OXFORD

INTERNATIONAL
AQA EXAMINATIONS

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INTERNATIONAL A-LEVEL

MATHEMATICS

(9660/MA05) Unit M2 Mechanics

Thursday 23 January 2020 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 graphics 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}

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

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

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1 A particle moves so that its velocity, $\boldsymbol{v}$ m s^{-1}, at time t seconds is given by

$$\boldsymbol{v} = \begin{bmatrix} 6\cos 3t \\ 2 - 8\sin 4t \\ 2t + 4\mathrm{e}^{-2t} \end{bmatrix}$$

1 (a) Find the speed of the particle when $t = \dfrac{2\pi}{3}$

[3 marks]

Answer _____

1 (b) The initial position of the particle is $\begin{bmatrix} 4 \\ 5 \\ 3 \end{bmatrix}$

Find the position vector of the particle at time t.

[5 marks]

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Answer _____

1 (c) The mass of the particle is 7.5 kg

Find the resultant force acting on the particle when $t = 0$

[4 marks]

Answer _____

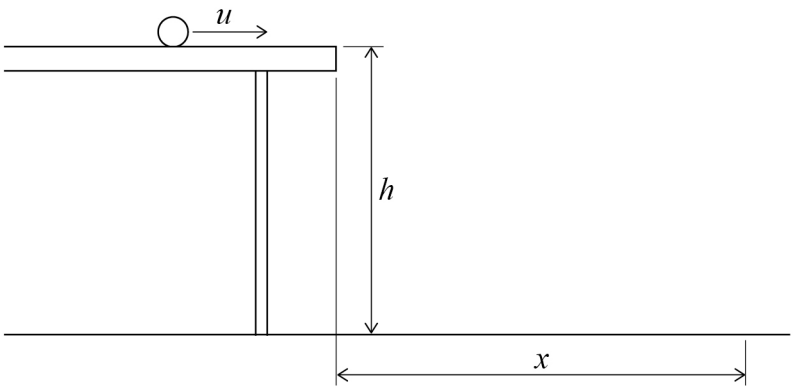
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2 A particle of mass m moves with constant velocity u across a smooth horizontal table, as shown in the diagram.

The top of the table is a distance h above the horizontal ground.

The particle leaves the end of the table and first hits the ground a horizontal distance x from the table.



2 (a) Show that the horizontal distance x is given by

$$x = u\sqrt{\frac{2h}{g}}$$

where g is the acceleration due to gravity.

[3 marks]

Do not write outside the box

2 (b) Find an expression, in terms of m, u, g and h, for the kinetic energy of the particle immediately before it hits the ground for the first time.

[3 marks]

Answer _____

2 (c) Explain why the kinetic energy of the particle immediately before it hits the ground is likely to be less than your answer to part **(b)**.

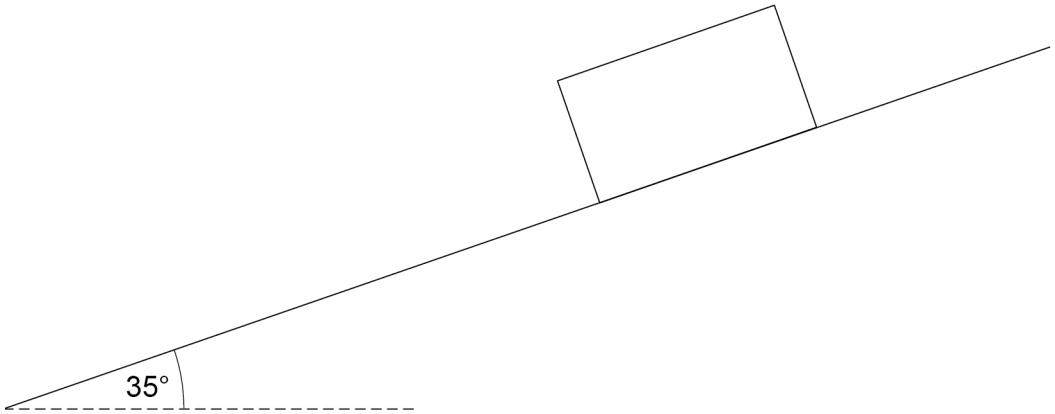
[1 mark]

7

Turn over ►

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3 A block of mass 12 kg slides from rest down a rough plane which is inclined at 35° to the horizontal.



