AQA

Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

A-level
FURTHER MATHEMATICS

Paper 3 Mechanics

Thursday 11 June 2020 Afternoon Time allowed: 2 hours

Materials
- You must have the AQA formulae and statistical tables booklet for A-level Mathematics and A-level Further Mathematics.
- You should have a scientific calculator that meets the requirements of the specification. (You may use a graphical calculator.)
- You must ensure you have the other optional Question Paper/Answer Book for which you are entered (**either** Discrete **or** Statistics). You will have 2 hours to complete **both** papers.

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 each question in the space provided for that question. If you require 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 **not** write outside the box around each page.
- Show all necessary working; otherwise marks for method may be lost.
- Do all rough work in this book. Cross through any work you do not want to be marked.

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

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 50.

Advice
- Unless stated otherwise, you may quote formulae, without proof, from the booklet.
- You do not necessarily need to use all the space provided.

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

1 A rigid rod, *AB*, has mass 2 kg and length 4 metres.

Two particles of masses 5 kg and 3 kg are fixed to *A* and *B* respectively to create a composite body, as shown in the diagram.



Find the distance of the centre of mass of the composite body from *B*.

Circle your answer.

[1 mark]

1.5 metres 1.6 metres 2.4 metres 2.5 metres

2 The tension, T newtons, in a spring is given by $T = 20e$, where e metres is the extension of the spring.

Calculate the work done when the extension is increased from 0.2 metres to 0.4 metres.

Circle your answer.

[1 mark]

0.4 J 0.9 J 1.2 J 1.6 J

Do not write outside the box

3 The speed, v, of a particle moving in a horizontal circle is given by the formula $v = r\omega$ where:

$v =$ speed

$r =$ radius

$\omega =$ angular speed.

Show that the dimensions of angular speed are T^{-1}

[2 marks]

Turn over for the next question

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4 A car has mass 1000 kg and travels on a straight horizontal road.

The maximum speed of the car on this road is $48\,m\,s^{-1}$

In a simple model, it is assumed that the car experiences a resistance force that is proportional to its speed.

When the car travels at $20\,m\,s^{-1}$, the magnitude of the resistance force is 600 newtons.

4 (a) Show that the maximum power of the car is 69 120 W

[2 marks]

4 (b) Find the maximum acceleration of the car when it is travelling at $25\,m\,s^{-1}$

[3 marks]

Do not write outside the box

4 (c) Find the maximum acceleration of the car when it is travelling at $3\,m\,s^{-1}$

[1 mark]

4 (d) Comment on the validity of the model in the context of your answers to parts **(b)** and **(c)**.

[2 marks]

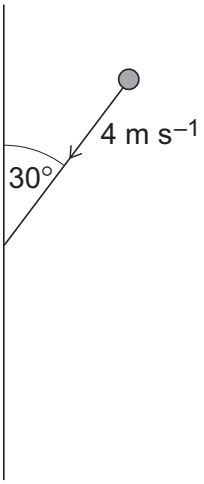
Turn over for the next question

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5 A ball, of mass 0.3 kg, is moving on a smooth horizontal surface.

The ball collides with a smooth fixed vertical wall and rebounds.

Before the ball hits the wall, the ball is moving at $4\,\text{m}\,\text{s}^{-1}$ at an angle of 30° to the wall as shown in the diagram.



The magnitude of the force, F newtons, exerted on the ball by the wall at time t seconds is modelled by

$$F = kt^2(0.1 - t)^2 \quad \text{for} \quad 0 \leq t \leq 0.1$$

where k is a constant.

The ball is in contact with the wall for 0.1 seconds.

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5 (a) Show that the impulse exerted on the ball by the wall while they are in contact has magnitude $\frac{k}{3\,000\,000}$

Fully justify your answer.

[4 marks]

Do not write outside the box

5 (b) Explain why $1\,800\,000 < k \leq 3\,600\,000$

Fully justify your answer.

[5 marks]

Do not write outside the box

5 (c) Given that $k = 2\,400\,000$

Find the speed of the ball after the collision with the wall.

[4 marks]

Do not write outside the box

6 A particle moves with constant speed on a circular path of radius 2 metres.

The centre of the circle has position vector $2\mathbf{j}$ metres.

At time $t = 0$, the particle is at the origin and is moving in the positive **i** direction.

The particle returns to the origin every 4 seconds.

The unit vectors **i** and **j** are perpendicular.

6 (a) Calculate the angular speed of the particle.

[2 marks]

6 (b) Write down an expression for the position vector of the particle at time t seconds.

[2 marks]

Do not write outside the box

6 (c) Find an expression for the acceleration of the particle at time t seconds.

[3 marks]

6 (d) State the magnitude of the acceleration of the particle.

[1 mark]

6 (e) State the time when the acceleration is first directed towards the origin.

[1 mark]

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7 **In this question use $g = 9.8\,\text{m s}^{-2}$**

A box, of mass 8 kg, is on a rough horizontal surface.

A string attached to the box is used to pull it along the surface.

The string is inclined at an angle of 40° above the horizontal.

The tension in the string is 50 newtons.

As the box moves a distance of x metres, its speed increases from $2\,\text{m s}^{-1}$ to $5\,\text{m s}^{-1}$

The coefficient of friction between the box and the surface is 0.4

7 (a) By using an energy method, find x.

[6 marks]

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7 (b) Describe how the model could be refined to obtain a more realistic value of x and use an energy argument to explain whether this would increase or decrease the value of x.

[2 marks]

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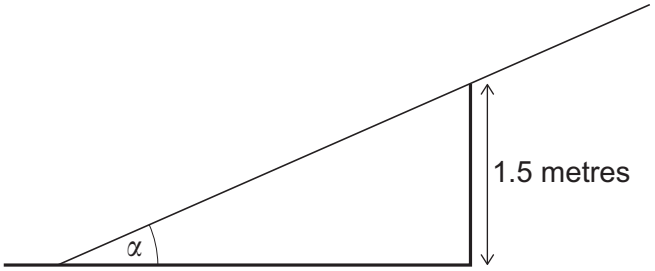
8 A ladder has length 4 metres and mass 20 kg

The ladder rests in equilibrium with one end on a horizontal surface and the ladder resting on the top of a vertical wall.

In this position the ladder is on the point of slipping.

The top of the wall is 1.5 metres above the horizontal surface.

The angle between the ladder and the horizontal surface is α, as shown in the diagram.



The coefficient of friction between the ladder and the wall is 0.5

The coefficient of friction between the ladder and the ground is also 0.5

Show that

$$\cos\alpha \sin^2\alpha = \frac{3}{10}$$

stating clearly any assumptions you make.

[8 marks]

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END OF QUESTIONS

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