OXFORD AQA

INTERNATIONAL QUALIFICATIONS

Please write clearly in block capitals.

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I declare this is my own work.

INTERNATIONAL A-LEVEL

MATHEMATICS

(9660/MA05) Unit M2 Mechanics

Tuesday 21 January 2025 07:00 GMT Time allowed: 1 hour 30 minutes

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
TOTAL	

Materials

- For this paper you must have the OxfordAQA 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 m s^{-2}

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 truck of mass 18 000 kg has an engine which can produce a maximum power output of 345 kilowatts.

When the truck moves with speed v m s^{-1} it experiences a resistance force of magnitude R newtons, where

$$R = kv^{\frac{9}{4}}$$

and k is a constant.

It is given that when the truck moves with speed 12 m s^{-1} along a straight, horizontal road, its maximum possible magnitude of acceleration is 1.5 m s^{-2}

1 (a) Show that $k = 6.53$, correct to three significant figures.

[3 marks]

1 (b) The truck moves with a constant speed of 18 m s^{-1} for a period of 30 seconds along the straight, horizontal road.

Find the work done against the resistance force in this period.

[2 marks]

Answer _____

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1 (c) Find the maximum possible speed of the truck along the straight, horizontal road.

[2 marks]

Answer _____

7

Turn over for the next question

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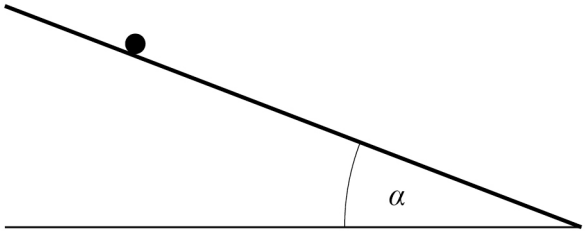
2 A particle of weight 100 newtons is at rest on a rough slope.

The slope is inclined at an angle of α to the horizontal, as shown in the diagram.



The particle is on the point of slipping down the slope.

The magnitude of the normal reaction force which acts on the particle due to its contact with the slope is 82 newtons.

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

2 (a) Find the angle α

Give your answer to the nearest degree.

[2 marks]

Answer _____

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2 (b) Find the magnitude of the friction force which acts on the particle due to its contact with the rough slope.

[2 marks]

Answer _____

2 (c) Find the value of μ

[1 mark]

Answer _____

5

Turn over for the next question

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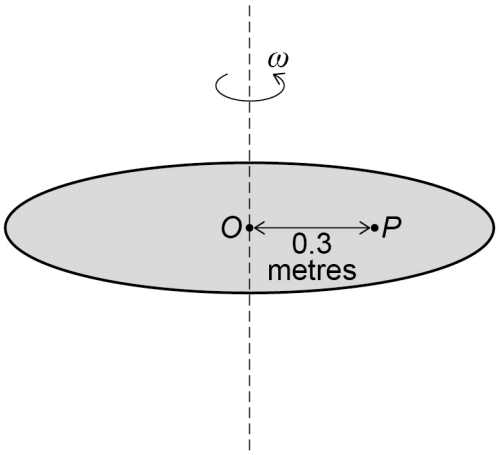
3 Particle P of mass 20 kg lies on a rough horizontal circular disc.

The centre of the disc is at the point O

The disc rotates with an angular speed of ω radians per second about a vertical axis through O

The particle is 0.3 metres from O as shown in **Figure 1**

Figure 1



The coefficient of friction between the particle and the rough horizontal circular disc is 0.45

3 (a) It is given that the particle does not slide.

Show that the maximum value of ω is 3.83, correct to three significant figures.

[4 marks]

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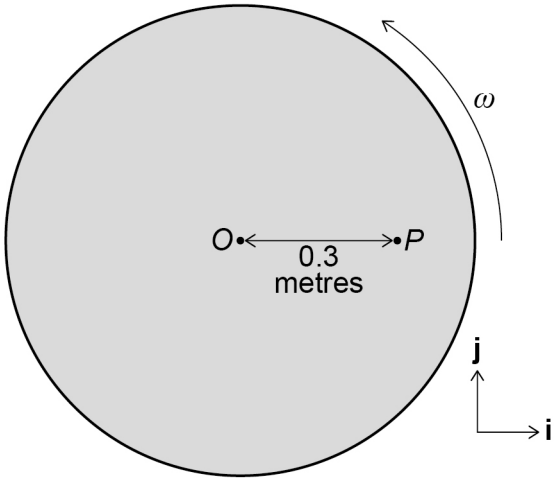
3 (b) **Figure 2** shows an aerial view of the particle on the disc, where **i** and **j** are perpendicular horizontal unit vectors.

