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Examiners' report

A LEVEL

FURTHER MATHEMATICS B (MEI)

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

H645

For first teaching in 2017

Y431/01 Summer 2025 series

Version 1

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 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.

Paper Y431 series overview

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

The report focuses on areas of improvement based on responses given by this year's cohort. However, it should not be construed that these were areas of development for all. Quite the contrary as most responses showed a high level of mathematical understanding and fluency with the skills developed during the course.

In some questions detailed working is explicitly required, as dictated by the 'show that' and 'determine' command words. Those who provided consistently complete solutions for all questions were ultimately most successful in understanding 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.

OCR support

Section 2b of the specification provides guidance of the meanings of some 'command word' instructions used in examination questions. Students can download a summary sheet from the qualification webpages.

Candidates at all levels exhibited excellent algebraic skills but provided comparatively little written explanation to justify choices or show their understanding of physical situations. Not only would this secure extra marks it would enhance candidates' own understanding of problems and focus their reasoning.

Candidates who drew diagrams undoubtedly obtained a clearer understanding of problems and produced more complete solutions. Candidates' misunderstanding of the geometry of problems had a significant impact for some. For example when resolving forces into components, incorrect angles were often used.

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 (WEP) when sign errors were introduced or the component values of some terms were omitted.

Most 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:
• produced clear diagrams to aid their understanding of problems • understood geometry and trigonometry requirements • interpreted three dimensional problems correctly • understood what was expected by each of the given command words in the questions • used calculators appropriately to support their solutions • used vectors confidently.	• were not confident with two and three dimensional problems • did not use vectors appropriately • did not consider the moments of forces appropriately.

Question 1 (a)

1 Particles A and B move towards each other on a smooth horizontal surface. Particle A has speed $3\,\mathrm{m\,s^{-1}}$ and particle B has speed $8\,\mathrm{m\,s^{-1}}$.

After they collide directly, A and B move away from each other, A with a speed of $5.2\,\mathrm{m\,s^{-1}}$ and B with a speed of $v\,\mathrm{m\,s^{-1}}$. The collision between A and B is perfectly elastic.

(a) Find the value of v. **[1]**

This was generally answered correctly, with most candidates drawing diagrams to support their solutions.

Question 1 (b)

(b) State the kinetic energy lost in the collision between A and B. **[1]**

Assessment for learning

A noticeable number of candidates did not recognise that an elastic collision conserves kinetic energy.

Question 1 (c)

Two different particles, C and D, move on a smooth horizontal surface. Particle C has a speed of $6.4\,\mathrm{m\,s^{-1}}$ towards D and particle D has a speed of $1.9\,\mathrm{m\,s^{-1}}$ away from C.

After they collide directly, the particles move away from each other. The speed of C after the collision is $0.2\,\mathrm{m\,s^{-1}}$. The coefficient of restitution between C and D is 0.8.

You are given that the mass of C is 3.5 kg.

(c) Determine the mass of D. **[4]**

Errors were mainly caused when candidates did not correctly account for the particles moving away from each other following the collision, instead they assumed that the points would continue to move in the same direction as before the collision.

Question 2 (a) (i)

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

Virtually all candidates were able to state the dimensions correctly using dimensions.

Question 2 (a) (ii)

(ii) State the dimensions of energy. **[1]**

Virtually all candidates were able to state the dimensions correctly using dimensions.

Question 2 (b)

The surface tension, S, of a liquid can be defined as force per unit length. It can **also** be defined as energy per unit area.

(b) Show that these two definitions of surface tension are dimensionally consistent with one another. **[2]**

This was well answered with only a small number of candidates not demonstrating this sufficiently with a suitable comparison of their results.

Question 2 (c)

When a droplet of liquid is placed on a non-absorbent horizontal surface, the maximum height h m of the droplet is modelled by the formula

$$h = \lambda S^{\alpha} g^{\beta} \rho^{\gamma},$$

where

- λ is a dimensionless constant,
- S is the surface tension of the liquid in $\mathrm{N\,m^{-1}}$,
- g is the acceleration due to gravity in $\mathrm{m\,s^{-2}}$,
- ρ is the density of the liquid in $\mathrm{kg\,m^{-3}}$.

