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Oxford Cambridge and RSA

A LEVEL

Examiners' report

FURTHER MATHEMATICS B (MEI)

H645

For first teaching in 2017

Y431/01 Summer 2022 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 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.

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 Y431/01 series overview

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

While this report will focus on areas of improvement, this should not imply that the solutions were produced to a low standard. Quite the opposite was the reality, and many solutions were produced to a very high standard and demonstrated candidates' mathematical understanding and problem-solving ability.

Successful responses often included a 'commentary' on the candidates' solutions, using diagrams appropriately, and extracted information from the questions accurately. This helped many to focus their reasoning.

Candidates omitted to provide the physical explanations required following calculations to justify choices of solutions.

A significant number of candidates did not appreciate the requirements of command words 'show that' and 'determine', it may be useful to refer to the command words poster.

OCR support

OCR's command words poster is available to download in both A2 and A4 versions from the 'Assessment guides' section on the OCR website.

Candidates who did well on this paper generally did the following:	Candidates who did less well on this paper generally did the following:
• provided commentaries to their solutions for themselves and the examiner • produced clear diagrams to support understanding of physical situations • provided written explanations related to the underlying physical properties • were able to use the knowledge of geometry developed in Y420.	• did not apply concepts appropriately, for example using constant acceleration equations when acceleration was not constant • described situations rather than explaining why they occurred in terms of the physical properties of a system such as forces • did not structure solutions clearly • used few diagrams.

Question 1 (a)

1 Newton's gravitational constant, G, is approximately $6.67 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$.

(a) Find the dimensions of G. **[2]**

Nearly all candidates answered this completely with the only errors made in omitting one dimension of force or more occasionally confusing the units and dimensions.

Question 1 (b)

The escape velocity, v, of a body from a planet's surface, is given by the formula

$$v = kG^{\alpha}M^{\beta}r^{\gamma},$$

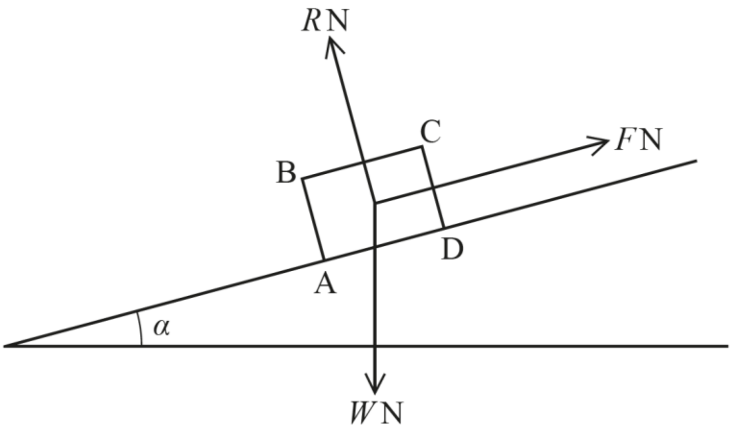
where M is the planet's mass, r is the planet's radius and k is a dimensionless constant.

(b) Use dimensional analysis to find α, β and γ. **[4]**

This was generally answered extremely well following the expected method to gain correct answers. A very small number of responses introduced errors by giving incorrect dimensions for velocity.

Question 2 (a)

2 The diagram below shows the cross-section through the centre of mass of a uniform block of weight W N, resting on a slope inclined at an angle α to the horizontal. The cross-section is a rectangle ABCD. The slope exerts a frictional force of magnitude F N and a normal contact force of magnitude R N.



(a) Explain why a triangle of forces may be used to model the scenario. **[2]**

Explanations were often incomplete, notably a significant number of candidates did not state that as the block is at rest the resultant force is zero. Overall responses suggested candidates were not familiar with modelling using polygons of forces.

Question 2 (b)

(b) In the space provided in the Printed Answer Booklet, draw such a triangle, fully annotated, including the angle α in the correct position. **[2]**

Generally diagrams were drawn with angles in the correct positions although the perpendicular between F and R often had to be assumed.

Question 2 (c)

The coefficient of friction between the block and the slope is μ.

(c) Given that the block is in limiting equilibrium, use your diagram in part **(b)** to show that $\mu = \tan\alpha$. **[2]**

The vast majority of candidates stated $F = \mu R$ without explanation, for which credit was given in this case, and used some appropriate trigonometry to complete the question.