Figure 2



In the case when $\omega = 3$, the position vector **r** metres of the particle relative to O at time t seconds is given by

$$\mathbf{r} = 0.3\cos(3t)\mathbf{i} + 0.3\sin(3t)\mathbf{j}$$

3 (b) (i) The velocity of the particle at time t seconds is **v** m s^{-1}

Find **v** in terms of t

[2 marks]

Answer _____

3 (b) (ii) The friction acting on the particle at time t seconds due to its contact with the disc is **F** newtons, where **F** is a vector.

Find **F** in terms of t

[3 marks]

Answer _____

9

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4 A football is kicked with speed u m s^{-1} at an angle α above the horizontal from a point O on horizontal ground.

The horizontal displacement of the football from O at time t seconds is x metres.

The vertical displacement of the football from O at time t seconds is y metres.

Assume that the only force that the football experiences whilst it is in the air is its weight.

4 (a) Show that

$$\frac{g\sec^2\alpha}{2u^2}x^2 - x\tan\alpha + y = 0$$

[5 marks]

Do not write outside the box

4 (b) A football is kicked with speed 15 m s^{-1} at an angle 60° above the horizontal from a point *O* on horizontal ground.

When the vertical displacement of the football from *O* is 7 metres, its horizontal displacement from *O* is x metres.

4 (b) (i) Find the possible values of x

Give your values to three significant figures.

[3 marks]

Answer _____

4 (b) (ii) The period of time that the football has a vertical displacement of at least 7 metres from *O* is T seconds.

Find the value of T

[2 marks]

Answer _____

10

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5 A **non-uniform** rod of mass 25 kg has length 11 metres.

The rod rests with one end against a rough vertical wall at the point Y

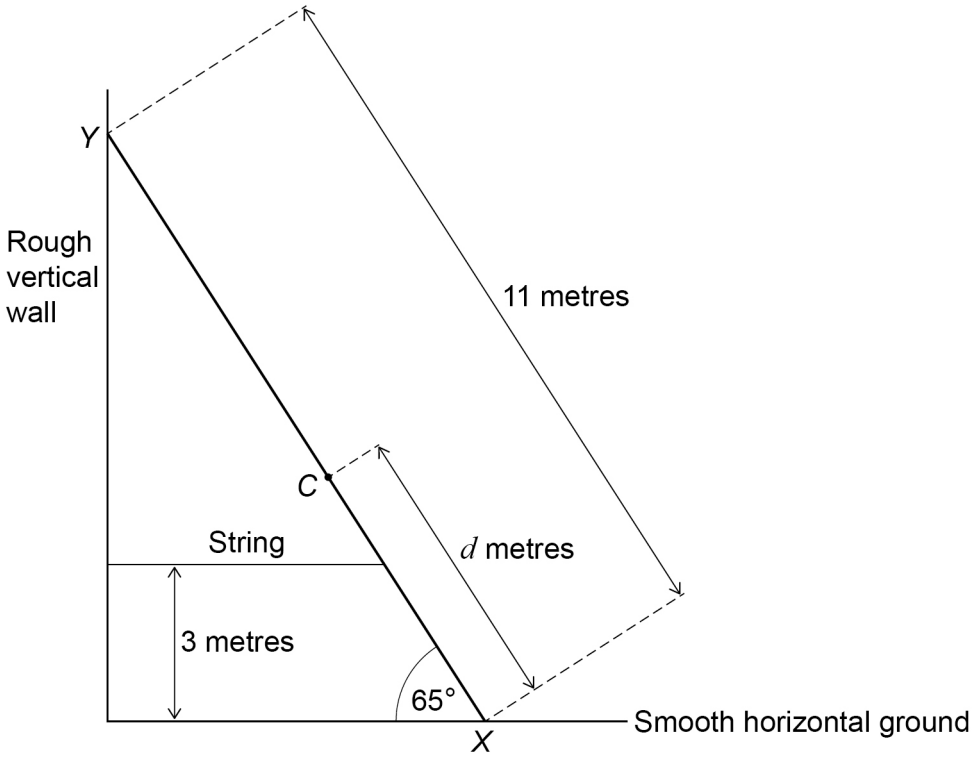
The other end of the rod is on smooth horizontal ground at the point X

The distance from X to the point C, the centre of mass of the rod, is d metres.

