Pearson Edexcel International A Level Mathematics

Mechanics 2

Past Paper Collection (from 2020)

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Last updated: July 1, 2024

Comments and suggestions to DrYuFromShanghai@QQ.com

Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel
International Advanced Level

Centre Number | Candidate Number

Wednesday 22 January 2020

Morning (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 (Blue), 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

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Information

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Turn over

Leave blank

1. A cyclist and his bicycle have a total mass of 75 kg. The cyclist is moving down a straight road that is inclined at an angle α to the horizontal, where $\sin\alpha = \frac{1}{15}$

The cyclist is working at a constant rate of 56 W. The magnitude of the resistance to motion is modelled as a constant force of magnitude 40 N. At the instant when the speed of the cyclist is $V\,\text{m}\,\text{s}^{-1}$, his acceleration is $\frac{1}{3}\,\text{m}\,\text{s}^{-2}$

Find the value of V.

(5)

Leave blank

Question 1 continued

Q1

(Total 5 marks)

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2.

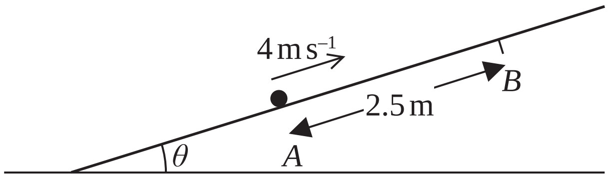

Figure 1

A rough straight ramp is fixed to horizontal ground. The ramp is inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{7}$. The points A and B are on a line of greatest slope of the ramp with $AB = 2.5$ m and B above A, as shown in Figure 1. A package of mass 2 kg is projected up the ramp from A with speed $4\,\text{m}\,\text{s}^{-1}$ and first comes to instantaneous rest at B. The coefficient of friction between the package and the ramp is μ. The package is modelled as a particle.

Use the work-energy principle to find the value of μ.

(6)

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Question 2 continued

Q2

(Total 6 marks)

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3.

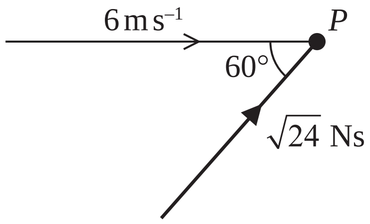

Figure 2

A particle P of mass 0.75 kg is moving along a straight line on a horizontal surface. At the instant when the speed of P is $6\,\text{m}\,\text{s}^{-1}$, it receives an impulse of magnitude $\sqrt{24}$ Ns. The impulse acts in the plane of the horizontal surface. At the instant when P receives the impulse, the line of action of the impulse makes an angle of 60° with the direction of motion of P, as shown in Figure 2.

Find

(i) the speed of P immediately after receiving the impulse,

(ii) the size of the angle between the direction of motion of P immediately before receiving the impulse and the direction of motion of P immediately after receiving the impulse.

(7)

Leave blank

Question 3 continued

(Total 7 marks)

Q3

Leave blank

4. [*The centre of mass of a uniform semicircular lamina of radius r is* $\frac{4r}{3\pi}$ *from the centre.*]

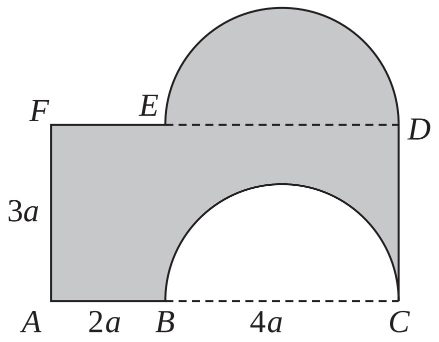

Figure 3

The uniform rectangular lamina *ABCDEF* has sides $AC = FD = 6a$ and $AF = CD = 3a$. The point *B* lies on *AC* with $AB = 2a$ and the point *E* lies on *FD* with $FE = 2a$.