Question 2 (d)

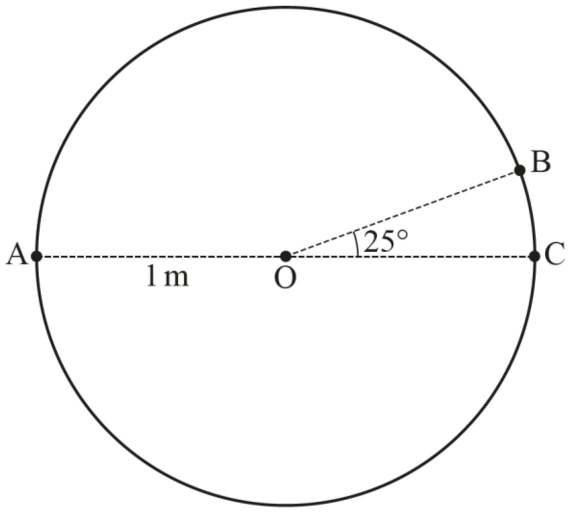
It is given that $\mathrm{AB} = 8.9\,\mathrm{cm}$ and $\mathrm{AD} = 11.6\,\mathrm{cm}$. The coefficient of friction between the slope and the block is 1.35. The slope is slowly tilted so that α increases.

(d) Determine whether the block topples first without sliding or slides first without toppling. **[2]**

Generally this was answered correctly and completely, the only common error being to invert the dimensions of the block and calculate an incorrect value for the toppling angle.

Question 3 (a)

3 A rough circular hoop, with centre O and radius 1 m, is fixed in a vertical plane. A, B and C are points on the hoop such that A and C are at the same horizontal level as O, and OB makes an angle of 25° above the horizontal, as shown in the diagram.



A bead P of mass 0.3 kg is threaded onto the hoop. P is projected vertically downwards from A on two separate occasions.

- The first time, when P is projected with a speed of $4\,\mathrm{m\,s^{-1}}$, it first comes to rest at B.
- The second time, when P is projected with a speed of $v\,\mathrm{m\,s^{-1}}$, it first comes to rest at C.

The situation is modelled by assuming that during the motion of P the magnitude of the frictional force exerted by the hoop on P is constant.

(a) Determine the value of v. **[5]**

Most candidates correctly used work and energy methods to answer this question successfully although some misread the question and confused aspects of the two situations. A significant number of candidates tried to apply the constant acceleration equations to this problem.

Question 3 (b)

(b) Comment on the validity of the modelling assumption used in this question. **[1]**

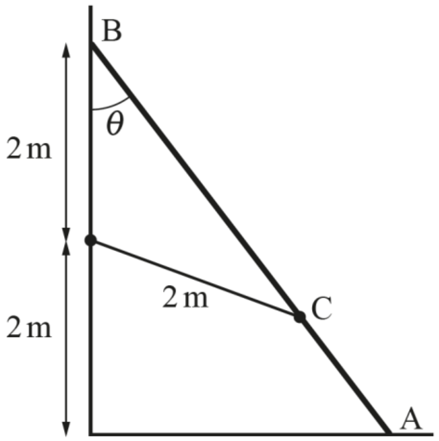
Many candidates suggested not accounting for air resistance rather than discussing the change in reaction in terms of the validity of the assumption given in the question.

Assessment for learning

Candidates should consider the specific assumptions made in the question to give an individual rather than a generic response when commenting on modelling assumptions.

Question 4 (a)

4 A uniform beam AB of mass 6 kg and length 5 m rests with its end A on smooth horizontal ground and its end B against a smooth vertical wall. The vertical distance between the ground and B is 4 m, and the angle between the beam and the downward vertical is θ. To prevent the beam from sliding, one end of a light taut rope of length 2 m is attached to the beam at C and the other end of the rope is attached to a point on the wall 2 m above the ground, as shown in the diagram.



(a) By considering the value of $\cos\theta$, determine the distance BC. **[2]**

This part was successfully completed by the majority of candidates with only a small number finding an incorrect value for $\cos\theta$.

Question 4 (b)

An object of mass 75 kg is placed on the beam at a point which is x m from A.

It is given that the tension in the rope is T N and the magnitude of the normal contact force between the ground and the beam is R N.

(b) By taking moments about B for the beam, show that $25R + 3675x - 16T = 19110$. **[4]**

Many constructed full solutions, illustrated in Exemplar 1. Often justifications failed at the beginning as moments were not taken correctly with missing or incorrect trigonometric components.

Assessment for learning

For 'show that' questions a full step-by-step justification is required.