(c) Use dimensional analysis to determine the values of α, β and γ. **[4]**

Most candidates were able to produce a set of equations and calculate all three values correctly. Errors, where they occurred, were often in creating the simultaneous equations despite an initial correct dimensional statement.

Question 2 (d)

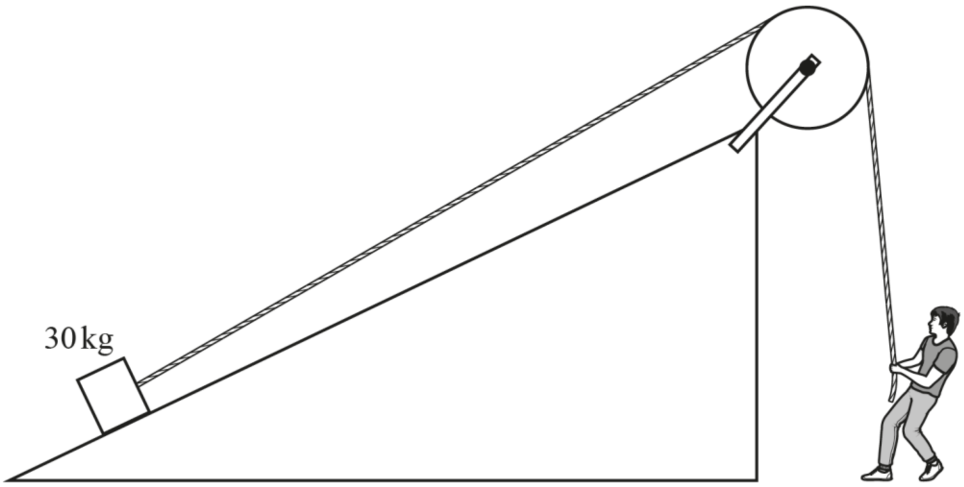
At room temperature, water has a density of $1\,\mathrm{g\,cm^{-3}}$ and a surface tension of $0.073\,\mathrm{N\,m^{-1}}$. When a small droplet of water is placed on a non-absorbent horizontal surface, it has maximum height $0.53\,\mathrm{cm}$.

(d) Find the value of λ. **[2]**

Many candidates produced a correct formula, but a significant number of candidates did not appreciate that the values given had to be converted into a consistent set of units, for example the value of density used in the formula was often 1 rather than 1000.

Question 3 (a)

3 The diagram shows a crate of mass 30 kg on a smooth inclined plane. One end of a light inextensible rope is attached to the crate. The rope passes over a smooth pulley which is fixed at the top of the plane. The other end of the rope is held by a worker.



At first, the crate is at rest at a point A on the plane. The worker pulls continuously on the rope so that the crate moves up the plane.

Subsequently, the crate comes to rest, in equilibrium with the rope taut, at a point B on the plane. The vertical distance between A and B is 3.5 m.

(a) Calculate the work done by the tension in the rope as the crate moves from A to B. **[1]**

Most candidates calculated this correctly.

Question 3 (b)

At a point C, which is between A and B on the plane, the rope makes an angle of 12° with AB. The crate passes through C with a speed of $0.8\,\mathrm{m\,s^{-1}}$. The tension in the rope when the crate is at C is 206 N.

(b) Calculate the power of the tension in the rope when the crate is at C. **[2]**

The majority included the force and velocity in this calculation correctly, however a number did not include the oblique angle of the rope.

Question 3 (c)

The worker now lets the crate slide back down to A, starting from rest at B. While moving from B to A, 894 J of work is done against the tension in the rope.

(c) Calculate the speed of the crate when it reaches A. **[2]**

The correct WEP equation was created by most and the speed of the crate correctly calculated.

Question 3 (d)

(d) State **one** limitation of the model that could affect the answer to part **(c)**. **[1]**

Nearly all candidates named a suitable resistive force which was not included in the model.

Question 4 (a)

4 A block of mass m kg rests on a rough plane inclined at an angle α to the horizontal. The coefficient of friction between the block and the plane is μ. At first the block is in equilibrium, and then α is gradually increased.

