OXFORD

INTERNATIONAL AQA EXAMINATIONS

Please write clearly in block capitals.

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INTERNATIONAL A-LEVEL

MATHEMATICS

(9660/MA05) Unit M2 – Mechanics

Monday 17 June 2019 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.
- Unless stated otherwise, the acceleration due to gravity, g, should be taken as $9.8\,\text{m}\,\text{s}^{-2}$

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
TOTAL	

Advice
- Unless stated otherwise, you may quote formulae, without proof, from the booklet.
- Show all necessary working; otherwise marks may be lost.

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

1 A boat moves so that its position, $\mathbf{r}$ metres, at time t seconds is given by

$$\mathbf{r} = (4e^{-0.5t} - 4)\,\mathbf{i} + (t + \sin t)\,\mathbf{j}$$

where the unit vectors $\mathbf{i}$ and $\mathbf{j}$ are directed east and north respectively.

1 (a) Find an expression for the velocity of the boat at time t.

[3 marks]

Answer _____

1 (b) Hence find the speed of the boat when $t = 5$

[2 marks]

Answer _____

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1 (c) Find the magnitude of the acceleration of the boat when $t = 5$

[2 marks]

Answer _____

7

Turn over for the next question

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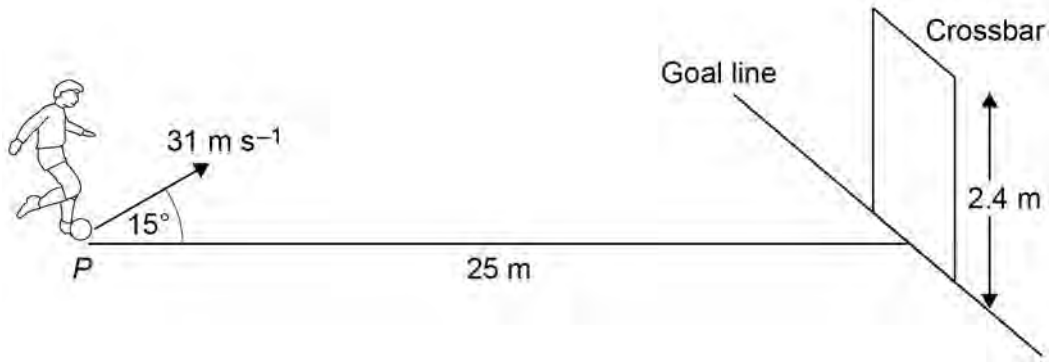
2 A footballer practises on horizontal ground by kicking a ball from a point *P* directly towards a goal.

The point *P* is such that

it is a perpendicular distance of 25 metres from the goal line

it is directly in front of the centre of the goal.

The ball leaves the footballer's foot with a speed of 31 m s^{-1} at an angle of 15° to the horizontal, as shown in the diagram below.



The ball may be modelled as a particle.

2 (a) Show that the time the ball takes to move the horizontal distance of 25 metres is 0.83 seconds, correct to two significant figures.

[1 mark]

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2 (b) To score a goal the ball must pass under the crossbar. The crossbar of the goal is 2.4 metres above the ground.

Determine whether or not the footballer scores a goal with this kick.

[4 marks]

5

Turn over for the next question

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3 An apple of mass 0.17 kg falls from a tree.

The centre of mass of the apple is initially at rest 2.5 metres above the ground.

3 (a) Take ground level as having zero gravitational potential energy.

Calculate the gravitational potential energy of the apple at its initial position.

[1 mark]

Answer _____

3 (b) Using the conservation of energy, find the speed of the apple when it hits the ground.

[2 marks]

Answer _____

3 (c) State how the actual speed of the apple is likely to be different to that found in part **(b)**.

Explain your answer.

[2 marks]

5

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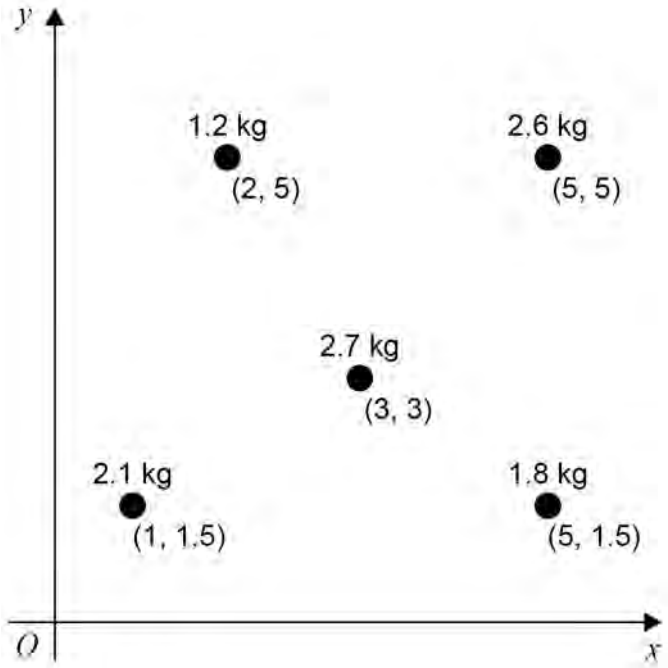
4 A system of five particles, along with their masses and coordinates, is shown in **Figure 1**.