Exemplar 1

4(b)	Taking moments about B :
	$6g \times \frac{5}{2} \times \sin\theta + \frac{16}{5} T\sin\theta + 75g \times (5-x)\sin\theta = 5R\sin\theta$
	$147 + \frac{16}{5}T + 3{,}675 - 735x = 5R$
	$735 + 16T + 18{,}375 - 3{,}675x = 25R$
	$16T + 19{,}110 - 3{,}675x = \cancel{24}\ 25R$
	$25R + 3{,}675x - 16T = 19{,}110$

Question 4 (c)

(c) Given that the rope can withstand a maximum tension of 720 N, determine the largest possible value of x. **[4]**

Many solutions successfully used the equation from part b to calculate x. The most common error involved not including the vertical component of T in the calculation of the reaction R and only considering the weight of the beam alone or the beam and additional mass.

Question 5 (a)

5 Point A lies 20 m vertically below a point B. A particle P of mass $4m$ kg is projected upwards from A, at a speed of $17.5\,\mathrm{m\,s^{-1}}$. At the same time, a particle Q of mass m kg is released from rest at point B. The particles collide directly, and it is given that the coefficient of restitution in the collision between P and Q is 0.6.

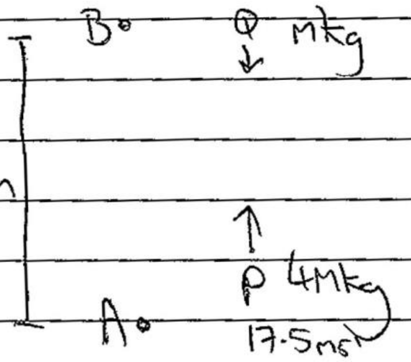
(a) Show that, immediately after the collision, P continues to travel upwards at $0.7\,\mathrm{m\,s^{-1}}$ and determine, at this time, the corresponding velocity of Q. **[8]**

The responses to this question were mixed. The majority of candidates realised to apply the constant acceleration equations, but these could become muddled on occasion as quantities other than position were equated to determine a time of collision. Successful solutions typically included a diagram and succinct summary as shown in Exemplar 2.

Exemplar 2

5(a)

Q ↓+ve　　　P ↑+ve



s	S_Q	s	S_P
u	0	u	17.5
v		v	
a	~~-9.8~~ 9.8	a	-9.8
t	T	t	T

$S = ut + \frac{1}{2}at^2$　　　$S_Q + S_P = 20$

$\frac{1}{2} \times 9.8 \times T^2 + 17.5T - \frac{9.8}{2}T^2 = 20$

$17.5T = 20$

$T = \frac{8}{7}$

$v = u + at$

(Q)　$0 + 9.8 \times \frac{8}{7} = 11.2\,\text{ms}^{-1}$ ↓

(P)　$17.5 - 9.8 \times \frac{8}{7} = 6.3$ ↑

Momentum　$6.3 \times 4m - 11.2m = 4mV_P + V_Qm$

(of R　$V_Q - V_P = 0.6(11.2 + 6.3) = 10.5$

→ ① $14 = 4V_P + V_Q$　② $V_Q - V_P = 10.5$

① − ② $= 3.5 = 5V_P$

$0.7 = V_P$　　(+ve ↑)

① + 4×② $56 = 5V_Q$

$11.2 = V_Q$　　　$V_P = 0.7\,\text{ms}^{-1}$

$V_Q = 11.2\,\text{ms}^{-1}$

(both upwards)

Question 5 (b)

In another situation, a particle of mass $3m$ kg is released from rest and falls vertically. After it has fallen 10 m, it explodes into two fragments. Immediately after the explosion, the lower fragment, of mass $2m$ kg, moves vertically downwards with speed v_1 m s^{-1}, and the upper fragment, of mass m kg, moves vertically upwards with speed v_2 m s^{-1}.

(b) Given that, in the explosion, the kinetic energy of the system increases by 72%, show that $2v_1^2 + v_2^2 = 1011.36$. **[3]**

Typically this was answered very well and completely even as a "stand alone" response to other parts of the question.

Question 5 (c)

(c) By finding another equation connecting v_1 and v_2, determine the speeds of the fragments immediately after the explosion. **[6]**

Candidates that attempted this were able to use the equation in part (b) and then substitute for one of the velocities. Often the final mark was lost as a pair of velocities were disregarded without clearly explaining why in the context of the possible motion of the two particles.

