OXFORD

INTERNATIONAL
AQA EXAMINATIONS

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 26 January 2021 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 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 $\mathrm{m\,s^{-2}}$

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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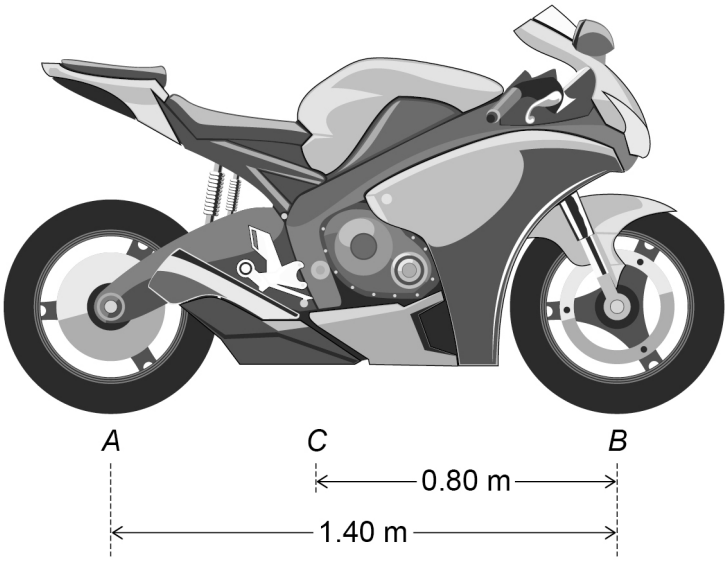
1 The diagram below shows a stationary motorcycle of mass 170 kg in equilibrium on horizontal ground.



The wheels are in contact with the ground at the points A and B where $AB = 1.40$ metres

The motorcycle's centre of mass is vertically above the point C where $BC = 0.80$ metres

1 (a) Find the magnitude of the reaction force which acts on the motorcycle's rear wheel at A due to its contact with the ground.

[3 marks]

Answer _____

Do not write outside the box

1 (b) Find the magnitude of the reaction force which acts on the motorcycle's front wheel at *B* due to its contact with the ground.

[2 marks]

Answer _____

5

Turn over for the next question

Do not write outside the box

2 A body of mass 10 kg moves so that its velocity $\mathbf{v}$ m s^{-1} at time t seconds is given by

$$\mathbf{v} = 2\sin 2t\,\mathbf{i} + \mathrm{e}^{-t}\,\mathbf{j} + \left(3t^2 - \cos t\right)\mathbf{k}$$

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

2 (a) (i) Find the acceleration of the body when $t = \frac{\pi}{3}$

[3 marks]

Answer _____

2 (a) (ii) Find the magnitude of the resultant force acting on the body when $t = \frac{\pi}{3}$

[2 marks]

Answer _____

Do not write outside the box

2 (b) When $t = 0$ the position of the body is $\mathbf{i} + 2\mathbf{j} + 3\mathbf{k}$

Find the position of the body at time t

[4 marks]