The template, *T*, shown shaded in Figure 3, is formed by removing the semicircular lamina with diameter *BC* from the rectangular lamina and then fixing this semicircular lamina to the opposite side, *FD*, of the rectangular lamina. The diameter of the semicircular lamina coincides with *ED* and the semicircular arc *ED* is outside the rectangle *ABCDEF*. All points of *T* lie in the same plane.

(a) Show that the centre of mass of *T* is a distance $\left(\frac{9 + 2\pi}{6}\right)a$ from *AC*.

(4)

The mass of *T* is *M*. A particle of mass *kM* is attached to *T* at *C*. The loaded template is freely suspended from *A* and hangs in equilibrium with *AF* at angle ϕ to the downward vertical through *A*.

Given that $\tan\phi = \frac{3}{2}$

(b) find the value of *k*.

(6)

Leave blank

Question 4 continued

Leave blank

Question 4 continued

Leave blank

Question 4 continued

Q4

(Total 10 marks)

Leave blank

5. At time t seconds ($t \geqslant 0$), a particle P has velocity $\mathbf{v}$ m s^{-1}, where

$$\mathbf{v} = (3t^2 - 4)\mathbf{i} + (2t - 4)\mathbf{j}$$

When $t = 0$, P is at the fixed point O.

(a) Find the acceleration of P at the instant when $t = 0$

(2)

(b) Find the exact speed of P at the instant when P is moving in the direction of the vector $(11\mathbf{i} + \mathbf{j})$ for the second time.

(4)

(c) Show that P never returns to O.

(4)

Leave blank

Question 5 continued

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Question 5 continued

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Question 5 continued

(Total 10 marks)

Q5

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6.

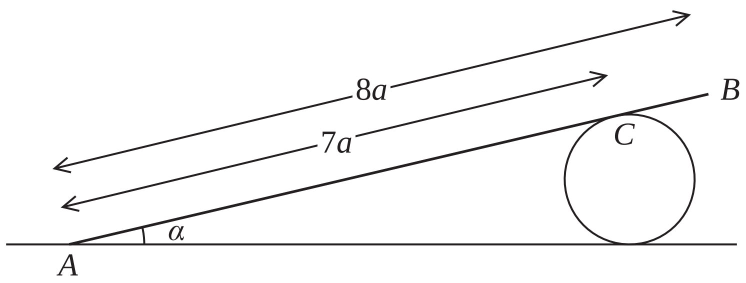

Figure 4

A uniform rod, AB, of weight W and length $8a$, rests in equilibrium with the end A on rough horizontal ground. The rod rests on a smooth cylinder. The cylinder is fixed to the ground with its axis horizontal. The point of contact between the rod and the cylinder is C, where $AC = 7a$, as shown in Figure 4. The rod is resting in a vertical plane that is perpendicular to the axis of the cylinder. The rod makes an angle α with the horizontal.

(a) Show that the normal reaction of the ground on the rod at A has magnitude $W\left(1 - \frac{4}{7}\cos^2\alpha\right)$

(6)

Given that the coefficient of friction between the rod and the ground is μ and that $\cos\alpha = \frac{3}{\sqrt{10}}$

(b) find the range of possible values of μ.

(5)

Leave blank

Question 6 continued

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Question 6 continued

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Question 6 continued

(Total 11 marks)

Q6

Leave blank

7.

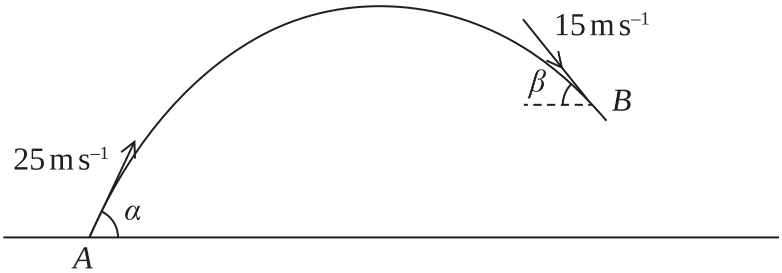

Figure 5

At time $t = 0$ a particle P is projected from a fixed point A on horizontal ground. The particle is projected with speed $25\,\text{m s}^{-1}$ at an angle α to the ground. The particle moves freely under gravity. At time $t = 3$ seconds, P is passing through the point B with speed $15\,\text{m s}^{-1}$ and is moving downwards at an angle β to the horizontal, as shown in Figure 5.