The coefficient of friction between the block and the plane is 0.65

3 (a) Draw a diagram to show all of the forces acting on the block, writing down the names of the forces on your diagram.

[1 mark]

3 (b) Find the resultant force acting on the block.

[4 marks]

Do not write outside the box

Answer

3 (c) The block now slides down a different rough plane at constant speed along a line of greatest slope.

This plane is inclined at an angle θ to the horizontal.

The coefficient of friction between the block and this plane is also 0.65

Find θ, giving your answer to the nearest 0.1°

[3 marks]

Answer

8

Turn over ►

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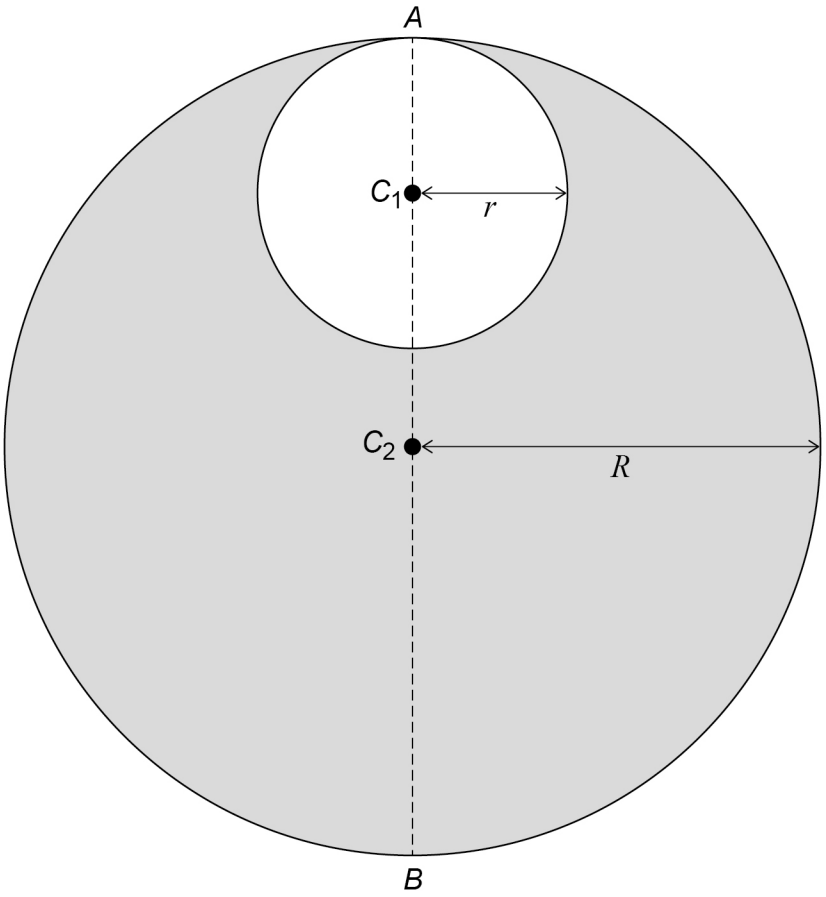
4 An artist is designing a new logo for a company by removing a circle from a larger circle of uniform lamina.

The smaller circle has radius r and centre C_1

The larger circle has radius R and centre C_2

The two circles meet at the point A.

C_1 and C_2 lie on the line AB, as shown in the diagram.



4 (a) Explain why the centre of mass of the logo is on the line AB.