Answer _____

9

Turn over ►

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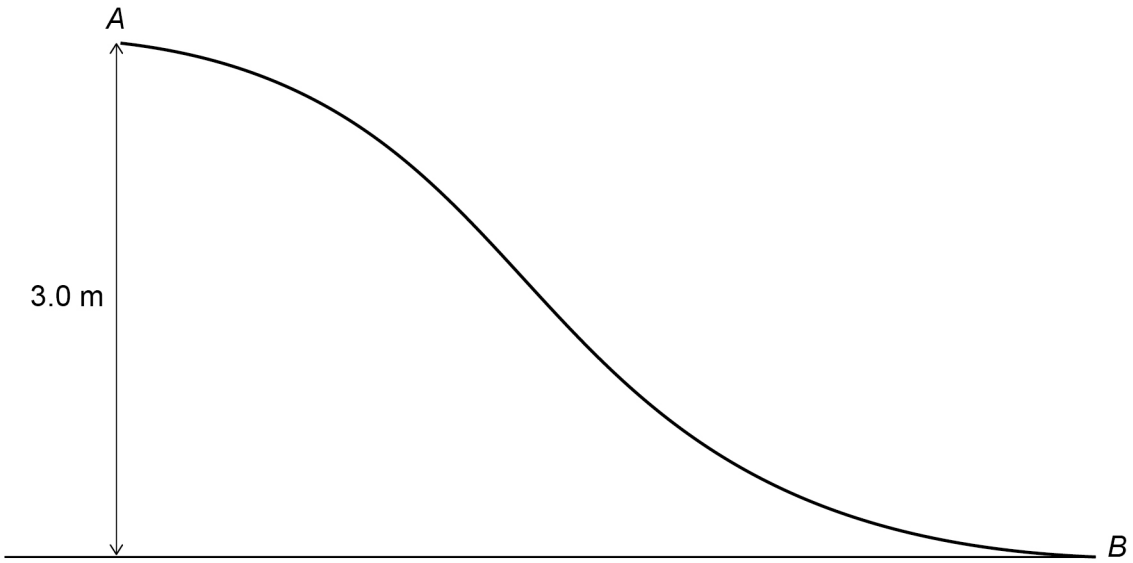
3 A child of mass 30 kg moves down a slide.

The diagram below shows the shape of the slide.



The child starts at position *A* which is at a height of 3.0 metres above the level of position *B*

The speed of the child at *A* is 1.2 m s^{-1}

The speed of the child at *B* is 4.0 m s^{-1}

The curved length of the slide between *A* and *B* is 12 metres

3 (a) Show that the child loses 882 J of gravitational potential energy moving from *A* to *B*

[1 mark]

3 (b) It is assumed that the child experiences a resistive force of constant magnitude R newtons at all times whilst moving from *A* to *B*

Find the value of R

[4 marks]

Do not write outside the box

Answer _____

3 (c) A student wants to determine the maximum speed the child could have at *B* if no resistive forces act on the child.

The student uses the following method:

$v^2 = u^2 + 2as$

$v^2 = 1.2^2 + 2 \times 9.8 \times 12$

$v^2 = 236.64$

$v = 15\ \text{m s}^{-1}$ (to 2 significant figures)

Give **two reasons** why the student's method for determining the maximum speed of the child is incorrect.

[2 marks]

Reason 1 _____

Reason 2 _____

7

Turn over ►

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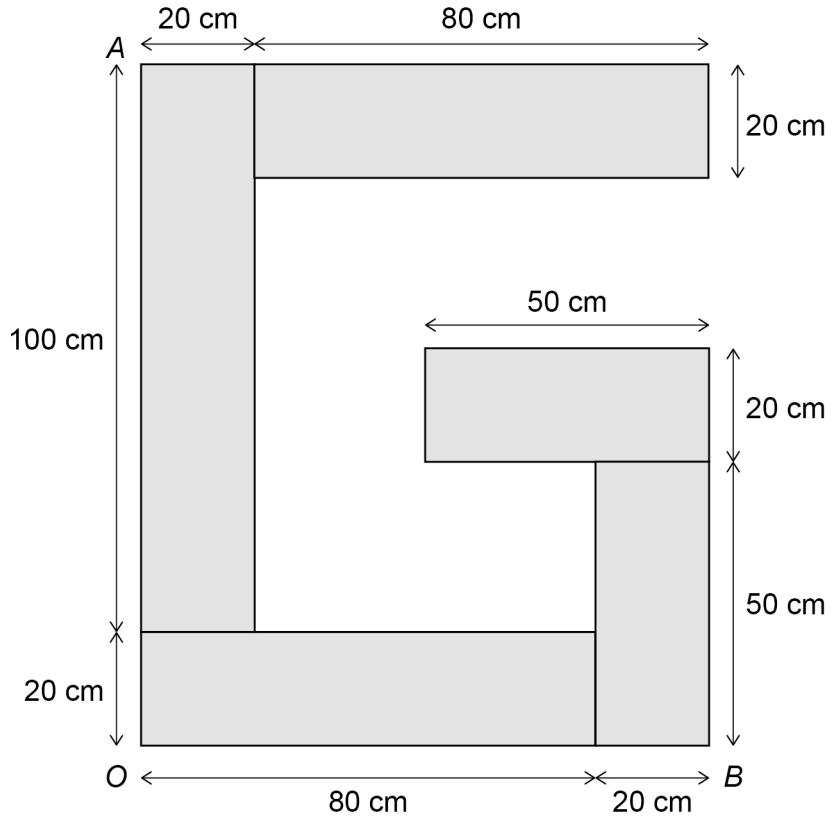
4 A design is made from five rectangular uniform laminas, as shown below.

