OXFORD AQA

INTERNATIONAL QUALIFICATIONS

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INTERNATIONAL A-LEVEL

MATHEMATICS

(9660/MA05) Unit M2 Mechanics

Thursday 18 January 2024 07:00 GMT Time allowed: 1 hour 30 minutes

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

Do not write outside the box

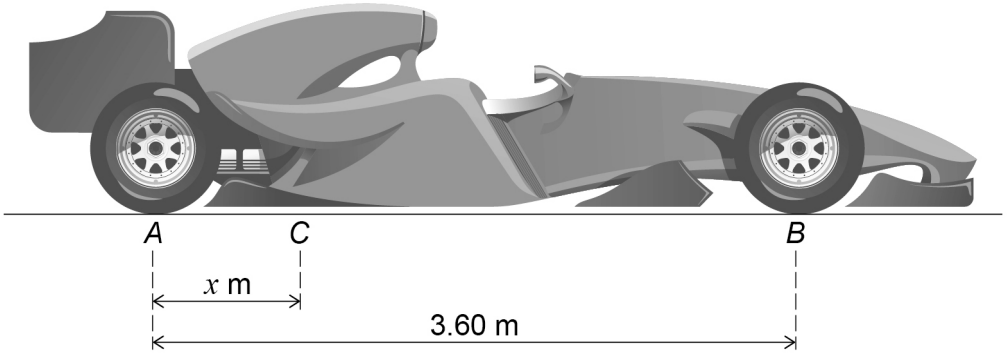
Answer **all** questions in the spaces provided.

1 (a) A racing car is at rest on horizontal ground.

The racing car's rear wheels are in contact with the ground at A

The racing car's front wheels are in contact with the ground at B where $AB = 3.60$ metres.

The centre of mass of the racing car is located vertically above a point C that is x metres in front of the rear wheels, as shown in the diagram.



The mass of the racing car is 800 kg. There is no driver in the car.

The magnitude of the total vertical reaction force which acts on the racing car's rear wheels due to their contact with the ground at A is 6100 newtons.

1 (a) (i) Find the value of x

[3 marks]

Answer _____

1 (a) (ii) Find the magnitude of the total vertical reaction force which acts on the racing car's front wheels.

[1 mark]

Answer _____

Do not write outside the box

1 (b) The racing car is now driven along a straight, horizontal section of race track.

The maximum power output of the racing car's engine is 780 kW

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

$$R = 0.95v^2$$

1 (b) (i) The racing car moves at a constant speed of 20 m s^{-1} for a period of 7.5 seconds.

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

[2 marks]

Answer _____

1 (b) (ii) Find the magnitude of the maximum resultant force that can act on the racing car when it is moving at 50 m s^{-1}

[2 marks]

Answer _____

1 (b) (iii) Find the maximum possible speed of the racing car.

[2 marks]

Answer _____

10

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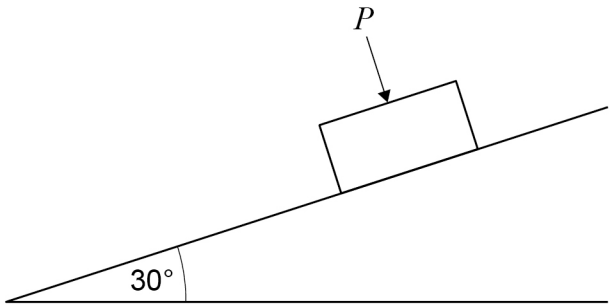
2 A block of mass 17 kg is at rest on a rough slope which is inclined at 30° to the horizontal.

The coefficient of friction between the block and the slope is 0.4

A force P newtons acts on the block along a line through the block's centre of mass, perpendicular to the plane of the slope, as shown in the diagram.



2 (a) Find the least possible value of P that prevents the block sliding down the slope.

[4 marks]

Answer _____

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2 (b) In the case when $P = 40$, the block slides from rest down the slope.

The force P newtons continues to act on the block in a direction perpendicular to the plane of the slope.

2 (b) (i) Explain why the force P newtons does no work on the block as it slides down the slope.
[1 mark]

2 (b) (ii) Explain why the loss in the block's gravitational potential energy is **not** equal to the gain in the block's kinetic energy after the block starts sliding down the slope.
[1 mark]

2 (b) (iii) Find the magnitude of the block's acceleration down the slope.
[2 marks]

Answer _____

2 (b) (iv) Find the distance the block has moved down the slope 6 seconds after it started sliding.
[2 marks]

Answer _____

10

Turn over ►

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3 Two blocks A and B are connected by a light inextensible string.

