OXFORD

INTERNATIONAL
AQA EXAMINATIONS

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

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I declare this is my own work.

INTERNATIONAL A-LEVEL

MATHEMATICS

(9660/MA05) Unit M2 Mechanics

Monday 24 January 2022 07:00 GMT Time allowed: 1 hour 30 minutes

Materials
- For this paper you must have the Oxford International AQA Booklet of Formulae and Statistical Tables (enclosed).
- You may use a graphical calculator.

Instructions
- Use black ink or black ball-point pen. Pencil should only be used for drawing.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.
- The **final** answer to questions requiring the use of calculators should be given to two significant figures, unless stated otherwise.
- Unless stated otherwise, the acceleration due to gravity, g, should be taken as 9.8 $\mathrm{m\,s^{-2}}$

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
TOTAL	

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

Advice
- Unless stated otherwise, you may quote formulae, without proof, from the booklet.
- Show all necessary working; otherwise marks may be lost.

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Answer **all** questions in the spaces provided.

1 A particle moves so that its position vector $\mathbf{r}$ metres relative to an origin O at time t seconds is

$$\mathbf{r} = \begin{bmatrix} \sin(2t) & \cos(3t) \\ \sin(2t) & \sin(3t) \\ & \cos(2t) \end{bmatrix}$$

1 (a) Show that the distance of the particle from O is constant.

[4 marks]

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1 (b) Find the velocity of the particle when $t = 0$

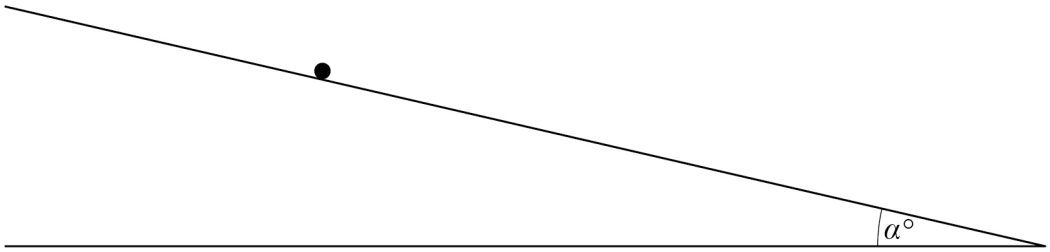
[5 marks]

Answer _____

9

Do not write outside the box

2 A particle of mass 5 kg is held at rest on a rough slope which is inclined at α degrees to the horizontal, as shown in the diagram.



The coefficient of friction between the particle and the slope is 0.25

2 (a) Draw a diagram to show all the forces acting on the particle when it is released.

Write down the names of the forces on your diagram.

[1 mark]

2 (b) In the case when $\alpha = 10$ show that the particle remains at rest when it is released.

[3 marks]

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2 (c) In the case when $\alpha = 20$ find the magnitude of the acceleration of the particle when it is released.

Give your answer to three significant figures.

[3 marks]

Answer _____

7

Turn over ►

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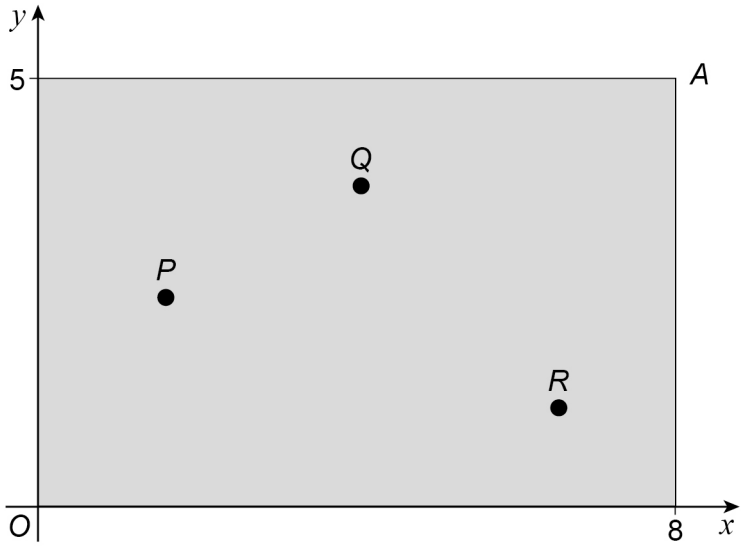
3 Three particles P, Q and R are fixed on a uniform rectangular lamina to create a system.

