OXFORD AQA
INTERNATIONAL QUALIFICATIONS

INTERNATIONAL AS/A LEVEL
FURTHER MATHEMATICS

Further Mechanics 1

Specimen paper 0X:00 GMT Time allowed: 1 hour 15 minutes

Materials
- For this paper you must have the OxfordAQA Pure Mathematics and Mechanics Examination Booklet (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 **three** significant figures, unless stated otherwise.
- The magnitude of the acceleration due to gravity, g, should be taken as 9.8 m s^{-2}

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 60.

Advice
- Unless stated otherwise, you may quote formulae, without proof, from the booklet.
- Show all necessary working; otherwise, marks may not be awarded.

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

1 A student models the speed v m s^{-1} of a wave travelling along the surface of the sea by

$$v = kd^{\alpha}\rho^{\beta}g^{\gamma}$$

where

- d is the depth of the sea in metres
- ρ is the density of sea water in kg m^{-3}
- g is the acceleration due to gravity in m s^{-2}
- k is a dimensionless constant

and α, β and γ are constants.

1 (a) Use dimensional analysis to find the value of α, the value of β and the value of γ

[3 marks]

$\alpha =$ _____ $\beta =$ _____ $\gamma =$ _____

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1 (b) The student visited a beach and recorded that when the depth of the sea was 2.3 metres, the speed of a wave travelling along the surface of the sea was 17 kilometres per hour.

Find the value of k

Give your answer to two significant figures.

[3 marks]

$k =$ _____

1 (c) The student wants to use the formula to predict the speed U m s^{-1} of a wave travelling along the surface of the sea when the depth of the sea is 4000 metres.

Find the value of U

[2 marks]

$U =$ _____

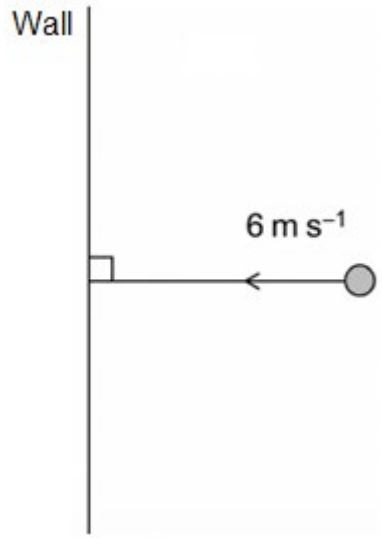
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2 A ball of mass m kg is moving on a smooth horizontal surface.

The ball collides with a smooth fixed vertical wall.

Before the ball hits the wall, the ball is moving at 6 m s^{-1} at an angle of 90° to the wall, as shown in **Figure 1**

Figure 1



The ball is in contact with the wall for 0.15 seconds and rebounds.

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

$$F = kt(0.3 - 2t)^2 \quad \text{for} \quad 0 \leq t \leq 0.15$$

where k is a constant.

2 (a) The impulse exerted on the ball by the wall while they are in contact has a magnitude of I N s

Show that $I = \dfrac{27k}{160\,000}$

[3 marks]

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2 (b) Find the range of possible values for k in terms of m

Fully justify your answer.

[5 marks]

Answer _____

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3 A logo consists of two uniform laminas made from the same material.

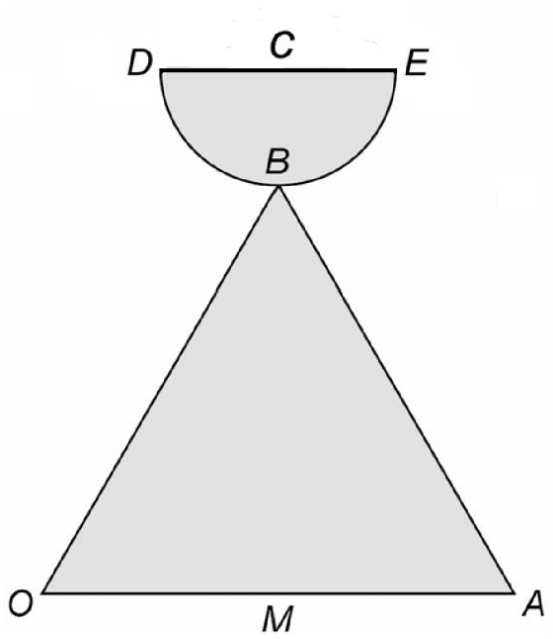
One of the laminas is an equilateral triangle OAB and the other lamina is a semicircle.