Question 6 (a)

6 **Fig. 6.1** shows a light rod ABC, of length 60 cm, where B is the midpoint of AC. Particles of masses 3.5 kg, 1.4 kg and 2.1 kg are attached to A, B and C respectively.

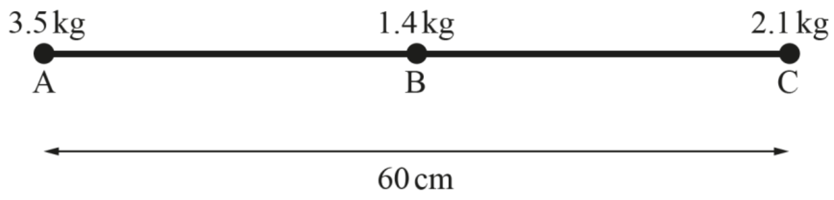


Fig. 6.1

The centre of mass is located at a point G along the rod.

(a) Determine the distance AG. **[2]**

This was routinely answered by nearly all candidates using standard methods.

Question 6 (b)

Two light inextensible strings, each of length 40 cm, are attached to the rod, one at A, the other at C. The other ends of these strings are attached to a fixed point D. The rod is allowed to hang in equilibrium.

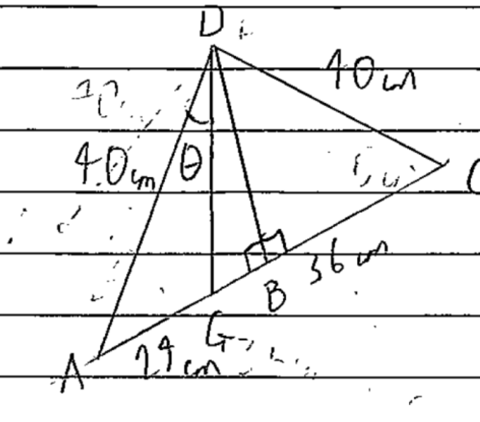
(b) Determine the angle AD makes with the vertical. **[3]**

Those who answered this successfully drew clear diagrams to support their reasoning, the problem and solution was easily understood and correctly answered as typified in Exemplar 3.

Exemplar 3

6(b)

The line DG is vertical. Hence we can draw the following triangle.



Not to scale

Where we want to find θ

$BD = \sqrt{40^2 - 30^2}$
$= 26.45$ cm

$GB = 6$ cm
$\angle GDB = \tan^{-1}\frac{6}{26.45}$
$= 12.78°$

$\angle ADB = \sin^{-1}\frac{30}{40}$
$= 48.59°$

$\theta = 48.59 - 12.78$
$= 35.8°$

Question 6 (c)

The two strings are now replaced by a single light inextensible string of length 80 cm. One end of the string is attached to A and the other end of the string is attached to C. The string passes over a smooth peg fixed at D. The rod hangs in equilibrium, but is not vertical, as shown in **Fig. 6.2**.

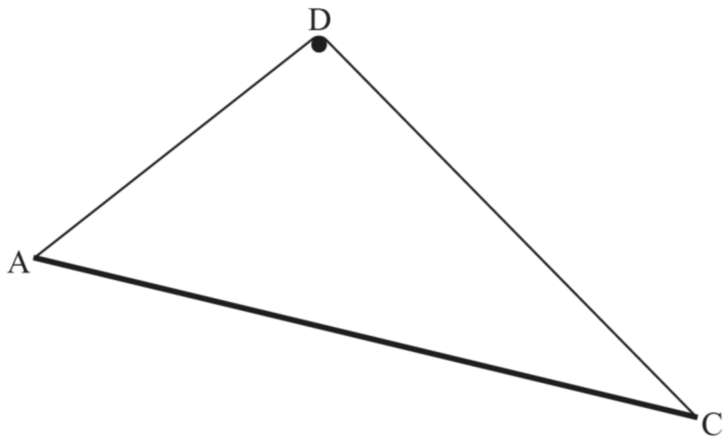


Fig. 6.2

(c) Explain why angle ADG and angle CDG must be equal. **[2]**

A small number of candidates referred to the constant tension in the single string and some went on to discuss the horizontal components. Unfortunately, a large number stated that the centre of mass must be below D and the vertical would bisect the angle without explaining that this was caused by the forces.

Question 6 (d)

(d) Determine the tension in the string. **[6]**

Only those with clear understanding of the geometry managed to find angles at D to resolve the tensions and weight successfully. Clear diagrams were a feature of successful solutions.

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