[1 mark]

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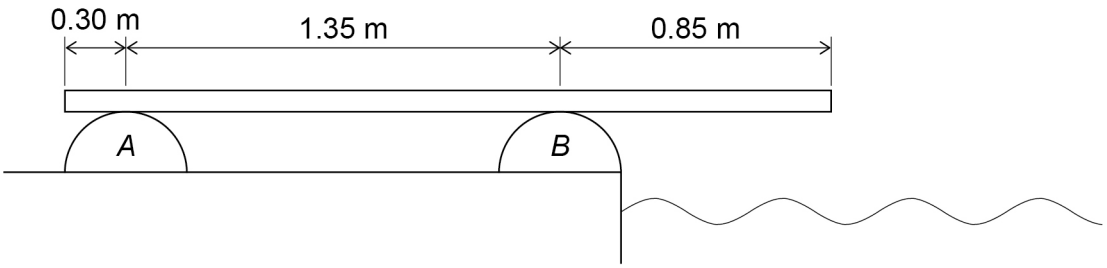
4 (b) Find, in terms of R and r, the distance of the centre of mass of the logo from the point B.
[5 marks]

Answer _____

6

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5 A diving board at a swimming pool is made by resting a plank of wood horizontally on two halves of a barrel, as shown in the diagram.



The plank of wood is uniform and rigid.

The plank makes contact with the half-barrels at each of the single points *A* and *B*

The plank is 2.5 metres long and has a mass of 40 kg

5 (a) A child of mass 25 kg walks along the diving board towards the swimming pool.

Determine whether or not the child can walk to the end without the diving board tipping.

[3 marks]

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5 (b) When a child of mass m kg stands on the end of the diving board over the swimming pool, the diving board is on the verge of tipping.

Find the value of m, giving your answer to three significant figures.

[2 marks]

Answer _____

5 (c) State, with a reason, one way in which the design of the diving board could be changed to increase your answer to part **(b)**.

[2 marks]

7

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6 A motorcycle and its rider have a combined mass of 250 kg

The motorcycle's engine has a maximum power output of 180 kilowatts.

The motorcycle and rider experience a force due to air resistance of magnitude $c\sqrt{v}$ newtons, where c is a constant and v is the speed of the motorcycle in m s^{-1}

6 (a) When travelling along a straight horizontal section of race track at 36 m s^{-1}, the maximum acceleration of the motorcycle and rider is known to be 5.0 m s^{-2}

Find the value of c.

[4 marks]

Answer _____

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6 (b) The motorcycle and rider travel at a constant speed of 25 m s^{-1} up a straight section of race track which is inclined at 6.0° to the horizontal.

Calculate the power output of the engine, giving your answer in kilowatts to two significant figures.

[4 marks]

Answer _____

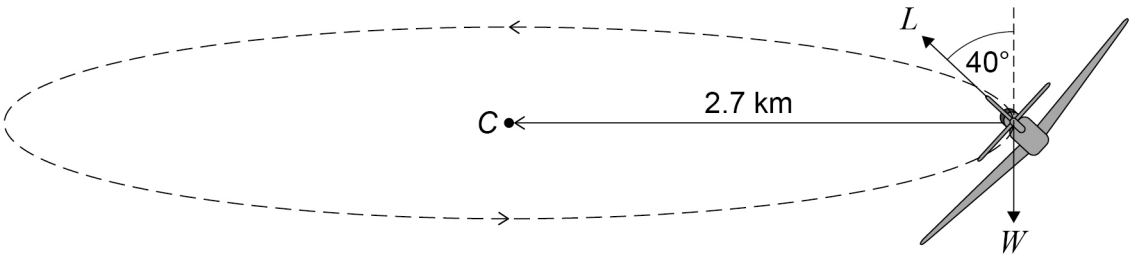
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7 An aeroplane of mass 12 000 kg is moving with a constant speed in a horizontal circle of radius 2.7 km and centre *C*, as shown in **Figure 1**

Figure 1

Not drawn accurately



The force provided by the wings of the aeroplane has magnitude L newtons and makes an angle of 40° to the vertical. The weight of the aeroplane is W newtons.

7 (a) (i) Show that the value of L is 1.54×10^5, correct to three significant figures.

[2 marks]

7 (a) (ii) Explain why the force provided by the wings of the aeroplane does not work on the aeroplane.

