Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Thursday 26 October 2023

Afternoon (Time: 1 hour 30 minutes)

Paper reference **WME02/01**

Mathematics

International Advanced Subsidiary/Advanced Level
Mechanics M2

You must have:
Mathematical Formulae and Statistical Tables (Yellow), calculator

Total Marks

Candidates may use any calculator permitted by Pearson regulations. Calculators must not have the facility for symbolic algebra manipulation, differentiation and integration, or have retrievable mathematical formulae stored in them.

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions and ensure that your answers to parts of questions are clearly labelled.
- Answer the questions in the spaces provided – *there may be more space than you need.*
- You should show sufficient working to make your methods clear. Answers without working may not gain full credit.
- Whenever a numerical value of g is required, take $g = 9.8\,\text{m}\,\text{s}^{-2}$, and give your answer to either 2 significant figures or 3 significant figures.

Information

- A booklet 'Mathematical Formulae and Statistical Tables' is provided.
- There are 7 questions in this question paper. The total mark for this paper is 75.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- If you change your mind about an answer, cross it out and put your new answer and any working underneath.

Turn over

1. At time t seconds, $t > 0$, a particle P is at the point with position vector $\mathbf{r}$ m, where

$$\mathbf{r} = \left(t^4 - 8t^2\right)\mathbf{i} + \left(6t^2 - 2t^{\frac{3}{2}}\right)\mathbf{j}$$

(a) Find the velocity of P when P is moving in a direction parallel to the vector $\mathbf{j}$

(4)

(b) Find the acceleration of P when $t = 4$

(3)

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Question 1 continued

(Total for Question 1 is 7 marks)

2.

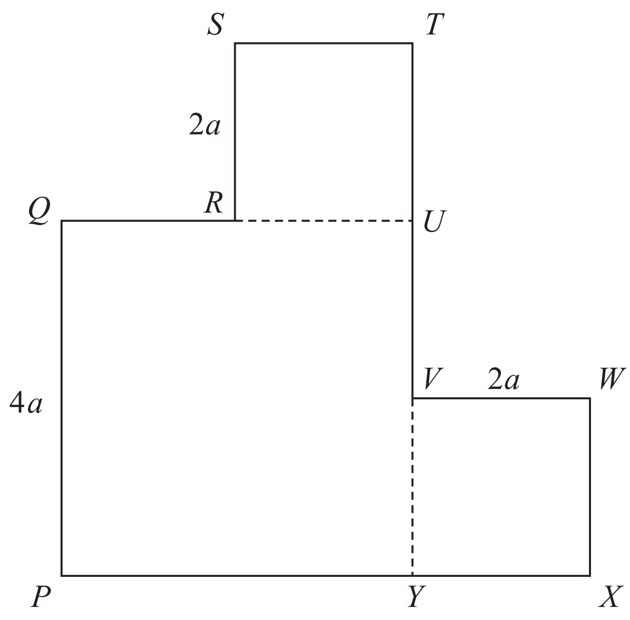

Figure 1

Figure 1 shows a template where

- *PQUY* is a uniform square lamina with sides of length $4a$
- *RSTU* is a uniform square lamina with sides of length $2a$
- *VWXY* is a uniform square lamina with sides of length $2a$
- the three squares all lie in the same plane
- the mass per unit area of *VWXY* is **double** the mass per unit area of *PQUY*
- the mass per unit area of *RSTU* is **double** the mass per unit area of *PQUY*
- the distance of the centre of mass of the template from *PX* is d

(a) Show that $d = \frac{5}{2}a$

(5)

The template is freely pivoted about Q and hangs in equilibrium with PQ at an angle of θ to the downward vertical.

(b) Find the value of $\tan\theta$

(6)

The mass of the template is M

The template is still freely pivoted about Q, but it is now held in equilibrium, with PQ vertical, by a horizontal force of magnitude F which acts on the template at X.
The line of action of the force lies in the same plane as the template.

(c) Find F in terms of M and g

(3)

Question 2 continued

Question 2 continued

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Question 2 continued

(Total for Question 2 is 14 marks)

3.

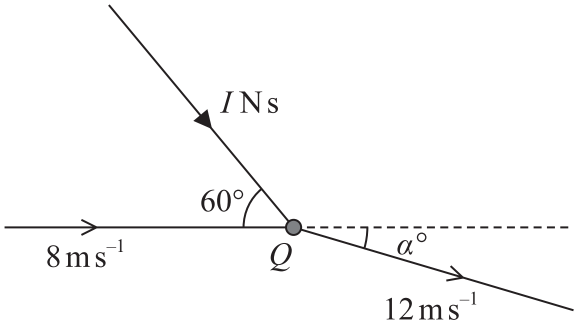

Figure 2

A particle Q of mass 0.25 kg is moving in a straight line on a smooth horizontal surface with speed $8\,\text{m s}^{-1}$ when it receives an impulse of magnitude I N s.

The impulse acts parallel to the horizontal surface and at 60° to the original direction of motion of Q.

Immediately after receiving the impulse, the speed of Q is $12\,\text{m s}^{-1}$

As a result of receiving the impulse, the direction of motion of Q is turned through $\alpha°$, as shown in Figure 2.

Find the value of I

(6)

Question 3 continued

Question 3 continued

Question 3 continued

(Total for Question 3 is 6 marks)

4. [*In this question* **i** *and* **j** *are unit vectors, with* **i** *horizontal and* **j** *vertical.*]

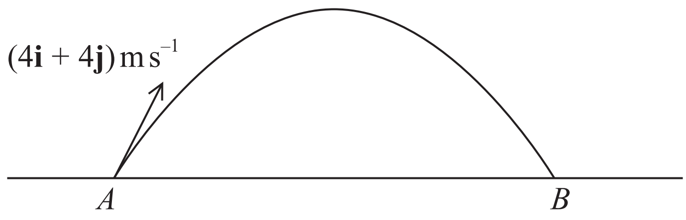

Figure 3

The fixed points A and B lie on horizontal ground.