The corner A of the lamina is at the point with coordinates (8, 5)

The system is shown in the diagram below.



The table below shows the mass of each particle and the coordinates of the points at which they are fixed.

Particle	Mass (kg)	Coordinates
P	3	(2, 2.5)
Q	4	(4, 4)
R	5	(7, 1)

The mass of the uniform rectangular lamina is 2 kg

3 (a) State, with a reason, the coordinates of the centre of mass of the uniform rectangular lamina.

[2 marks]

3 (b) Find the exact coordinates of the centre of mass of the system.

[4 marks]

Do not write outside the box

Answer

3 (c) The system is freely suspended from A and hangs in equilibrium.

Find the angle between the vertical and the line from A to the position of R, giving your answer to the nearest degree.

[4 marks]

Answer

10

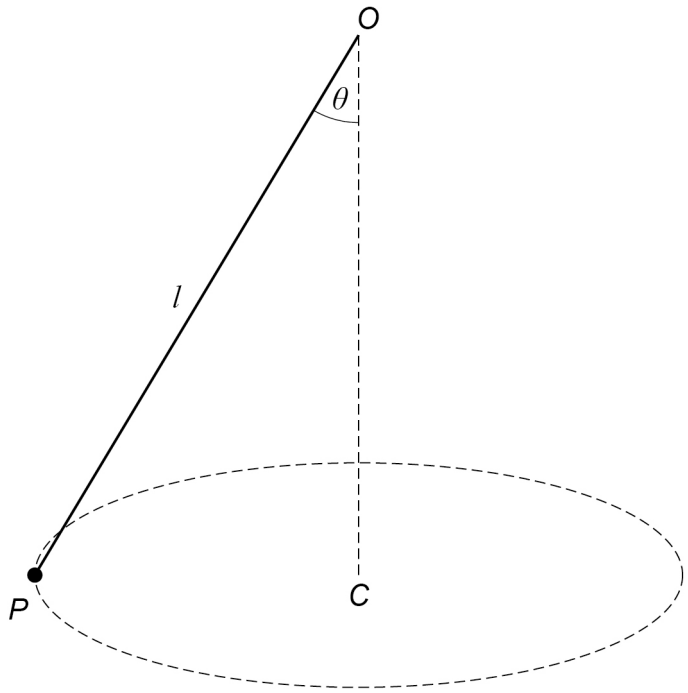
Do not write outside the box

4 A particle P of mass 3 kg is attached to one end of a light inextensible string of length l metres.

The other end of the string is attached to a fixed point O

The point O is vertically above the point C

The particle is set into motion and moves in a horizontal circle with centre C so that the angle POC is θ, as shown in the diagram.



The tension in the string is 60 newtons.

The distance PC is 0.6 metres.

4 (a) Find the value of l

Give your answer to three significant figures.

[4 marks]

Do not write outside the box

Answer

4 (b) Find the magnitude of the acceleration of the particle P and state its direction.

[3 marks]

Magnitude

Direction

4 (c) Find the angular speed of the particle P

[2 marks]

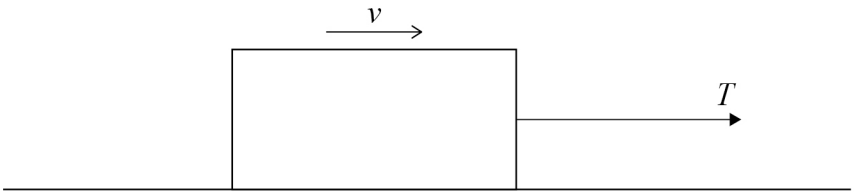
Answer

9

Do not write outside the box

5 A block of mass 20 kg is pulled across a rough horizontal surface by a light inextensible string with tension T newtons.

The speed of the block is v m s^{-1} and the string is horizontal, as shown in the diagram.



The coefficient of friction between the block and the surface is 0.5

The block also experiences an air resistance force of magnitude $31\sqrt{v}$ newtons.

The tension in the string remains constant throughout the motion.

5 (a) When $v = 4$ the acceleration of the block is 2 m s^{-2} in the direction of motion.

Find the value of T

[3 marks]

Answer _____

Do not write outside the box

5 (b) Find the rate at which work is done by the tension in the string when $v = 8$

[2 marks]

Answer _____

5 (c) Find the maximum value of v

Give your answer to three significant figures.