[1 mark]

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7 (b) Find the angular speed of the aeroplane, giving your answer to three significant figures.
[3 marks]

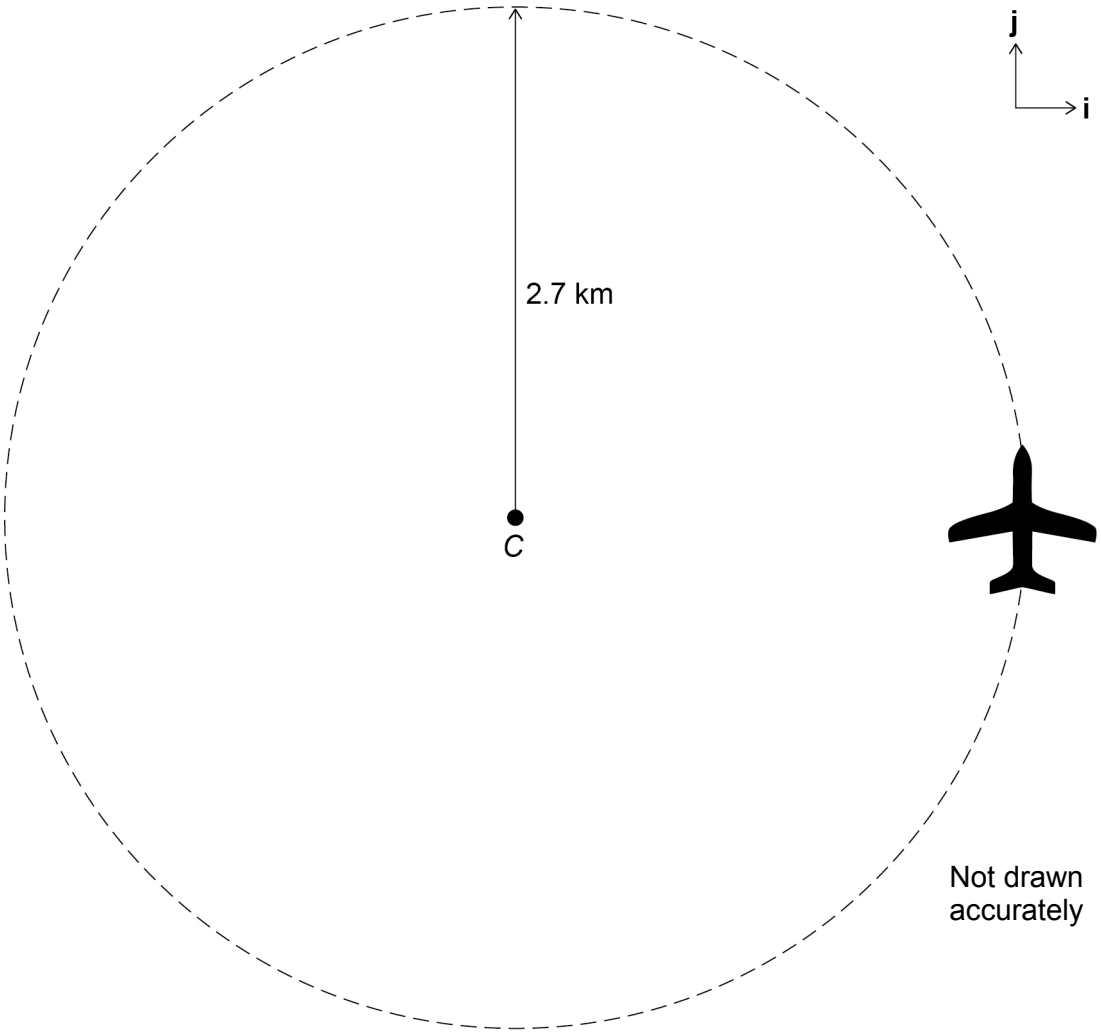
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7 (c) **Figure 2** shows the view of the aeroplane from above and the horizontal circle it is moving in.

Figure 2



The unit vectors **i** and **j** are directed due east and due north respectively.

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7 (c) (i) The initial position of the aeroplane is due east of C.

Find the position vector of the aeroplane relative to C, in metres, at time t seconds.

[3 marks]

Answer _____

7 (c) (ii) Using your answer to part **(c)(i)**, find the acceleration of the aeroplane at time t seconds.

