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

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 graphic 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 in a horizontal plane so that its position vector, $\mathbf{r}$ metres, at time t seconds is given by

$$\mathbf{r} = \begin{bmatrix} 5\sin\left(\frac{\pi t}{6}\right) \\ 5\cos\left(\frac{\pi t}{6}\right) \end{bmatrix}$$

1 (a) (i) Find the velocity of the particle at time t seconds.

[2 marks]

Answer _____

1 (a) (ii) Find the acceleration of the particle at time t seconds.

[1 mark]

Answer _____

Do not write outside the box

1 (b) Using your answers to **part (a)**, show that the velocity of the particle is always perpendicular to the acceleration of the particle.

[3 marks]

1 (c) Describe the path that the particle follows.

[1 mark]

7

Turn over for the next question

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2 Five particles, *A*, *B*, *C*, *D* and *E*, are placed at different positions in an x-y plane.

The table below shows the mass and coordinates of each particle.

Particle	Mass (kg)	Coordinates
A	1.25	(3, 1)
B	2.5	(4, 2)
C	3.75	(5, 3)
D	2.5	(1, 2)
E	1.25	(2, 1)

Find the coordinates of the centre of mass of the particles.

[3 marks]

Answer _____

3

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3 A body, of mass 2 kg is acted upon by the three forces $\mathbf{F}_1$ newtons, $\mathbf{F}_2$ newtons and $\mathbf{F}_3$ newtons, where

$$\mathbf{F}_1 = \begin{bmatrix} 2 \\ -1 \\ 5 \end{bmatrix} \qquad \mathbf{F}_2 = \begin{bmatrix} 3 \\ 0 \\ 2 \end{bmatrix} \qquad \mathbf{F}_3 = \begin{bmatrix} 7 \\ 3 \\ -3 \end{bmatrix}$$

3 (a) Find the acceleration of the body.

[3 marks]

Answer _____

3 (b) Another force, $\mathbf{F}_4$ newtons, now acts on the body so that the body is in equilibrium.

Find $\mathbf{F}_4$

[1 mark]

Answer _____

4

Turn over ►

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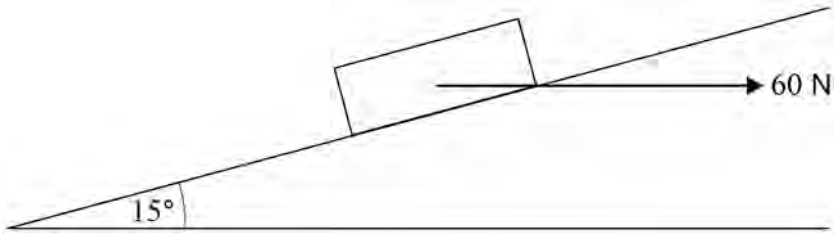
4 A block, of weight 500 newtons, is at rest on a rough slope and is prevented from moving down the slope by a horizontal force of 60 newtons, as shown in the diagram.

The slope is inclined at an angle of 15° to the horizontal.



Throughout this question you may use the following results:

$$\sin 15^\circ = \frac{\sqrt{6}-\sqrt{2}}{4} \qquad \text{and} \qquad \cos 15^\circ = \frac{\sqrt{6}+\sqrt{2}}{4}$$

4 (a) The magnitude of the frictional force which acts on the block is F newtons.

Find F, giving your answer in the form $a\sqrt{6}+b\sqrt{2}$ where a and b are constants.

[4 marks]

Answer _____

Do not write outside the box

4 (b) The coefficient of friction between the block and the slope is μ

Find the range of possible values for μ

[4 marks]

Answer _____

8

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5 A pebble is projected with a speed of 15 m s^{-1} at an angle of 39^{o} above the horizontal from a point O on horizontal ground.

5 (a) (i) Find the time of flight of the pebble, giving your answer to three significant figures.

[3 marks]

Answer _____

5 (a) (ii) Find the range of the pebble.

[2 marks]

Answer _____

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5 (a) (iii) State an assumption you have made in **part (a)(ii)**

[1 mark]

5 (b) (i) Find the maximum height of the pebble.

[2 marks]

Answer

5 (b) (ii) State the horizontal displacement of the pebble from O when it is at its maximum height.

[1 mark]

Answer

9

Turn over for the next question

Do not write outside the box

6 A cyclist is riding her bicycle at a constant speed of 6.0 m s^{-1} along a straight horizontal road.

The combined mass of the cyclist and her bicycle is 70 kg

6 (a) Calculate the kinetic energy of the cyclist and her bicycle.

[2 marks]

Answer _____

6 (b) The cyclist's constant power output is 150 W

6 (b) (i) Explain why the total resistive force acting on the cyclist and her bicycle must be 25 N

[2 marks]

6 (b) (ii) State, with a reason, the work done each second by the cyclist against the total resistive force which acts on the cyclist and her bicycle.

[2 marks]

Do not write outside the box

6 (c) The cyclist begins to ride up a 100 metre section of straight road which is inclined at 1.5^{o} to the horizontal.

The total resistive force which acts on the cyclist and her bicycle along the 100 metre section of road is constant and has magnitude 25 N

The speed of the cyclist and bicycle at the start of this section of road is 6.0 m s^{-1} and she now produces a constant driving force of 40 N

6 (c) (i) Find the acceleration of the cyclist and her bicycle on the 100 metre section of road.

[4 marks]

Answer _____

6 (c) (ii) Find the speed of the cyclist and her bicycle at the end of the 100 metre section of road.

[2 marks]

Answer _____

6 (c) (iii) Calculate the change in gravitational potential energy of the cyclist and her bicycle by riding up the 100 metre section of road.