[3 marks]

Answer _____

8

Turn over ►

Do not write outside the box

6 A particle of mass 12 kg starts from rest and slides along a curved track.

The particle starts at position A, which is at a height of 8 metres above horizontal ground.

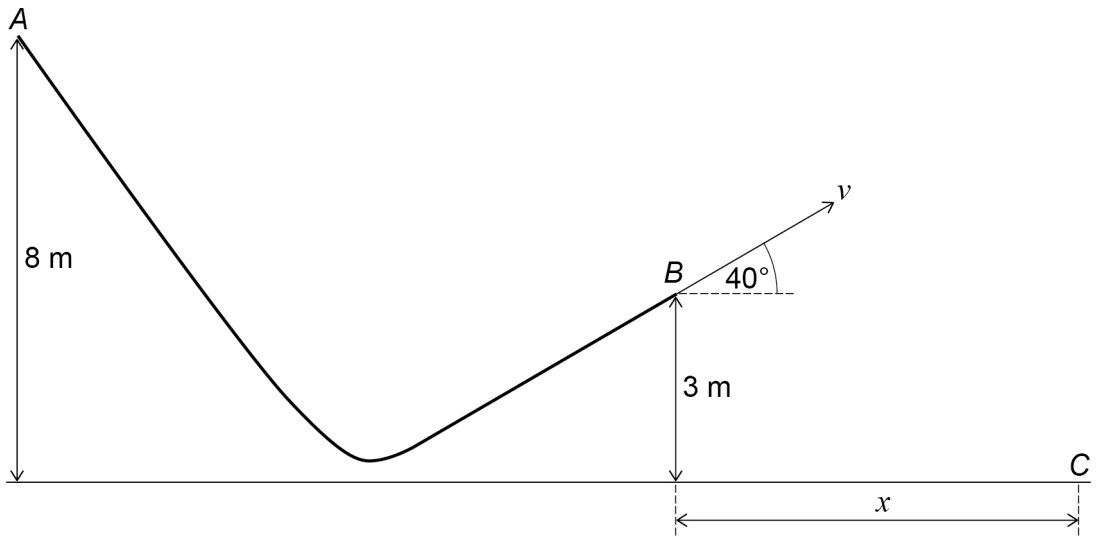
The particle leaves the curved track at position B, which is at a height of 3 metres above the same horizontal ground.

The length of the curved track between A and B is 20 metres.

When in motion between A and B, the particle experiences a constant resistive force of magnitude 16 newtons due to its contact with the curved track.

At B, the velocity of the particle is v m s^{-1} at an angle of 40° above the horizontal.

After leaving the track at position B, the particle reaches the ground for the first time at position C, which has a horizontal displacement of x metres from B, as shown in the diagram.



6 (a) Show that the value of v is 6.7 correct to two significant figures.

[4 marks]

Do not write outside the box

6 (b) Find the maximum height of the particle above the horizontal ground during its motion between B and C

[3 marks]

Answer _____

6 (c) Find the value of x

[5 marks]

Answer _____

6 (d) Find the speed of the particle as it reaches C

[2 marks]

Answer _____

14

Turn over ►

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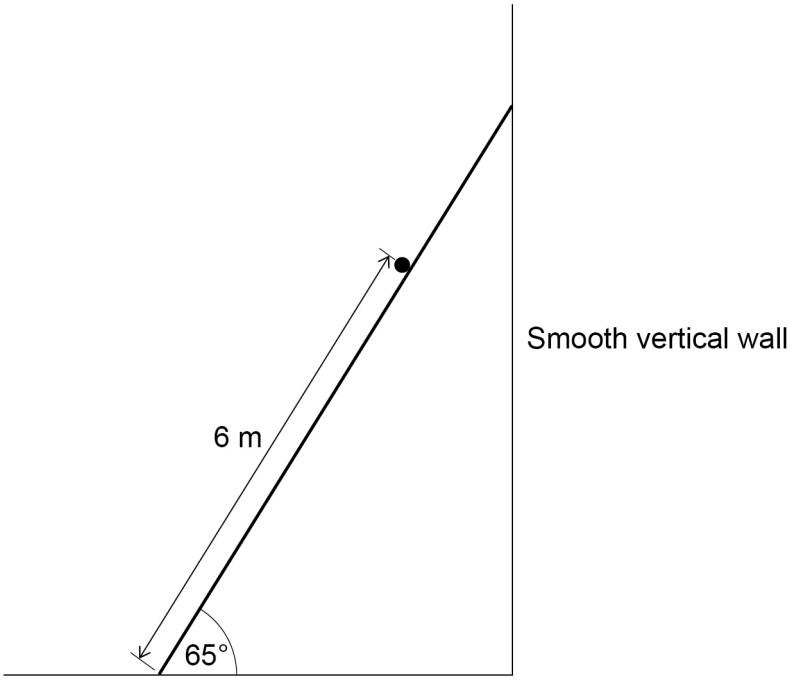
7 A uniform ladder of mass 25 kg has length 8 metres.

