OXFORD

INTERNATIONAL
AQA EXAMINATIONS

Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____

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.

Do not write outside the box

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

Do not write outside the box

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

Do not write outside the box

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 _____

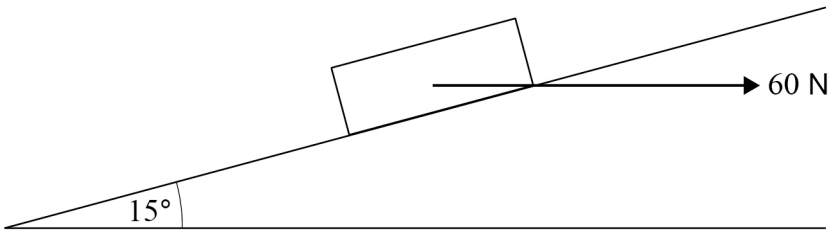
4

Turn over ►

Do not write outside the box

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

Do not write outside the box

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 _____

Do not write outside the box

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 _____

Do not write outside the box

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

Do not write outside the box

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

Do not write outside the box

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

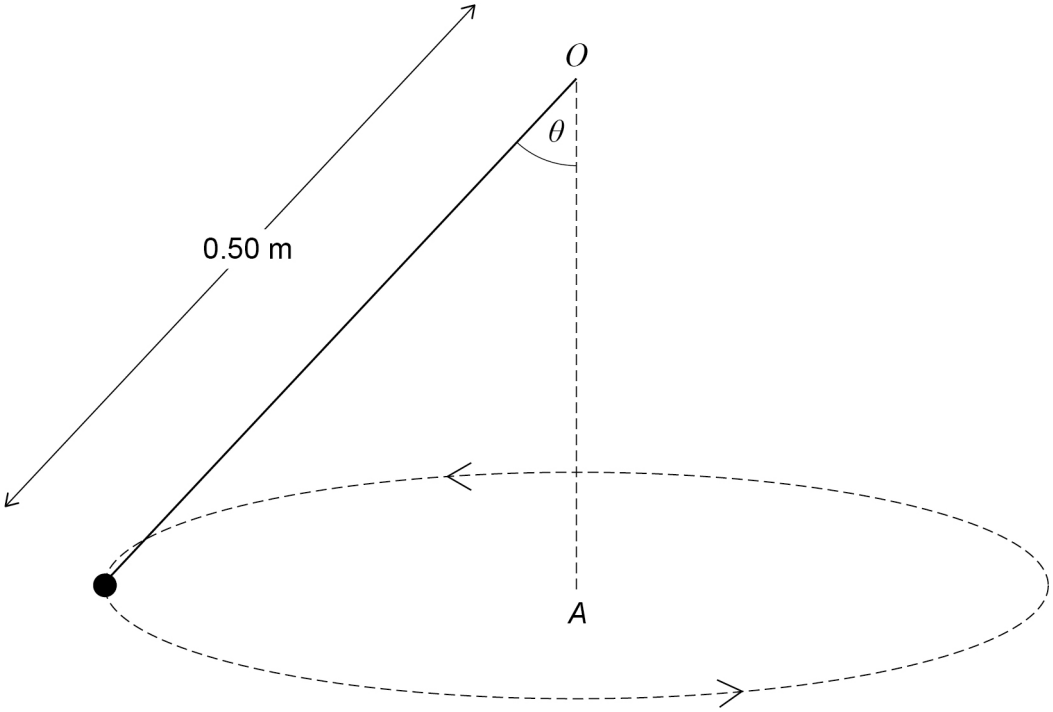
Do not write outside the box

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]

Do not write outside the box

8 (b) Show that

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

[6 marks]

Question 8 continues on the next page

Do not write outside the box

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 _____

Do not write outside the box

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

[2 marks]

Answer _____

13

Turn over for the next question

Do not write outside the box

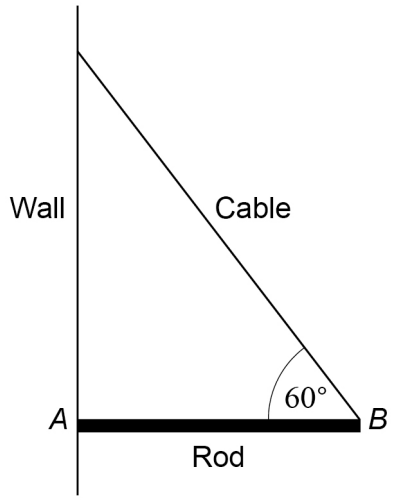
9 A **non-uniform** rod AB is attached to a vertical wall by a smooth hinge at A

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]

Do not write outside the box

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

There are no questions printed on this page

Do not write outside the box

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

Do not write outside the box

Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**