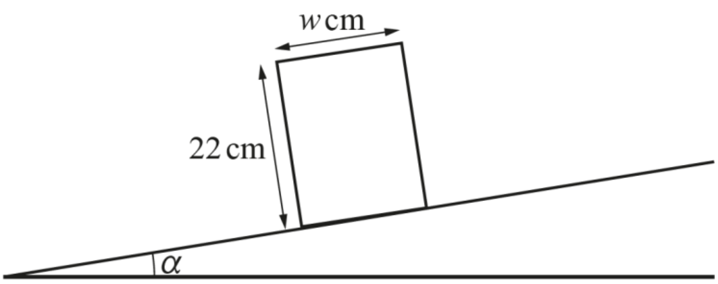
(a) Assuming that the block does not topple first, show that at the point of sliding $\mu = \tan\alpha$. **[2]**

This was completed by most candidates and the majority showed clear diagrams which supported their solutions.

Question 4 (b)

The block is modelled as a uniform rectangular prism whose cross section has width w cm and height 22 cm. **Fig. 4.1** shows the block placed on the inclined plane so that the cross section contains a line of greatest slope.

Fig. 4.1



The coefficient of friction between the block and the plane is 0.6.

At first, the block is in equilibrium. As α is increased, equilibrium is broken by the block sliding, rather than toppling.

(b) Determine the range of possible values of w. **[3]**

The most common error was caused by candidates using the reciprocal for the toppling angle, i.e. stating $\tan\alpha = \frac{22}{w}$ incorrectly. A significant number also compared the two values incorrectly.

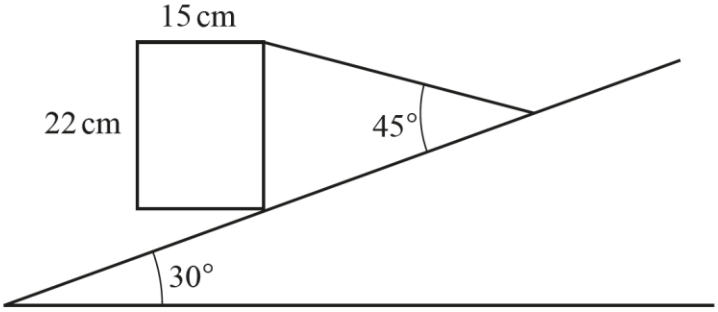
Question 4 (c)

For the remainder of the question you are given that $w = 15$, $m = 10$ and $\alpha = 30°$.

One end of a light inextensible string is attached to one of the top edges of the block. The other end of the string is attached to a point further up the inclined plane.

The string makes an angle of 45° with the inclined plane so that the block is held in equilibrium with its base horizontal, as shown in **Fig. 4.2**. Both the string and the centre of mass of the block lie in the same vertical plane as a line of greatest slope.

Fig. 4.2



(c) Determine the tension in the string. **[3]**

A noticeable number of candidates did not realise to take moments. Other errors occurred from incorrect geometry and trigonometry, with resolving T incorrectly relative to the plane using 22.5° rather than 15° or 75°.

Assessment for learning

Candidates need support in resolving forces into components with compound angles, such as in this problem.

Question 4 (d)

(d) Determine the angle between the inclined plane and the total contact force that the inclined plane exerts on the block. **[6]**

Candidates produced equal numbers of solutions either resolving perpendicular and parallel relative to the plane or horizontally and vertically. A number who resolved horizontally and vertically found the angle between the total contact force and the horizontal and did not then calculate the angle relative to the plane.

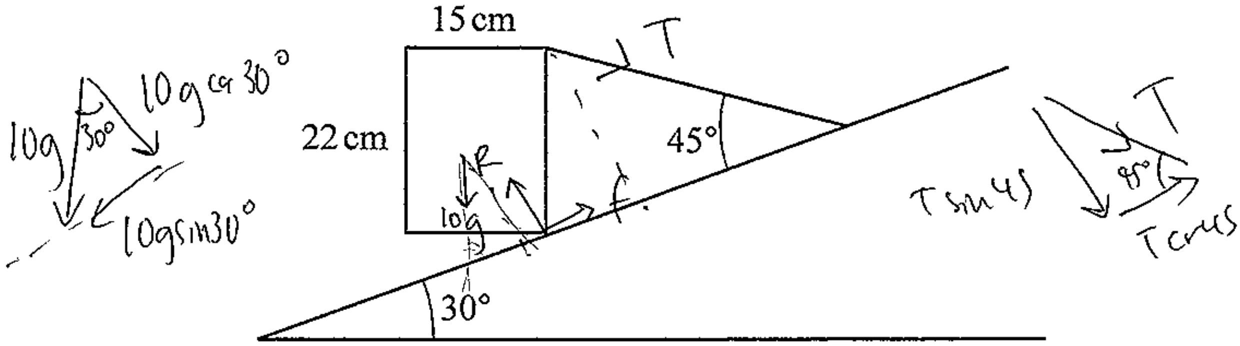
Assessment for learning

Only a small number of candidates used a total contact force in their solutions which made them more complex having separate terms for Friction and Reaction.