[2 marks]

Answer _____

14

Do not write outside the box

7 A particle is projected with speed u m s^{-1} at an angle α degrees above the horizontal from a point O on horizontal ground.

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

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

7 (a) (i) Write down an expression for x in terms of u, α and t

[1 mark]

Answer _____

7 (a) (ii) Write down an expression for y in terms of u, α, g and t

[1 mark]

Answer _____

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7 (b) Using your answers to **part (a)**, show that the formula for the trajectory of the particle is

$$y = x\tan\alpha - \frac{gx^2}{2u^2}\sec^2\alpha$$

[4 marks]

Question 7 continues on the next page

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7 (c) (i) Find an expression for the maximum height reached by the particle in terms of u, α and g

[3 marks]

Answer _____

7 (c) (ii) The particle reaches a maximum height of 16 metres when it is projected with speed 20 m s^{-1}

Find the value of α

[2 marks]

Answer _____

11

Turn over for the next question

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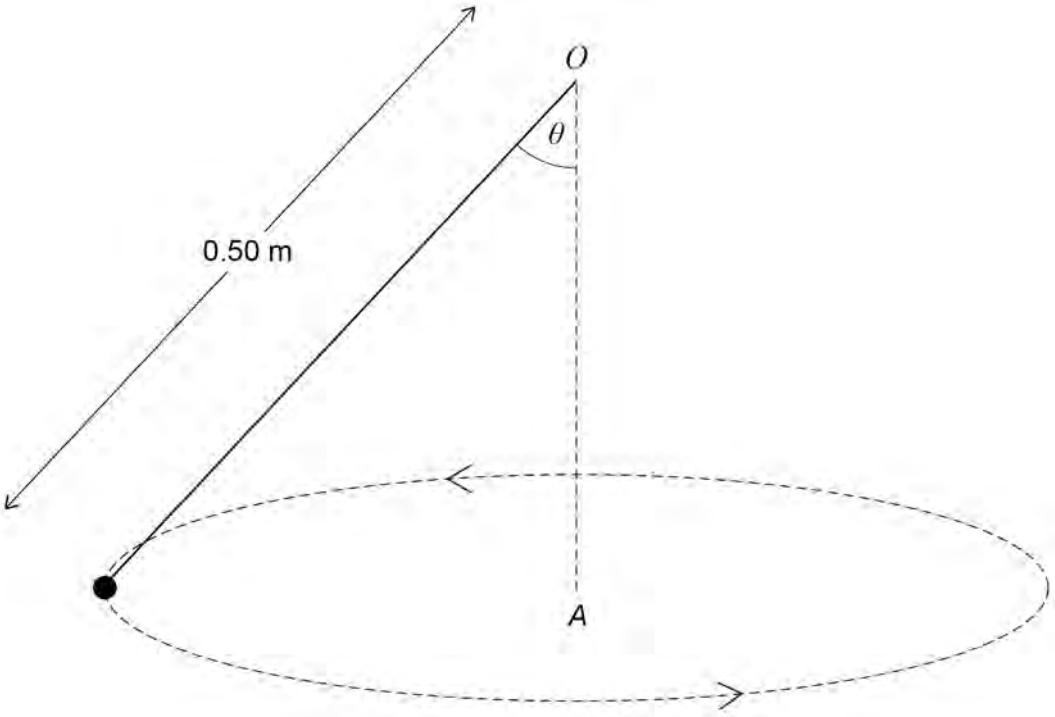
8 A light inextensible string of length 0.50 metres has one of its ends attached to a fixed point O

The other end of the string is attached to a particle of mass m kg

The particle is set into motion so that it moves with constant speed v m s^{-1} in a horizontal circle about a centre *A*, where *A* is directly below O

The string makes an angle θ degrees to the vertical, where $0 \leq \theta \leq 90$ as shown in the diagram.



8 (a) The string is described as light.

Explain what is meant by light in this context.

[1 mark]

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8 (b) Show that

$$g \sin^2 \theta = 2v^2 \cos \theta$$

[6 marks]

Question 8 continues on the next page

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8 (c) The speed of the particle is 4.0 m s^{-1}

8 (c) (i) By forming a quadratic equation in $\cos\theta$ find the value of θ

[4 marks]

Answer _____

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8 (c) (ii) Find the angular speed of the particle.

[2 marks]

Answer _____

13

Turn over for the next question

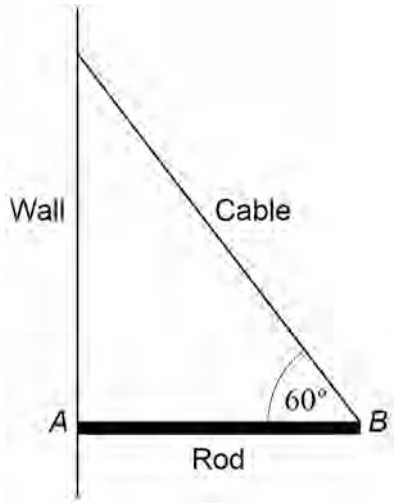
9 A **non-uniform** rod AB is attached to a vertical wall by a smooth hinge at A

A light inextensible cable is attached to the rod at B

The cable makes an angle of 60° to the horizontal.

The other end of the cable is attached to the vertical wall directly above A

The rod is held in equilibrium in a horizontal position, as shown in the diagram.



The rod has mass 8.0 kg and length 1.2 metres.

The centre of mass of the rod is 0.7 metres from A

9 (a) Explain what is meant by equilibrium.

[2 marks]

9 (b) Find the tension in the cable, giving your answer to three significant figures.

[3 marks]

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Answer _____

9 (c) Calculate the magnitude and direction of the reaction force which acts on the rod at *A*, showing the direction of the reaction force on a labelled diagram.

[6 marks]

Answer _____

11

END OF QUESTIONS

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