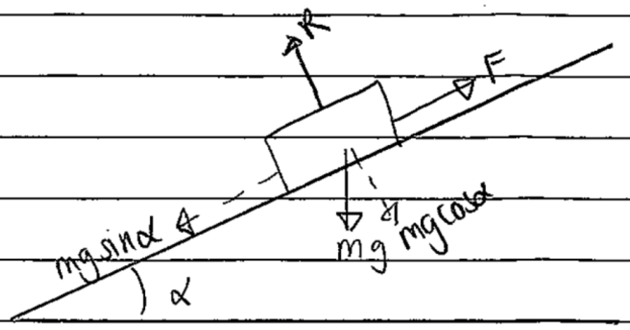
6 A block B of mass m kg rests on a rough slope inclined at angle α to the horizontal. The coefficient of friction between B and the slope is $\frac{5}{9}$.

(a) When B is in limiting equilibrium, show that $\tan\alpha = \frac{5}{9}$. **[3]**

The answer is given, so candidates' working should be clearly set out and fully explained. Ideally, there should be mention of resolving parallel and perpendicular to the slope and an indication of where limiting friction is used (as in the following exemplar). Very often, correct equations were written down without any explanation, sometimes without a diagram.

Exemplar 2

6(a)



$R(\nwarrow)$: $R - mg\cos\alpha = 0$

$R = mg\cos\alpha$

$R(\nearrow)$: $mg\sin\alpha - F = 0$

$F = mg\sin\alpha$

in limiting equilibrium : $F = \mu R$

$mg\sin\alpha = \frac{5}{9} \times mg\cos\alpha$

$\tan\alpha = \frac{5}{9}$ as required

Few responses matched this standard, although most candidates did understand how to obtain the result.

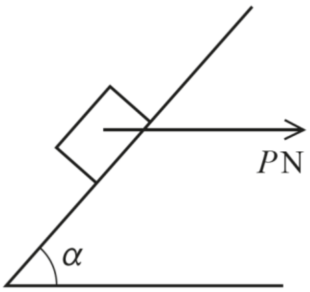
Question 6 (b)

(b) If $\alpha = 40°$, determine the acceleration of B down the slope. **[2]**

This was well understood and most of those who attempted it answered it correctly.

Question 6 (c)

A horizontal force of magnitude P N is now applied to B, as shown in the diagram below. At first B is at rest.



P is gradually increased.

(c) Show that, for B to slide on the slope,

$$P\left(\cos\alpha - \tfrac{5}{9}\sin\alpha\right) > mg\left(\tfrac{5}{9}\cos\alpha + \sin\alpha\right).$$ **[3]**

This was another challenging part. Candidates needed to realise that the additional force *P* increases the normal reaction and hence increases the maximum frictional force. If equilibrium is broken, the block will slide up the slope, with friction acting down the slope. Few candidates were able to correctly bring together all that was required. Some of those whose working did not at first lead to the given answer were however able to find and correct their mistake.

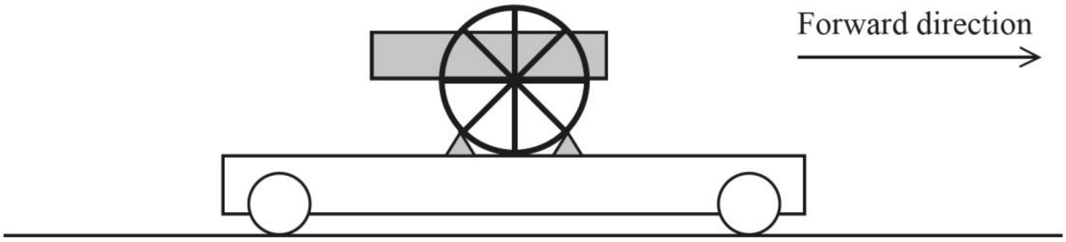
Question 6 (d)

(d) Determine, in degrees, the least value of α for which B will not slide no matter how large P becomes. **[2]**

This was the most challenging part. Many did not attempt it and the majority of candidates scored no marks. Few realised that the inequality in part (c) cannot be satisfied if the coefficient of *P* is zero (or negative).

Question 7 (a) (i)

7 The diagram shows a cannon fixed to a trolley. The trolley runs on a smooth horizontal track.



A driver boards the trolley with two cannon balls. The combined mass of the trolley, driver, cannon and cannon balls is 320 kg. Each cannon ball has a mass of 5 kg. Initially the trolley is at rest.

A force of 480 N acts on the trolley in the forward direction for 4 seconds.

(a) **(i)** Calculate the magnitude of the impulse of the force on the trolley. **[1]**

Almost all candidates answered this correctly.

Question 7 (a) (ii)

(ii) Calculate the speed of the trolley after the force stops acting. **[1]**

This was also answered correctly by almost all the candidates.

Question 7 (b)

The driver now fires a cannon ball horizontally in the backward direction. The cannon ball and cannon separate at a rate of $90\,\mathrm{m\,s^{-1}}$.

(b) Show that, after the firing of the cannon ball, the trolley moves with a speed of $7.41\,\mathrm{m\,s^{-1}}$, correct to **3** significant figures. **[3]**

The conservation of momentum should lead to an equation such as $5v_1 + 315v_2 = 320u$ where $v_2 - v_1 = 90$ and many candidates formed this correctly. There was sometimes confusion about the masses and a very common error was to assume that the cannon ball moves at 90 ms^{-1}. The answer is given, so again candidates' method needs to be clear. Several candidates wrote down the equation $-5 \times 90 + 320v_2 = 1920$ (which is correct and gives the right answer) without explaining where it comes from; this was not accepted as a valid method.

Question 7 (c)

The driver now reverses the direction of the cannon and fires the second cannon ball horizontally in the forward direction. Again, the cannon ball and cannon separate at a rate of $90\,\mathrm{m\,s^{-1}}$.

(c) Calculate the overall percentage change in the kinetic energy of the trolley (alone) from before the first cannon ball is fired to after the second is fired, giving your answer correct to **2** decimal places. You should make clear whether the change in kinetic energy is a gain or a loss. **[4]**

This was found to be very challenging. Candidates first needed to adapt their work in part (b) for different masses and the cannon being fired in the opposite direction. Few found the correct final speed ($5.98\ \mathrm{ms^{-1}}$). The mass of the trolley is unknown, but this does not matter as only the percentage change is required; some candidates used different masses when calculating the initial and final kinetic energy.

Question 7 (d)

(d) Give a reason why one of the modelling assumptions that was required in answering parts **(a)**, **(b)** and **(c)** may not have been appropriate. **[1]**

Most candidates commented that the assumption that the track is perfectly smooth is unlikely to be true in practice.

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