At time $t = 0$, a particle P is projected from A with velocity $(4\mathbf{i} + 4\mathbf{j})\,\text{m s}^{-1}$

Particle P moves freely under gravity and hits the ground at B, as shown in Figure 3.

At time T_1 seconds, P is at its highest point above the ground.

(a) Find the value of T_1

(2)

At time $t = 0$, a particle Q is also projected from A but with velocity $(5\mathbf{i} + 7\mathbf{j})\,\text{m s}^{-1}$

Particle Q moves freely under gravity.

(b) Find the vertical distance between Q and P at time T_1 seconds, giving your answer to 2 significant figures.

(3)

At the instant when particle P reaches B, particle Q is moving at $\alpha°$ below the horizontal.

(c) Find the value of α.

(4)

At time T_2 seconds, the direction of motion of Q is perpendicular to the initial direction of motion of Q.

(d) Find the value of T_2

(3)

Question 4 continued

Question 4 continued

Question 4 continued

(Total for Question 4 is 12 marks)

5. A cyclist is travelling on a straight horizontal road and working at a constant rate of 500 W.

The total mass of the cyclist and her cycle is 80 kg.

The total resistance to the motion of the cyclist is modelled as a constant force of magnitude 60 N.

(a) Using this model, find the acceleration of the cyclist at the instant when her speed is $6\,\mathrm{m\,s^{-1}}$

(4)

On the following day, the cyclist travels up a straight road from a point A to a point B.

The distance from A to B is 20 km.

Point A is 500 m above sea level and point B is 800 m above sea level.

The cyclist starts from rest at A.

At the instant she reaches B her speed is $8\,\mathrm{m\,s^{-1}}$

The total resistance to the motion of the cyclist from non-gravitational forces is modelled as a constant force of magnitude 60 N.

(b) Using this model, find the total work done by the cyclist in the journey from A to B.

(5)

Later on, the cyclist is travelling up a straight road which is inclined at an angle α to the horizontal, where $\sin\alpha = \frac{1}{20}$

The cyclist is now working at a constant rate of P watts and has a constant speed of $7\,\mathrm{m\,s^{-1}}$

The total resistance to the motion of the cyclist from non-gravitational forces is again modelled as a constant force of magnitude 60 N.

(c) Using this model, find the value of P

(4)

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Question 5 continued

Question 5 continued

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Question 5 continued

(Total for Question 5 is 13 marks)

6.

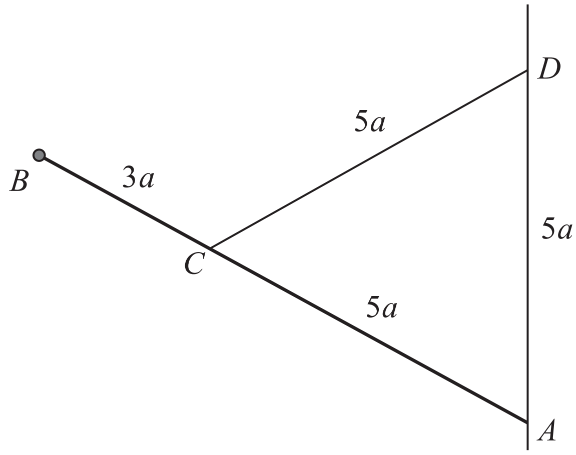

Figure 4

A uniform rod AB has length $8a$ and weight W.

The end A of the rod is freely hinged to a fixed point on a vertical wall.

A particle of weight $\frac{1}{4}W$ is attached to the rod at B.

A light inelastic string of length $5a$ has one end attached to the rod at the point C, where $AC = 5a$.

The other end of the string is attached to the wall at the point D, where D is above A and $AD = 5a$, as shown in Figure 4.

The rod rests in equilibrium.

The tension in the string is T.

(a) Show that $T = \frac{6}{5}W$

(3)

(b) Find, in terms of W, the magnitude of the force exerted on the rod by the hinge at A.

(6)

Question 6 continued

Question 6 continued

Question 6 continued

(Total for Question 6 is 9 marks)

7. Particle P has mass $4m$ and particle Q has mass $2m$.

The particles are moving in opposite directions along the same straight line on a smooth horizontal surface.

Particle P collides directly with particle Q.

Immediately **before** the collision, the speed of P is $2u$ and the speed of Q is $3u$.

Immediately **after** the collision, the speed of P is x and the speed of Q is y.

The direction of motion of each particle is reversed as a result of the collision.

The total kinetic energy of P and Q after the collision is half of the total kinetic energy of P and Q before the collision.

(a) Show that $y = \frac{8}{3}u$

(6)

The coefficient of restitution between P and Q is e.

(b) Find the value of e.

(3)

After the collision, Q hits a smooth fixed vertical wall that is perpendicular to the direction of motion of Q.

Particle Q rebounds.

The coefficient of restitution between Q and the wall is f.

Given that there is no second collision between P and Q,

(c) find the range of possible values of f.

(3)

Given that $f = \frac{1}{4}$

(d) find, in terms of m and u, the magnitude of the impulse received by Q as a result of its impact with the wall.

(2)

Question 7 continued

Question 7 continued

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Question 7 continued

Question 7 continued

(Total for Question 7 is 14 marks)

TOTAL FOR PAPER IS 75 MARKS

P 7 4 3 2 3 A 0 2 8 2 8