The point M is the midpoint of OA

The point C is the midpoint of DE

The semicircle touches the triangle at B so that the points C, B and M all lie on the same straight line, and DE is parallel to OA, as shown in **Figure 2**

Figure 2



The equilateral triangle has side length $2d$ metres.

The length of DE is d metres.

It is given that the centre of mass of the triangular lamina is $\frac{1}{3}$ of the way along the line segment MB from M

It is given that the centre of mass of the semicircular lamina is $\frac{2d}{3\pi}$ metres of the way along the line segment CB from C

3 (a) Explain why the centre of mass of the logo lies on the straight line through C, B and M **[1 mark]**

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3 (b) The distance of the centre of mass of the logo from C is kd metres.

Find the value of k

Give your answer to three decimal places.

[6 marks]

$k =$ _____

3 (c) The logo is freely suspended from O and hangs in equilibrium.

The angle between the vertical and the line OM is α degrees.

Find the value of α

[2 marks]

$\alpha =$ _____

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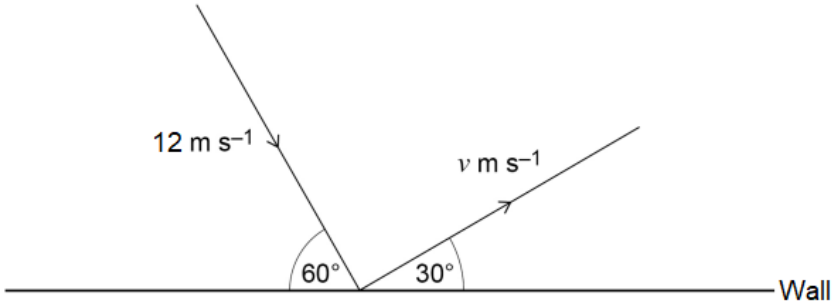
4 A ball of mass 0.5 kg is moving on a smooth horizontal surface.

The ball collides with a smooth vertical wall which is fixed to the surface.

When the ball collides with the wall its velocity is 12 m s^{-1} at an angle of 60° to the wall.

When the ball leaves the wall its velocity is v m s^{-1} at an angle of 30° to the wall as shown in **Figure 3**

Figure 3



4 (a) Find the value of v

Give your answer in an exact form.

[3 marks]

$v =$ _____

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4 (b) The coefficient of restitution between the wall and the ball is e

Find the value of e

[3 marks]

$e =$ _____

4 (c) Find the magnitude of the impulse exerted on the ball by the wall during the collision.

Give your answer in an exact form.

[3 marks]

Answer _____

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5 When the time is 13:00, two ships A and B are a distance of 12 km apart.

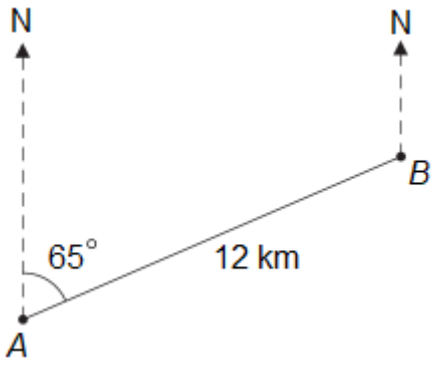
At this time, B is on a bearing of 065° from A

Ship A travels on a bearing of 065° at a constant speed of 28 km h^{-1}

Ship B travels due north at a constant speed of 15 km h^{-1}

Figure 4 shows the initial positions of A and B

Figure 4



5 (a) (i) Find speed of A relative to B

[2 marks]

Answer _____

5 (a) (ii) Use your answer to **part (a)(i)** to find the minimum distance between A and B

[4 marks]

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Answer _____

5 (b) Find the time when the distance between A and B is minimum.

Give your answer to the nearest minute.

[2 marks]

Answer _____

Turn over for the next question

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6 Two spheres P and Q of the same radius are at rest on a smooth horizontal surface.