(a) By considering energy, find the height of B above the ground.

(3)

(b) Find the size of angle α.

(3)

(c) Find the size of angle β.

(3)

(d) Find the least speed of P as P travels from A to B.

(2)

As P travels from A to B, the speed, $v\,\text{m s}^{-1}$, of P is such that $v \leqslant 15$ for an interval of T seconds.

(e) Find the value of T.

(3)

Leave blank

Question 7 continued

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Question 7 continued

Leave blank

Question 7 continued

Q7

(Total 14 marks)

Leave blank

8. A particle A has mass $4m$ and a particle B has mass $3m$. The particles are moving along the same straight line on a smooth horizontal plane. They are moving in opposite directions towards each other and collide directly.

Immediately before the collision the speed of A is $2u$ and the speed of B is $3u$.

The direction of motion of each particle is reversed by the collision.

The total kinetic energy lost in the collision is $\frac{473}{24}mu^2$

Find

(i) the coefficient of restitution between A and B,

(ii) the magnitude of the impulse received by A in the collision.

(12)

Leave blank

Question 8 continued

Leave blank

Question 8 continued

Leave blank

Question 8 continued

Leave blank

Question 8 continued

Q8

(Total 12 marks)

TOTAL FOR PAPER: 75 MARKS

END

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International Advanced Level

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Tuesday 20 October 2020

Afternoon (Time: 1 hour 30 minutes) | Paper Reference **WME02/01**

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International Advanced Subsidiary/Advanced Level
Mechanics M2

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Turn over

Leave blank

1. A particle of mass 2 kg is moving with velocity $(5\mathbf{i} + 3\mathbf{j})\,\text{m s}^{-1}$ when it receives an impulse $\mathbf{I}$ N s, such that $\mathbf{I} = a\mathbf{i} + b\mathbf{j}$

Immediately after receiving the impulse, the particle is moving with velocity $\lambda(\mathbf{i} + \mathbf{j})\,\text{m s}^{-1}$, where λ is a constant.

Given that the magnitude of $\mathbf{I}$ is $\sqrt{40}$, find the two possible impulses.

(5)

Leave blank

Question 1 continued

Q1

(Total 5 marks)

Leave blank

2. A truck of weight 9000 N is travelling up a hill on a straight road that is inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{15}$

When the truck travels up the hill with the engine working at $3P$ watts, the truck is moving at a constant speed of $12\,\mathrm{m\,s^{-1}}$

Later on, the truck travels down the hill along the same road, with the engine working at P watts. At the instant when the speed of the truck is $12\,\mathrm{m\,s^{-1}}$, the acceleration of the truck is $\frac{g}{20}$

The resistance to motion of the truck from non-gravitational forces is a constant force of magnitude R newtons in all circumstances.

Find (i) the value of P,

(ii) the value of R.

(9)

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Question 2 continued

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Question 2 continued

Leave blank

Question 2 continued

Q2

(Total 9 marks)

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3.

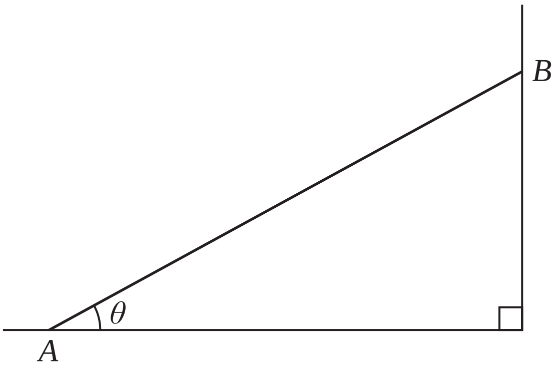

Figure 1

A uniform rod AB, of mass 25 kg and length 3 m, has end A resting on rough horizontal ground. The end B rests against a rough vertical wall.