Misconception

Many candidates used limiting friction in this part of the problem, i.e. assuming $F = \mu R$.

Exemplar 1



Resolve forces parallel / perpendicular to the slope

NL2 R( ): $R - 10g\cos 30° - T\sin 45° = 0$

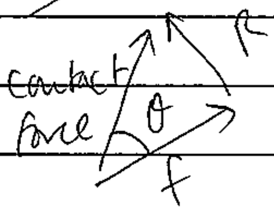
$R = 10g\cos 30° + T\sin 45°$

NL2 R( ): $f + T\cos 45° - 10g\sin 30° = 0$

$f = 10g\sin 30° - T\cos 45°$

$f = 24.5$ (STO B)

$R = 109.3$ (STO C)



$\tan\theta = \dfrac{R}{f}$

$\theta = \tan^{-1}\left(\dfrac{109.3}{24.5}\right) = 77.347°$

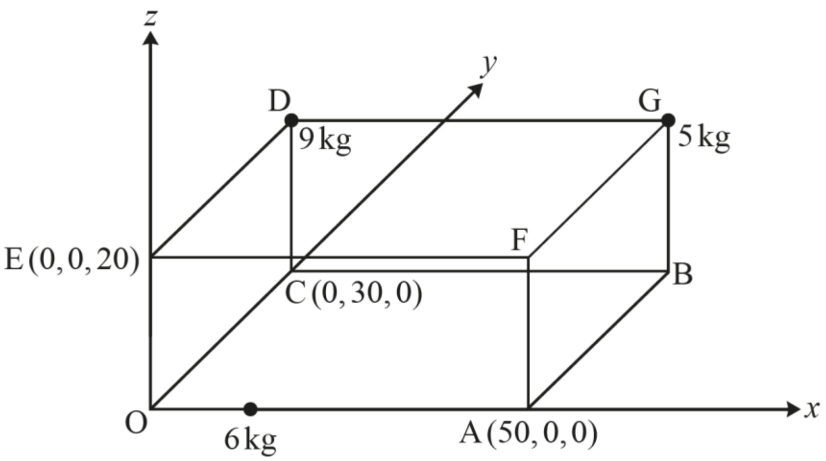
$\theta = 77.3°$

A clear complete solution, with diagrams, supporting the solution effectively.

Question 5 (a)

5 The diagram shows a cuboid frame OABCDEFG where O is the origin of the coordinate system in which the points A, C and E have coordinates (50, 0, 0), (0, 30, 0) and (0, 0, 20) respectively.

The frame is made of 12 light inextensible rods.



Three particles are attached to the frame as follows:

- A particle of mass 9 kg at D.
- A particle of mass 5 kg at G.
- A particle of mass 6 kg at the point $(\lambda, 0, 0)$ on OA, where $0 \leqslant \lambda \leqslant 50$.

The centre of mass of the frame with the three particles attached lies at $(\bar{x}, \bar{y}, \bar{z})$.

(a) Show that $\bar{y} = 21$ and $\bar{z} = 14$. **[2]**

Most candidates completed this, with only a handful that did not present a convincing calculation to obtain the given values.

Question 5 (b)

(b) Find the range of possible values of $\bar{x}$. **[3]**

Centre of mass calculations were routinely completed successfully and there were only occasional numerical slips.

Question 5 (c)

For the remainder of the question, you are given that the particle of mass 6 kg is fixed at A.

The frame is now suspended by two light vertical wires, one attached at O and the other at C. The frame hangs in equilibrium with OC horizontal.

(c) Find the tension in each of the two wires. **[3]**

Those candidates who produced a clear diagram or expressed their understanding of the three dimensional nature of the problem often performed well.

