OCR
Oxford Cambridge and RSA

Friday 16 May 2025 – Afternoon

AS Level Further Mathematics B (MEI)

Y411/01 Mechanics a

Time allowed: 1 hour 15 minutes

You must have:
- the Printed Answer Booklet
- the Formulae Booklet for Further Mathematics B (MEI)
- a scientific or graphical calculator

QP

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INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided in the **Printed Answer Booklet**. If you need extra space use the lined page at the end of the Printed Answer Booklet. The question numbers must be clearly shown.
- Fill in the boxes on the front of the Printed Answer Booklet.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.
- Give your final answers to a degree of accuracy that is appropriate to the context.
- The acceleration due to gravity is denoted by $g\,\text{m s}^{-2}$. When a numerical value is needed use $g = 9.8$ unless a different value is specified in the question.
- Do **not** send this Question Paper for marking. Keep it in the centre or recycle it.

INFORMATION
- The total mark for this paper is **60**.
- The marks for each question are shown in brackets **[ ]**.
- This document has **12** pages.

ADVICE
- Read each question carefully before you start your answer.

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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 kg s^{-2} .

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

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]**

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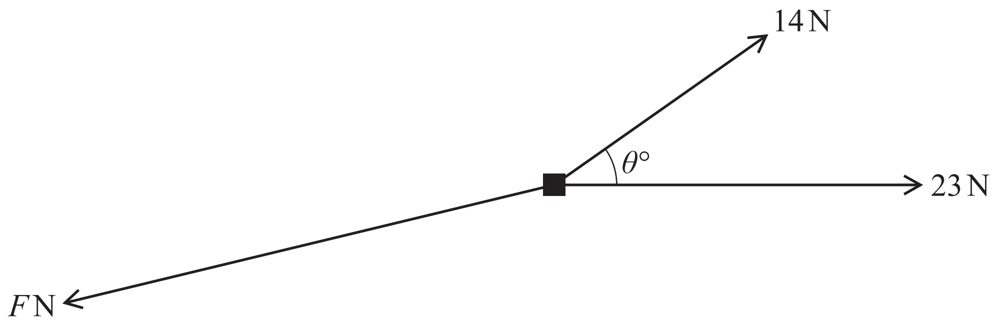
2 A small block of mass 5 kg is placed on a rough horizontal surface. The coefficient of friction between the block and the surface is $\frac{5}{7}$.

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]**

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

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

The value of θ is now increased slightly.

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

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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]**

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]**

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]**

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

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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]**

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]

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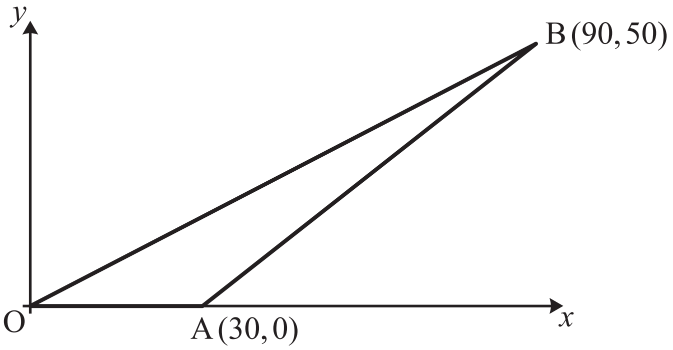
5 **Fig 5.1** shows a uniform triangular lamina OAB where O is the origin of the coordinate system in which the points A and B have coordinates (30, 0) and (90, 50) respectively.

Fig 5.1



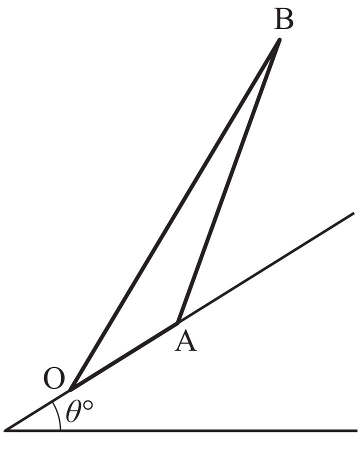
(a) Calculate the coordinates of the centre of mass of OAB. **[2]**

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]**

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]**

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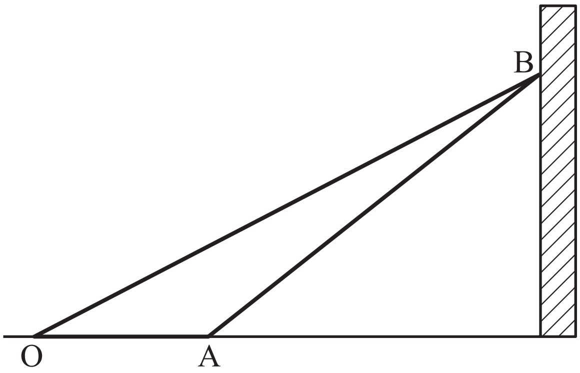
Prism S is now placed on rough horizontal ground so that OA is horizontal, but with B in contact with a smooth vertical wall, as shown in **Fig. 5.3**. The vertical plane containing O, A and B is perpendicular to the wall.

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]**

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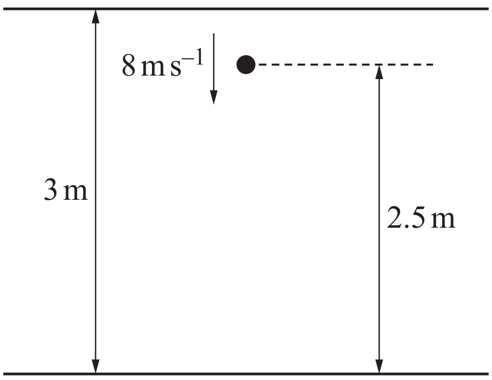
6 **Throughout this question you should assume that there is no air resistance.**

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]**

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]**

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

(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]**

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

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

Turn over for question 7

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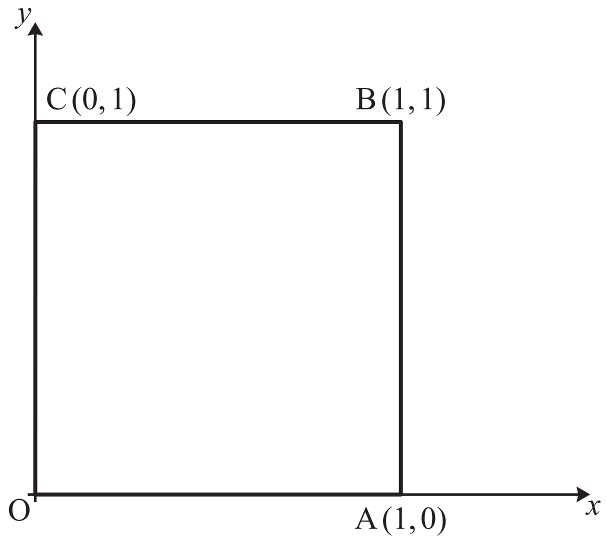
7 The diagram shows a light square lamina OABC where O is the origin of the coordinate system in which the points A, B and C have coordinates (1, 0), (1, 1) and (0, 1) respectively. Coordinates refer to the axes shown and the units are metres.



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]**

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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]**

(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]**

END OF QUESTION PAPER

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