A light inextensible string has one of its ends attached to the vertical wall.

The other end of the string is attached to the rod so that the string is horizontal and 3 metres vertically above the horizontal ground.

The vertical plane containing the rod and string is perpendicular to the wall and the angle between the rod and the horizontal ground is 65°, as shown in the diagram.



The coefficient of friction between the wall and the rod is 0.4

The magnitude of the tension in the string is 40 newtons.

The rod is in equilibrium with the magnitude of the friction at Y at its maximum possible value.

5 (a) State with a reason the magnitude of the reaction force acting on the rod due to its contact with the vertical wall.

[2 marks]

Magnitude of reaction force _____

Reason _____

_____

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5 (b) By taking moments about X, find the value of d

[4 marks]

Answer _____

6

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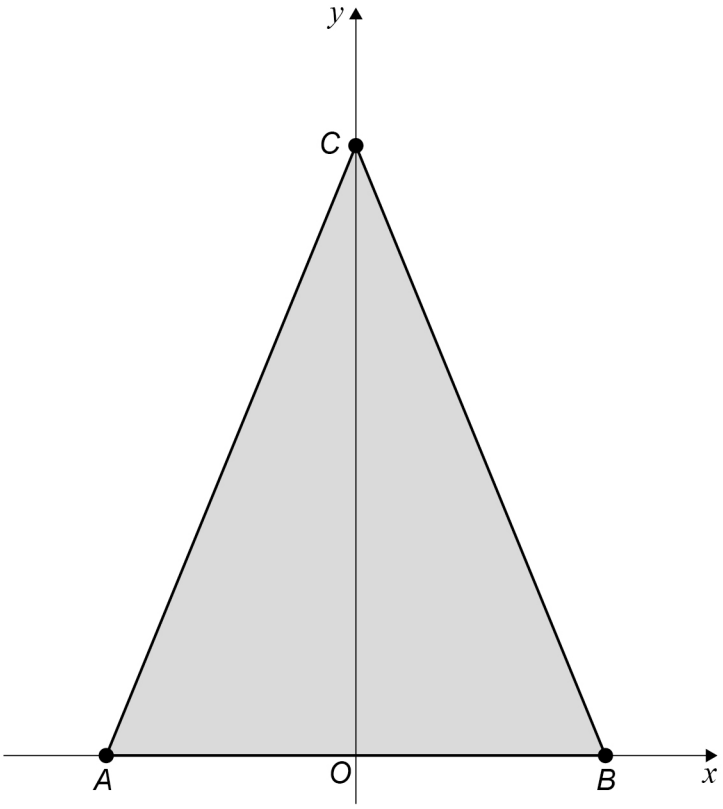
6 Three particles A, B and C are fixed on the vertices of a uniform triangular lamina to create a system, as shown in the diagram below.



The table below shows the mass and the coordinates, relative to the origin O, of the point at which each particle is fixed to the lamina, where d is a constant.

Particle	Mass (kg)	Coordinates (metres)
A	2	$(-5, 0)$
B	4	$(5, 0)$
C	7	$(0, d)$

The triangular lamina has mass 6 kg

The centre of mass of the triangular lamina is located at $\left(0, \frac{d}{3}\right)$

6 (a) The lamina is described as uniform.

Explain what is meant by uniform in this context.

[1 mark]

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6 (b) (i) Find the x-coordinate of the centre of mass of the system.

Give your answer in an exact form.

[2 marks]

Answer _____

6 (b) (ii) Find in terms of d the y-coordinate of the centre of mass of the system.

Give your answer in an exact form.

[2 marks]

Answer _____

6 (c) It is given that, when the system is freely suspended from O and hangs in equilibrium, the angle between the vertical and the line OC is 5 degrees.

Find the value of d

[3 marks]

Answer _____

8

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7 A particle of mass 3.2 kg is held at rest on the roof of a building.

The roof is smooth and is inclined at an angle of 40° to the horizontal.

The particle is released and it slides 2.5 metres down the roof.