The rod is in a vertical plane perpendicular to the wall.

The coefficient of friction between the rod and the ground is $\frac{4}{5}$

The coefficient of friction between the rod and the wall is $\frac{3}{5}$

The rod rests in limiting equilibrium.

The rod is at an angle of θ to the ground, as shown in Figure 1.

Find the exact value of $\tan\theta$.

(9)

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Question 3 continued

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Question 3 continued

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Question 3 continued

Q3

(Total 9 marks)

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4.

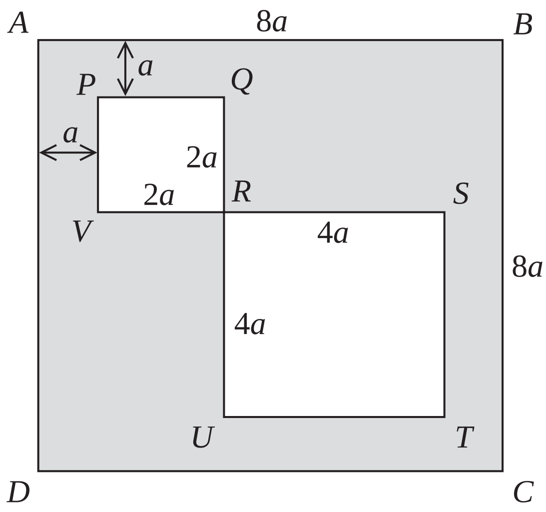

Figure 2

The uniform lamina L, shown shaded in Figure 2, is formed by removing the square $PQRV$, of side $2a$, and the square $RSTU$, of side $4a$, from a uniform square lamina $ABCD$, of side $8a$. The lines QRU and VRS are straight. The side AD is parallel to PV and the side AB is parallel to PQ. The distance between AD and PV is a and the distance between AB and PQ is a. The centre of mass of L is at the point G.

(a) Show that the distance of G from the side AD is $\dfrac{42}{11}a$

(5)

The mass of L is M. A particle of mass kM is attached to L at C.

The lamina, with the attached particle, is freely suspended from B and hangs in equilibrium with BC making an angle of 45° with the horizontal.

(b) Find the value of k.

(4)

Leave blank

Question 4 continued

Leave blank

Question 4 continued

Leave blank

Question 4 continued

Q4

(Total 9 marks)

Leave blank

5. At time t seconds ($t \geqslant 0$), a particle P has velocity $\mathbf{v}\,\mathrm{m\,s^{-1}}$, where

$$\mathbf{v} = (3t^2 - 9t + 6)\mathbf{i} + (t^2 + t - 6)\mathbf{j}$$

(a) Find the acceleration of P when $t = 3$

(3)

When $t = 0$, P is at the fixed point O.

The particle comes to instantaneous rest at the point A.

(b) Find the distance OA.

(7)

Leave blank

Question 5 continued

Leave blank

Question 5 continued

Leave blank

Question 5 continued

Q5

(Total 10 marks)

Leave blank

6.

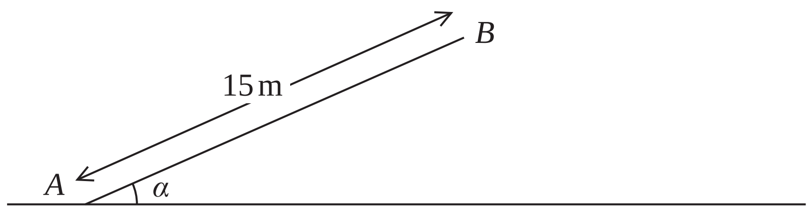

Figure 3

A rough straight ramp is fixed to horizontal ground. The ramp has length 15 m and is inclined at an angle α to the ground, where $\tan\alpha = \frac{5}{12}$. The line *AB* is a line of greatest slope of the ramp, where *A* is at the bottom of the ramp, and *B* is at the top of the ramp, as shown in Figure 3.