Figure 1



4 (a) Find the coordinates of the centre of mass of the system of particles.

[4 marks]

Answer _____

Question 4 continues on the next page

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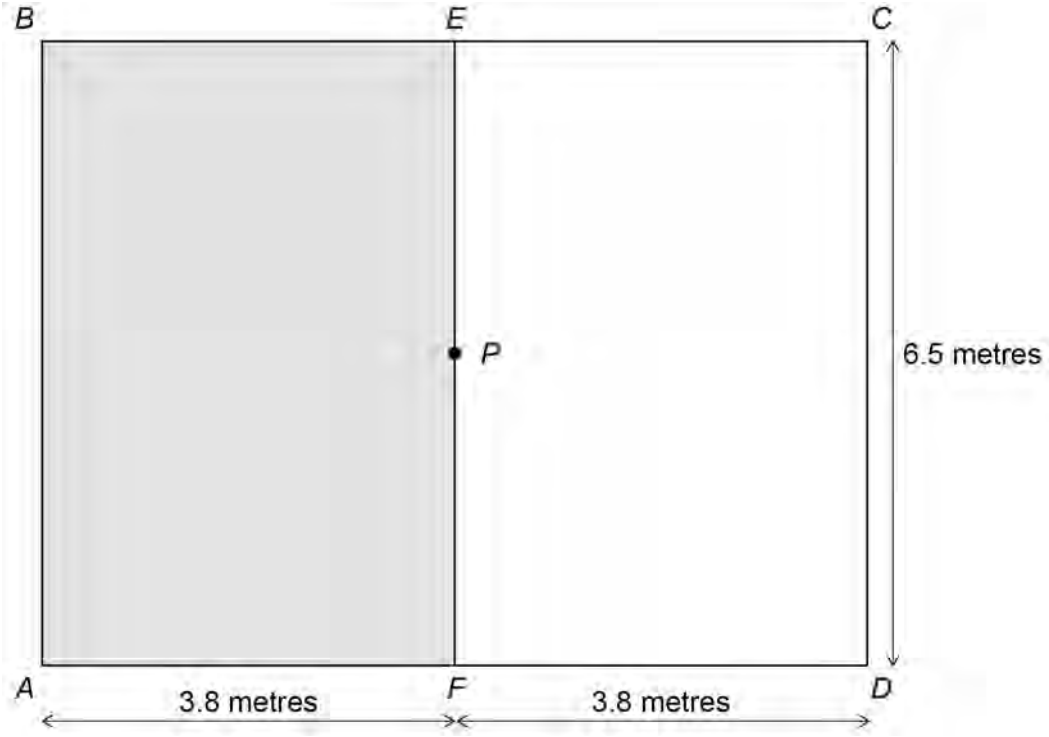
4 (b) The rectangular board *ABCD* is made by joining together the two uniform rectangular boards *ABEF* and *ECDF* with dimensions as shown in **Figure 2**.

Figure 2



The point *P* is the midpoint of the line *EF*.

The board *ABEF* has mass $1.5m$ kilograms.

The board *ECDF* has mass m kilograms.

The board *ABCD* is freely suspended from the point *B* and is in equilibrium.

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

[7 marks]

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Answer _____

11

Turn over for the next question

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5 A child of mass 35 kg starts from rest at the top of a slide.

The slide is inclined at 25° to the horizontal.

The coefficient of dynamic friction between the child and the slide is 0.2

The child may be modelled as a particle.

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

[1 mark]

5 (b) (i) Find the acceleration of the child down the slide.

[5 marks]

Answer _____

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5 (b) (ii) Calculate the work done against friction when the child has moved through a vertical height of 2.2 metres.

[2 marks]

Answer _____

5 (c) State how your answer to part **(b) (i)** would be different if the child was not modelled as a particle.

Explain your answer.

[2 marks]

10

Turn over for the next question

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6 A car of mass 1300 kg is moving along a straight horizontal racing track.

The car experiences a resistive force of magnitude $4v^{\frac{3}{2}}$ newtons, where v is the speed of the car in metres per second.