The laminas do not overlap and are made from the same material.



4 (a) (i) Find the distance of the centre of mass of the design from *OA*, giving your answer in exact form.

[4 marks]

Answer _____

Do not write outside the box

4 (a) (ii) Find the distance of the centre of mass of the design from *OB*, giving your answer in exact form.

[3 marks]

Answer _____

4 (a) (iii) Explain how you have used the fact that each rectangular lamina is uniform.

[1 mark]

4 (b) The design is suspended from the point *A* and is in equilibrium.

Find, to the nearest degree, the angle between *OA* and the vertical.

[3 marks]

Answer _____

11

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5 A particle of mass 5 kg is acted upon by a constant driving force **F** newtons and accelerates at $\begin{bmatrix} 2 \\ 3 \end{bmatrix}$ m s^{-2}

The initial velocity of the particle is $\begin{bmatrix} 0 \\ 4 \end{bmatrix}$ m s^{-1}

At time t seconds after the force **F** newtons begins to act the velocity of the particle is **v** m s^{-1}

5 (a) Find **F**

[1 mark]

Answer _____

5 (b) (i) Find **v** in terms of t

[2 marks]

Answer _____

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5 (b) (ii) Find the kinetic energy of the particle when $t = 6$

[3 marks]

Answer _____

5 (c) The work done on the particle each second is P joules, where P is the scalar product of the driving force **F** newtons and the velocity **v** m s^{-1}

Find the range of values of t for which P exceeds 580

[3 marks]

Answer _____

9

Turn over ►

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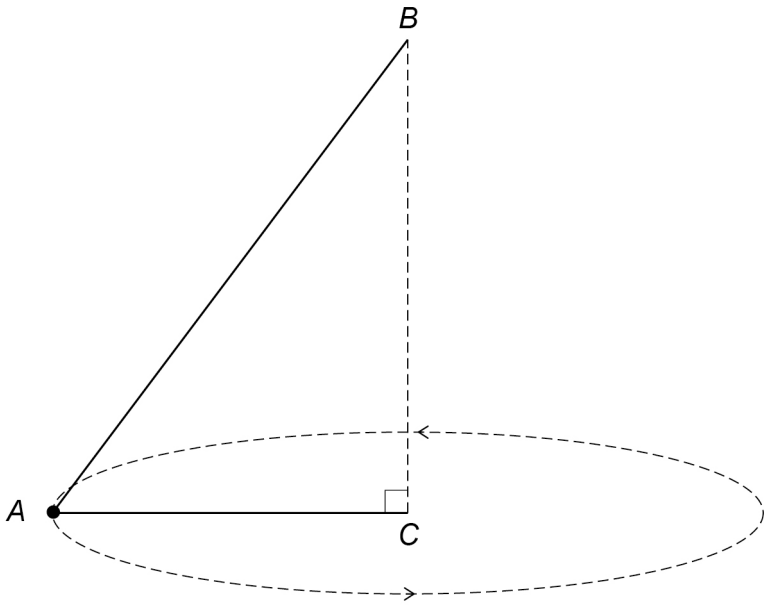
6 A particle of mass 2.4 kg is attached to two light inextensible strings.