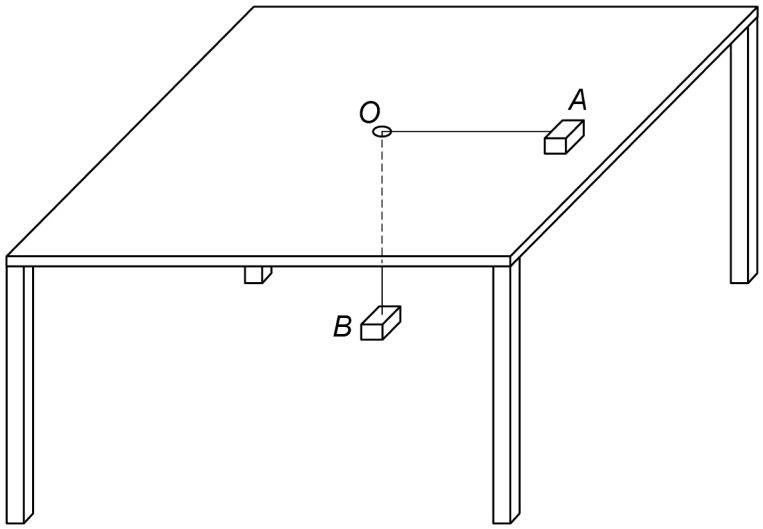
The mass of A is 4.9 kg and the mass of B is m kg

Block A moves on a smooth horizontal table so that its velocity $\mathbf{v}$ m s^{-1} at time t seconds is given by

$$\mathbf{v} = -6\sin(4t)\mathbf{i} + 6\cos(4t)\mathbf{j}$$

where $\mathbf{i}$ and $\mathbf{j}$ are perpendicular horizontal unit vectors.

The string passes through a smooth hole at O so that B hangs in equilibrium vertically below O, as shown in the diagram.



3 (a) When $t = 0$ the position of A is $1.5\mathbf{i}$ relative to O

Show that the distance of A from O is constant throughout its motion.

[5 marks]

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3 (b) (i) Write down the angular speed of A

Include units in your answer.

[2 marks]

Answer _____ Units _____

3 (b) (ii) Find the magnitude of the resultant force which acts on A and state its direction.

[3 marks]

Magnitude _____

Direction _____

3 (c) Find the value of m

[2 marks]

Answer _____

12

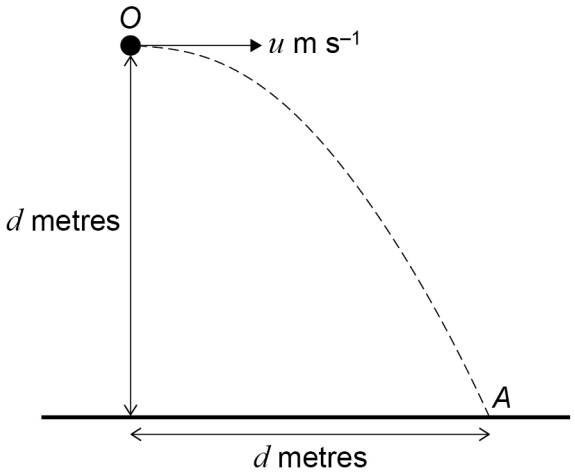
Turn over ►

Do not write outside the box

4 A particle is projected horizontally from a point O with speed u m s^{-1}

The point O is d metres above horizontal ground.

The particle hits the ground for the first time at the point A, which has a horizontal displacement of d metres from O, as shown in the diagram.



4 (a) Find u in terms of d and g

[3 marks]

Answer _____

Do not write outside the box

4 (b) Find the speed at which the particle hits the ground at A

Give your answer in the form $\sqrt{k}\ u$, where k is an integer.

[3 marks]

Answer _____

6

Turn over for the next question

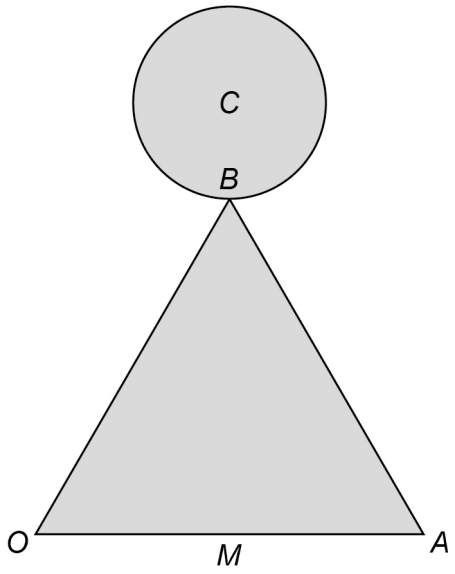
Do not write outside the box

5 A government department is designing a new logo by using two uniform laminas made from the same material.

The logo consists of an equilateral triangle OAB and a circle with centre C

The point M is the midpoint of OA

The circle and triangle touch such that the C, B and M all lie on the same straight line, as shown in the diagram.



The equilateral triangle has side length $2d$ and the circle has diameter d

The centre of mass of the equilateral triangle is one-third of the way along the line segment MB from M

5 (a) Explain why the centre of mass of the logo lies on the straight line through C, B and M

[1 mark]

5 (b) The distance of the centre of mass of the logo from M is kd

Find the value of k

Give your answer to three significant figures.

[6 marks]

Do not write outside the box

Answer _____

5 (c) The logo is freely suspended from O and hangs in equilibrium.

Find the angle between the vertical and the line OM

Give your answer to the nearest degree.