Question 5 (d)

(d) Calculate the angle that the plane OABC makes with the downward vertical. **[2]**

The main obstacle to the final part of this problem was understanding the geometry and which distances were required to calculate the angle requested.

Question 5 (e)

The wire attached to C snaps, and the frame is left suspended in equilibrium only by the vertical wire attached at O.

(e) Calculate the angle that OA now makes with the downward vertical. **[2]**

Only a small number of candidates were able to find the correct ratio to calculate the angle between OA and the vertical. A large proportion of correct solutions used the scalar product approach.

Question 6 (a)

6 In this question the unit vectors **i** and **j** are directed horizontally.

Two skaters, Amos and Beth, move on a horizontal ice rink. The masses of Amos and Beth are 70 kg and 50 kg respectively.

At first Amos and Beth move as a single body with velocity $4\mathbf{i}\ \mathrm{m\,s^{-1}}$. Amos then exerts an impulse on Beth of $(35\mathbf{i}+70\mathbf{j})$ N s so that they move apart with different speeds.

(a) Determine Beth's speed after separation. **[3]**

Many correct answers were produced, but after calculating a correct velocity some did not calculate the speed. Incorrect velocities were usually produced from incorrect masses being used in the Impulse-momentum equations.

Question 6 (b)

(b) Determine the total gain in kinetic energy of the two skaters. **[3]**

Most solutions appreciated that the gain in kinetic energy was required, but many used incorrect speeds resulting from incorrect calculations of velocity of Amos.

Question 6 (c)

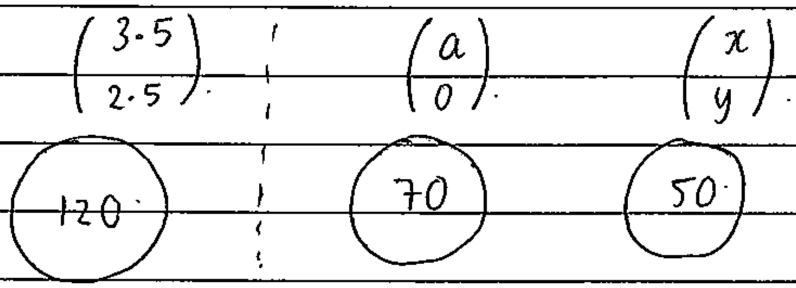
On another occasion Amos and Beth are moving as a single body with velocity $(3.5\mathbf{i}+2.5\mathbf{j})\ \mathrm{m\,s^{-1}}$.

Amos exerts an impulse on Beth so that they move apart with equal speeds, and Amos travels in the **i** direction.

(c) Determine the possible speeds of the skaters after separation. **[6]**

The most common errors in solutions to this question were incorrect velocity calculations. Those proficient in using vectors established the relationship between the two velocities and produced a complete solution.

Exemplar 2



where $a^2 = x^2 + y^2$.

conservation of linear momentum: (x direction).

$(120 \times 3\cdot5) = 50x + 70a$.

$42 = 5x + 7a$.

~~conservation of linear momentum~~: $\frac{42-5x}{7} = a$.

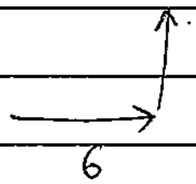
~~$(120 \times 2\cdot5) = 70x$~~

conservation of linear momentum: (y direction).

$(120 \times 2\cdot5) = 50y$.

$\Rightarrow y = 6$. $a^2 = x^2 + 36$.

$\left(\frac{42-5x}{7}\right)^2 = x^2 + 36$.



$(42-5x)^2 = 49x^2 + 1764$.

$(42-5x)(42-5x) = 17\cancel{64} - 420x + 25x^2 = 49x^2 + 17\cancel{64}$

$24x^2 + 420x = 0$.

$x^2 + \frac{35}{2}x = 0$

if $x = 0$ then $a = 6$. then speeds would be $6\ ms^{-1}$.

$x\left(x + \frac{35}{2}\right) = 0$

$\Rightarrow x = -\frac{35}{2} = -17\cdot5\ ms^{-1}$

$a = \frac{37}{2} = 18\cdot5\ ms^{-1}$

in this case both speeds $= 18\cdot5\ ms^{-1}$.

A clear solution which considers the vector quantities appropriately.

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