The first string is attached to a fixed point *B* and has length 1.5 metres

The second string is attached to a fixed point *C* and has length 0.9 metres

The point *C* is 1.2 metres vertically below *B*

The particle is set into motion from the point *A*, as shown in the diagram below, and moves around a horizontal circle with centre *C* at a constant speed of 6 m s^{-1} so that both strings are taut, as shown in the diagram.



6 (a) (i) Both strings are described as inextensible.

Explain what is meant by inextensible.

[1 mark]

6 (a) (ii) State, with a reason, whether or not the particle is accelerating.

[2 marks]

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6 (b) (i) Find the tension in the string attached to B

[3 marks]

Answer _____

6 (b) (ii) Find the tension in the string attached to C, giving your answer to three significant figures.

[4 marks]

Answer _____

10

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7 A sphere of weight 500 N is initially at rest in a liquid.

A constant force of magnitude 2000 N acts vertically upwards on the sphere.

The sphere begins moving vertically upwards through the liquid.

The sphere also experiences a resistive force. When the speed of the sphere is v m s^{-1} the resistive force is kv^2 newtons vertically downwards, where k is a constant.

7 (a) Show that the magnitude of the acceleration of the sphere is 29.4 m s^{-2} when the sphere is initially at rest.

[2 marks]

7 (b) The acceleration of the sphere is 9.8 m s^{-2} upwards when the sphere is moving upwards at 5 m s^{-1}

Find the value of k

[3 marks]

Answer _____

Do not write outside the box

7 (c) Find the maximum speed of the sphere.

[2 marks]

Answer _____

7

Turn over for the next question

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8 An object is projected with speed u m s^{-1} at an angle θ degrees above the horizontal from a point *O* on horizontal ground, where $0 < \theta < 90$

8 (a) (i) Show that the time taken for the object to reach its maximum height above the ground is

$$\frac{u \sin \theta}{g}$$

[2 marks]

8 (a) (ii) State an assumption you have made in **part (a)(i)**.

[1 mark]

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8 (b) The object lands at the point *A* on the same horizontal ground.

The distance *OA* is equal to the maximum height reached by the object.

Find the value of θ

[6 marks]

Answer _____

9

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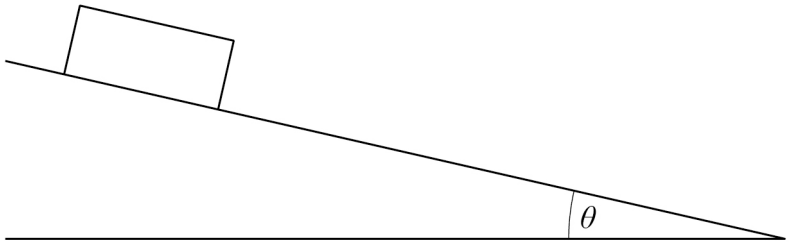
9 A block of mass 12 kg starts from rest on a rough slope which is inclined at θ to the horizontal, as shown in the diagram.



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

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

[1 mark]

9 (b) The block accelerates uniformly down the slope at 3.2 m s^{-2}

Find the value of θ using $A\sin\theta - B\cos\theta = R\sin(\theta - \alpha)$

Give your answer to the nearest degree.

[8 marks]

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Answer _____

9 (c) Without further calculation, state, with a reason, how your answer to **part (b)** may change if

9 (c) (i) the mass of the block **increases** to 15 kg and the coefficient of friction **remains** as 0.4 **[2 marks]**

9 (c) (ii) the mass of the block **remains** as 12 kg and the coefficient of friction **increases** to 0.5 **[2 marks]**

13

END OF QUESTIONS

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