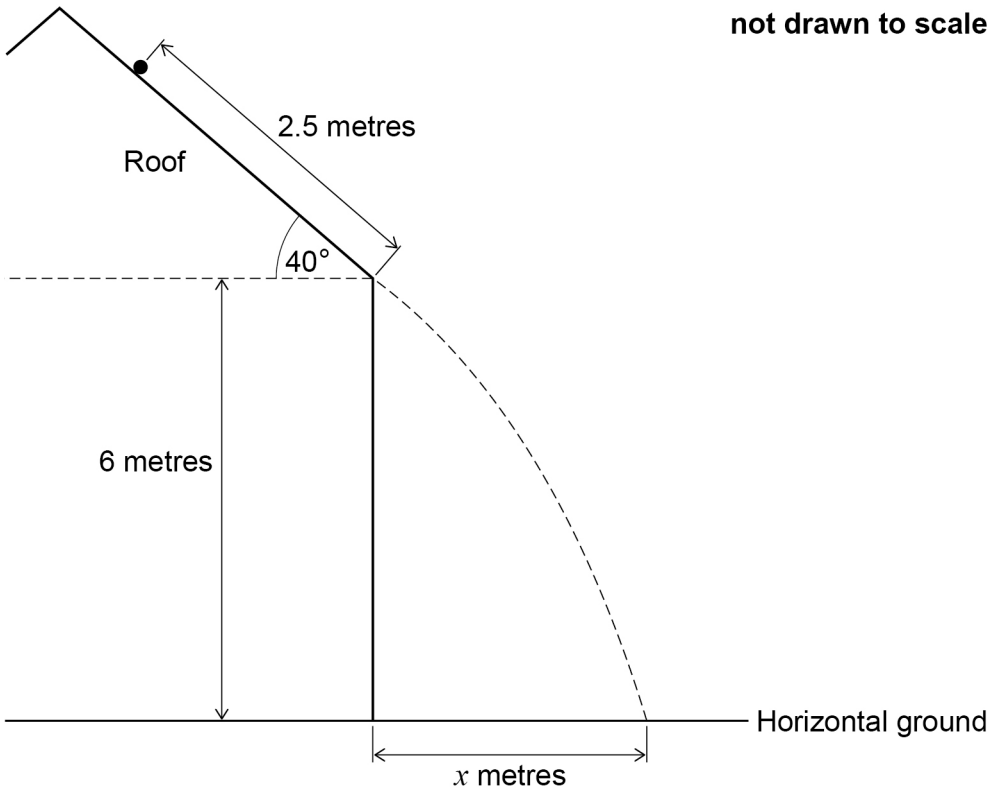
After moving 2.5 metres down the roof, the particle moves through the air towards the horizontal ground below.

Assume that the particle experiences no air resistance throughout its motion.

The ground is 6 metres vertically below the edge of the roof.

The particle first collides with the ground at a point which is x metres horizontally from the edge of the roof, as shown in the diagram.

not drawn to scale



7 (a) The speed of the particle when it leaves the roof is u m s^{-1}

Use an energy method to find the value of u

[3 marks]

Answer _____

Do not write outside the box

7 (b) Find the value of x

[5 marks]

Answer _____

7 (c) The particle first collides with the ground with velocity v m s^{-1} at an angle α degrees to the downward vertical.

Find the value of v and the value of α

Give your values to three significant figures.

[5 marks]

$v =$ _____ $\alpha =$ _____

13

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8 Two spheres X and Y are moving in the same direction in a straight line on a smooth horizontal surface.

The spheres have the same radius.

Sphere X has mass 2 kg and the magnitude of its momentum is 19.2 kg m s^{-1}

Sphere Y has mass 5 kg and the magnitude of its momentum is 7.5 kg m s^{-1}

The spheres and their initial momentum are shown in the diagram.

The two spheres collide.

After the collision, the magnitude of the momentum of X is 2.4 kg m s^{-1}

8 (a) Find the **two** possible values for the magnitude of the momentum of sphere Y after the collision.

[3 marks]

Answer _____ and _____

8 (b) Before the collision, the sum of the kinetic energies of X and Y is E joules.

Show that the value of E is 97.785

[3 marks]

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8 (c) After the collision, the sum of the kinetic energies of X and Y is F joules.

Find the **two** possible values of $E - F$

Give your values to three significant figures.

[6 marks]

Answer _____ and _____

12

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9 A body of mass 3 kg experiences a resultant force **F** newtons at time t seconds where

$$\mathbf{F} = \left(36t^2 - 18t\right)\mathbf{i} + \left(6\cos t - 24\sin 2t\right)\mathbf{j} + 3\mathrm{e}^{-\frac{t}{3}}\mathbf{k}$$

where **i**, **j** and **k** are perpendicular unit vectors.

The body starts from rest at the origin *O*

When $t = 2$ the body is at the point *A*

Find the distance *OA*

Give your answer to three significant figures.

[10 marks]

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Answer _____

10

END OF QUESTIONS

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