[2 marks]

Answer _____

9

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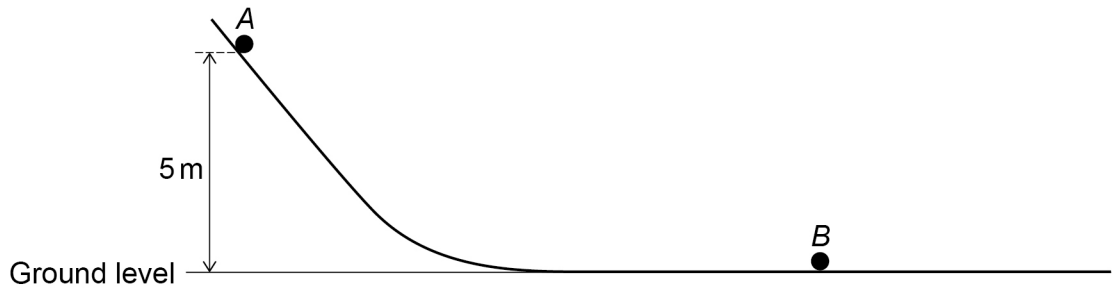
6 Two particles A and B are on a smooth track which has two sections: a raised curved section, and a horizontal section at ground level.

Particle A of mass 3 kg is released from rest at a point on the curved section of the track which is 5 metres vertically above ground level.

Particle B of mass 10 kg is at rest on the horizontal section of the track.

Particle A collides with particle B

The track and the initial positions of A and B are shown in the diagram.



The speed of A immediately after its collision with B is 2 m s^{-1}

6 (a) Find the **two** possible speeds for B immediately after the collision.

Give your values to three significant figures.

[6 marks]

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Answer _____ and _____

6 (b) For the case where *B* has the **smaller** of the two possible speeds found in **part (a)**, the two particles are in contact for 0.20 seconds during the collision.

Find the magnitude of the average force which acts on *B* during the collision.

[2 marks]

Answer _____

6 (c) For the case where *B* has the **larger** of the two possible speeds found in **part (a)**, find the total kinetic energy that is lost during the collision.

[2 marks]

Answer _____

10

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7 The weight **W** newtons of a particle of mass 5 kg is given by

$$\mathbf{W} = \begin{bmatrix} 0 \\ 0 \\ -49 \end{bmatrix}$$

Two variable forces $\mathbf{F}_1$ newtons and $\mathbf{F}_2$ newtons at time t seconds are given by

$$\mathbf{F}_1 = \begin{bmatrix} 10\cos^2 t \\ 30t \\ 50\mathrm{e}^{-2t} \end{bmatrix} \quad \text{and} \quad \mathbf{F}_2 = \begin{bmatrix} 10\sin^2 t \\ 90t^2 \\ -31 \end{bmatrix}$$

The two variable forces act on the particle.

At $t = 0$ the particle is moving with velocity $\begin{bmatrix} 3 \\ -1 \\ 5 \end{bmatrix}$ $\mathrm{m\,s^{-1}}$ and is at the origin O

7 (a) Find the velocity of the particle in terms of t

[5 marks]

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Answer

7 (b) Find the distance between the particle and O when $t = 0.8$

Give your answer to three significant figures.

[6 marks]

Answer

11

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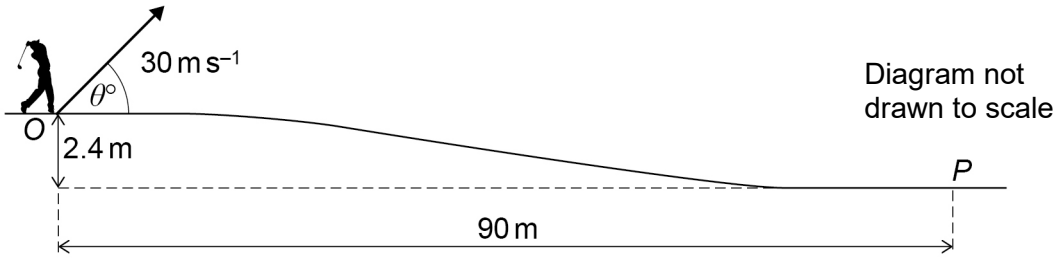
8 A player uses a golf club to hit a golf ball from horizontal ground at a point O

The ball leaves O with velocity $30\ \text{m s}^{-1}$ at an angle θ degrees above the horizontal.

The ball reaches the ground for the first time at the point P

Point P is on horizontal ground which is 2.4 metres vertically below the level of O

The horizontal displacement between O and P is 90 metres, as shown in the diagram.



Assume that the golf ball experiences negligible air resistance.

8 (a) Find the **two** possible values of θ

Give your values to three significant figures.

[9 marks]

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Answer _____ and _____

8 (b) Use the appropriate value for θ found in **part (a)** to find the larger time for the golf ball to move from O to P

[2 marks]

Answer _____

8 (c) Comment on the assumption that the golf ball experiences negligible air resistance.

[1 mark]

12

END OF QUESTIONS

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ANSWER IN THE SPACES PROVIDED

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