[2 marks]

Answer _____

11

Turn over ►

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8 In a contest, motorless carts are driven downhill along a 1600 m course.

The vertical height change between the start line and finish line of the course is 150 m

The combined mass of a cart and driver is 120 kg

The cart and driver have an initial speed of 8.0 m s^{-1} as they cross the start line.

8 (a) Find the maximum theoretical speed with which the cart and driver could cross the finish line.

[4 marks]

Answer _____

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8 (b) (i) The cart and driver actually cross the finish line with a speed of 30 m s^{-1}

Find the average total resistive force acting on the cart and driver during the contest.

[4 marks]

Answer _____

8 (b) (ii) State the names of **two** different resistive forces which may act on the cart and driver during the contest.

[2 marks]

10

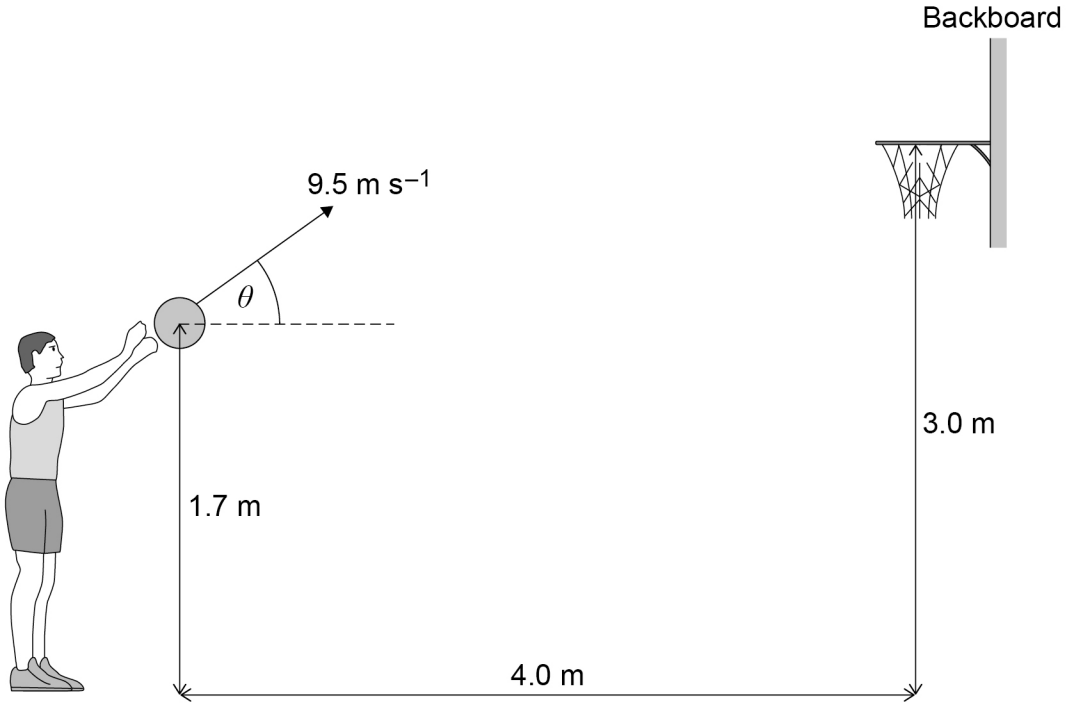
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9 A basketball player is throwing a basketball towards a basketball hoop.

The basketball is initially 1.7 m above the ground and a horizontal distance of 4.0 m from the basketball hoop.

The basketball hoop is 3.0 m above the ground.

The basketball leaves the basketball player's hands with a speed of 9.5 m s^{-1} at an angle of θ to the horizontal.



The basketball player throws the ball so that it passes straight through the hoop from above and does not rebound off the backboard.

You may assume that air resistance is negligible.

9 (a) Find the angle θ, giving your answer to the nearest degree.

[10 marks]

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Answer _____

Question 9 continues on the next page

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9 (b) Other than air resistance being negligible, state one further assumption that you made in part **(a)**.

[1 mark]

11

END OF QUESTIONS

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