The ladder rests with one end against a smooth vertical wall and the other end on rough horizontal ground.

To do their job, a person of mass 75 kg needs to stand on the ladder at a distance of 6 metres from the base of the ladder. The person is modelled as a particle.

The ladder is in equilibrium and makes an angle of 65° to the horizontal, as shown in the diagram.



7 (a) The vertical wall is described as being smooth.

Explain what is meant by smooth.

[1 mark]

7 (b) (i) Find the magnitude of the normal reaction force exerted on the ladder by the wall.

[4 marks]

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Answer _____

7 (b) (ii) State, with a reason, the magnitude of the normal reaction force exerted on the wall by the ladder.

[2 marks]

7 (b) (iii) State, with a reason, the magnitude of the friction force exerted on the ladder by the ground.

[2 marks]

Question 7 continues on the next page

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7 (c) The coefficient of friction between the ladder and the ground is μ

The maximum possible friction force between the ladder and the ground is F newtons.

It is only safe for the person to use the ladder if the friction force between the ladder and the ground does not exceed $0.8F$ newtons.

The person stands at the same position on the ladder.

Find the smallest possible value of μ for which it is safe to use the ladder.

[3 marks]

Answer _____

Do not write outside the box

7 (d) When the ground is wet, the coefficient of friction between the ladder and the ground is 0.35

State, with a reason, whether it is safe for the person to use the ladder when the ground is wet.

[2 marks]

14

Turn over for the next question

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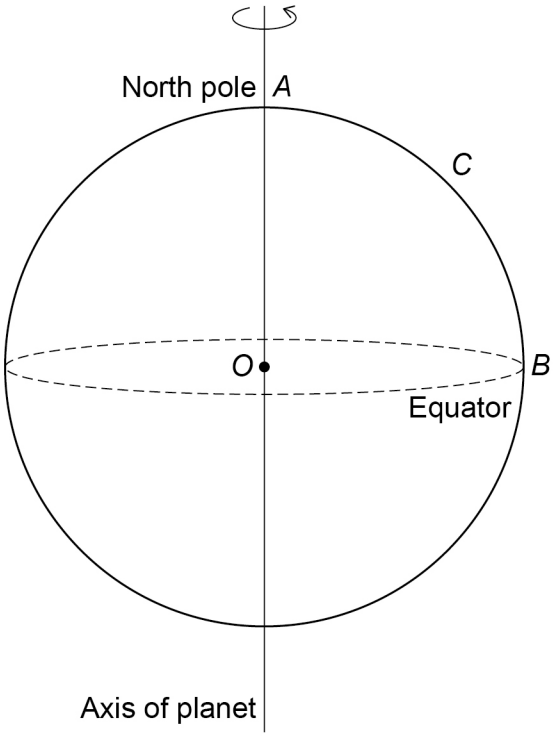
8 Three identical spacecraft A, B and C land on the surface of a spherical planet.

The centre of the planet is located at O

Spacecraft A lands at the North pole of the planet.

Spacecraft B lands on the Equator of the planet.

Spacecraft C lands at the midpoint of the arc AB, as shown in the diagram.



The radius of the planet is 6000 km

The time taken for the planet to complete one rotation about its axis is 10 hours.

The angular speed at all points on the surface of the planet is constant throughout its rotation.

8 (a) Show that the speed of spacecraft B due to the rotation of the planet is $1050\ \text{m s}^{-1}$ correct to three significant figures.

[3 marks]

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8 (b) Explain why the speed of spacecraft *A* due to the rotation of the planet is zero.

[1 mark]

8 (c) Find the magnitude of the acceleration experienced by spacecraft *B*

[2 marks]

Answer

8 (d) The mass of spacecraft *C* is 185 kg

Find the magnitude of the resultant force experienced by spacecraft *C*

[3 marks]

Answer

9

END OF QUESTIONS

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