A vertical wall is perpendicular to the straight line through the centres of P and Q

Sphere Q is closer to the wall than sphere P

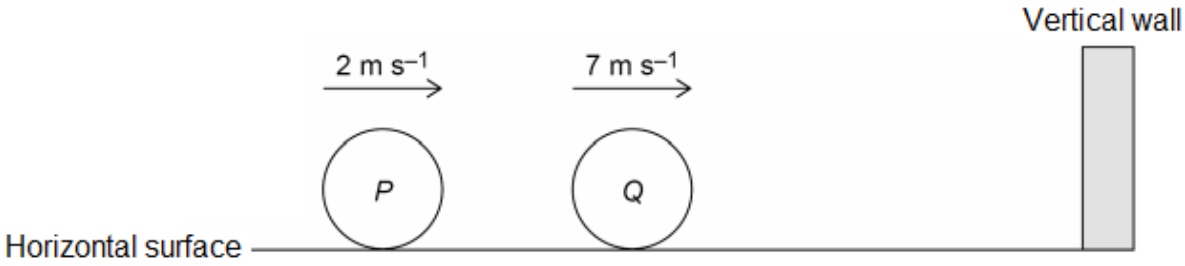
The spheres are set into motion so that they both move directly towards the wall.

Sphere P has mass 0.6 kg and moves with speed 2 m s^{-1}

Sphere Q has mass 1.2 kg and moves with speed 7 m s^{-1}

Figure 5 shows the initial velocities of P and Q, the horizontal surface and the vertical wall.

Figure 5



6 (a) (i) Sphere Q collides with the wall.

The coefficient of restitution between sphere Q and the wall is 0.9

Find the speed of Q after it collides with the wall

[1 mark]

Answer _____

6 (a) (ii) Sphere Q now collides with sphere P

The coefficient of restitution between the two spheres is 0.5

After this collision the speed of Q is v_Q m s^{-1} and the speed of P is v_P m s^{-1}

Find the value of v_Q and the value of v_P

[4 marks]

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$v_Q =$ _____ $v_P =$ _____

6 (a) (iii) Find the magnitude of the impulse exerted on P by Q during the collision.

[2 marks]

Answer _____

6 (b) During the collision between the spheres, the spheres are in contact for 0.025 seconds.

Find the magnitude of the average force exerted by one sphere on the other during the collision.

[2 marks]

Answer _____

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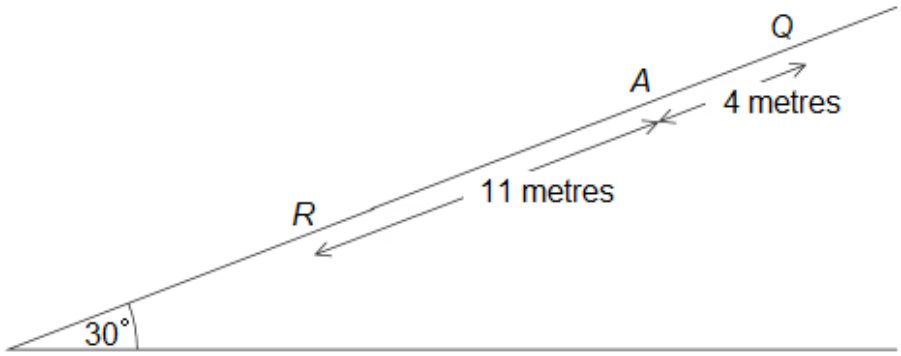
7 A particle P of mass 6 kg is held at the point A on a rough plane which is inclined at 30° to the horizontal.

The points Q and R are also on the inclined plane where $QR = 15$ metres.

The point A is between Q and R so that $AQ = 4$ metres and $AR = 11$ metres.

The three points R, A and Q are on a line of greatest slope of the plane as shown in **Figure 6**

Figure 6



Particle P is attached to two light elastic strings, PQ and PR

The string PQ has natural length 4 metres and modulus of elasticity 176 newtons.

The string PR has natural length 6 metres and modulus of elasticity 108 newtons.

The coefficient of friction between P and the plane is 0.5

Particle P is released from rest at the point A and begins to move.

Particle P next comes to rest when it has moved x metres.

Assume that P experiences no air resistance during its motion.

7 (a) (i) Find the magnitude of the friction force which acts on P

Give your answer in an exact form in terms of g

[1 mark]

Answer _____

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7 (a) (ii) Show that the initial elastic potential energy stored in string PR is 225 joules.

[1 mark]

7 (a) (iii) Use an energy method to find the value of x

[5 marks]

$x =$ _____

7 (b) It is given that P does experience air resistance.

State with a reason the effect, if any, this would have on your answer to **part (a)(iii)**.

[2 marks]

END OF QUESTIONS

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