The car's engine is working at a constant rate of 160 000 W

6 (a) Find an expression for the resultant force acting on the car when it is moving with speed v.

[3 marks]

Answer _____

6 (b) Calculate the acceleration of the car when its speed is 20 m s^{-1}

[2 marks]

Answer _____

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6 (c) Find the maximum speed of the car.

[3 marks]

Answer _____

8

Turn over for the next question

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7 Two carts of identical shape are on a straight horizontal track.

Cart *A* has a mass of 0.55 kg and cart *B* has a mass of 0.35 kg

Cart *A* moves towards and collides with cart *B*.

Before the collision, cart *A* is moving at 8.2 m s^{-1} and cart *B* is stationary.

After the collision, cart *B* moves at a speed of 6.4 m s^{-1}

During the collision, each cart experiences a constant force and the carts are in contact for 0.25 seconds.

7 (a) (i) Find the magnitude of the impulse which acts on cart *B* during the collision.

[2 marks]

Answer _____

7 (a) (ii) State, with a reason, the magnitude of the impulse which acts on cart *A* during the collision.

[2 marks]

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7 (b) Find the magnitude of the force experienced by cart *B* during the collision.

[2 marks]

Answer _____

7 (c) Calculate the kinetic energy lost during the collision.

[5 marks]

Answer _____

11

Turn over for the next question

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8 A golf ball is hit from a point on horizontal ground with a speed u at a fixed angle θ to the ground.

Assuming air resistance is negligible, prove that the horizontal distance the golf ball travels before hitting the ground for the first time is proportional to u^2

[5 marks]

5

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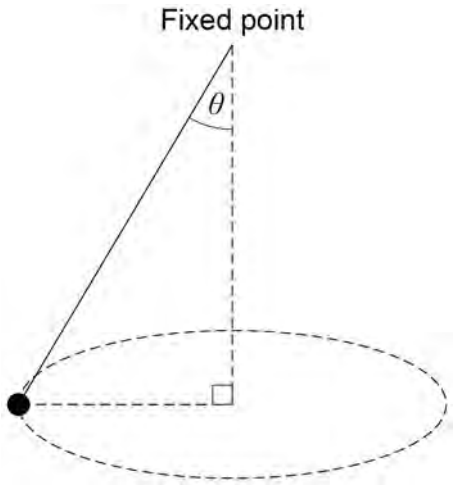
9 A particle of mass 0.35 kg is attached to one end of a light inextensible string.

The other end of the string is attached to a fixed point.

The particle is set into circular motion so that the string remains taut and makes a fixed angle θ to the vertical, as shown in the diagram.



9 (a) Find, in terms of θ, the magnitude of the resultant force which acts on the particle.

[2 marks]

Answer _____

9 (b) Explain why the kinetic energy of the particle does not change even though there is a resultant force acting on the particle.

[2 marks]

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9 (c) The radius of the horizontal circle followed by the particle is 0.62 metres, and the time for one revolution of the circle is 0.48 seconds.

Determine the angle θ.

[6 marks]

Answer _____

10

Turn over for the next question

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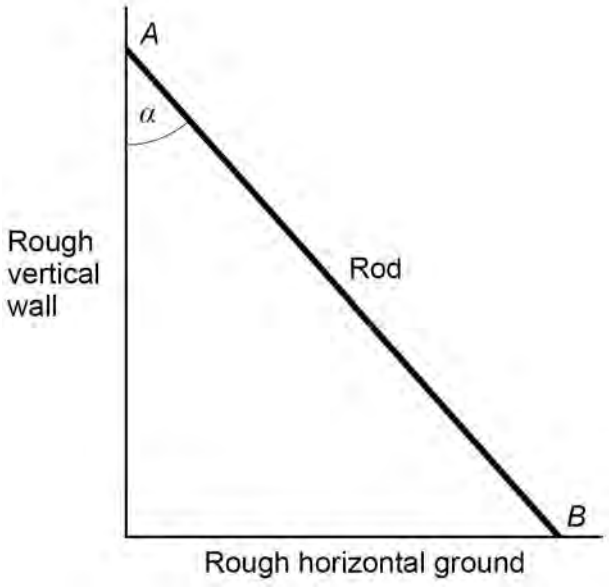
10 A uniform rod, *AB,* of mass M is in equilibrium, with one end in contact with a rough vertical wall. The other end is on rough horizontal ground.

The coefficient of friction between the wall and the rod is μ and the coefficient of friction between the ground and the rod is also μ.

The rod makes an angle α with the wall, as shown in the diagram.



Given that the rod is on the point of slipping, find tan α in terms of μ.

[8 marks]

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Answer _____

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END OF QUESTIONS

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