A particle *P* of mass 6 kg is projected up the ramp with speed 14 m s^{-1} from *A* in a straight line towards *B*. The coefficient of friction between *P* and the ramp is 0.25

(a) Find the work done against friction as *P* moves from *A* to *B*.

(3)

At the instant *P* reaches *B*, the speed of *P* is v m s^{-1}. After leaving the ramp at *B*, the particle *P* moves freely under gravity until it hits the horizontal ground at the point *C*. Immediately before hitting the ground at *C*, the speed of *P* is w m s^{-1}

(b) Use the work-energy principle to find

(i) the value of v,

(ii) the value of w.

(7)

Leave blank

Question 6 continued

Leave blank

Question 6 continued

Leave blank

Question 6 continued

Q6

(Total 10 marks)

Leave blank

7. Particle A of mass $3m$ is moving in a straight line with speed $2u$ on a smooth horizontal surface. Particle A collides directly with particle B of mass m, which is moving along the same straight line and in the same direction as A.

Immediately before the collision, the speed of B is u.

As a result of the collision, the direction of motion of B is unchanged and the kinetic energy gained by B is $\frac{48}{25}mu^2$

(a) Find the coefficient of restitution between A and B.

(8)

After the collision, B hits a smooth fixed vertical wall that is perpendicular to the direction of motion of B. The coefficient of restitution between B and the wall is f.

Given that the speed of B immediately after first hitting the wall is equal to the speed of A immediately after its first collision with B,

(b) find the value of f.

(2)

Leave blank

Question 7 continued

Leave blank

Question 7 continued

Leave blank

Question 7 continued

Q7

(Total 10 marks)

Leave blank

8. [*In this question, the unit vectors* **i** *and* **j** *are in a vertical plane, with* **i** *being horizontal and* **j** *being vertically upwards*.]

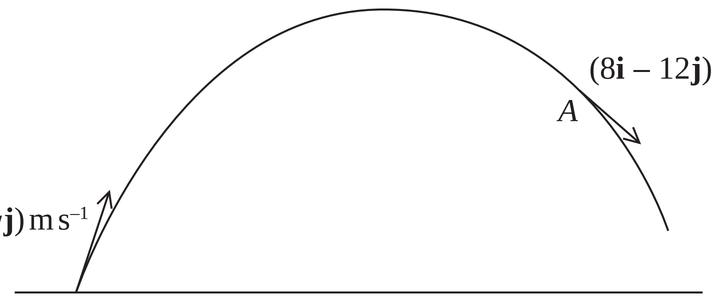

Figure 4

At time $t = 0$, a small ball is projected from a fixed point O on horizontal ground. The ball is projected from O with velocity $(p\mathbf{i} + q\mathbf{j})\,\text{m s}^{-1}$, where p and q are positive constants. The ball moves freely under gravity.

At time $t = 3$ seconds, the ball passes through the point A with velocity $(8\mathbf{i} - 12\mathbf{j})\,\text{m s}^{-1}$, as shown in Figure 4.

(a) Find the speed of the ball at the instant it is projected from O.

(5)

For an interval of T seconds the speed, $v\,\text{m s}^{-1}$, of the ball is such that $v \leqslant 10$

(b) Find the value of T.

(4)

At the point B on the path of the ball, the direction of motion of the ball is perpendicular to the direction of motion of the ball at A.

(c) Find the vertical height of B above A.

(4)

Leave blank

Question 8 continued

Leave blank

Question 8 continued

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Question 8 continued

Leave blank

Question 8 continued

Q8

(Total 13 marks)

TOTAL FOR PAPER: 75 MARKS

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Turn over ▶

Leave blank

1. A particle P of mass 1.5 kg is moving with velocity $(4\mathbf{i} + 6\mathbf{j})\,\text{m s}^{-1}$ when it receives an impulse of magnitude 15 Ns. Immediately after P receives the impulse, the velocity of P is $v\mathbf{i}\,\text{m s}^{-1}$.

Find the two possible values of v.

(7)

Leave blank

Question 1 continued

Q1

(Total 7 marks)

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2.

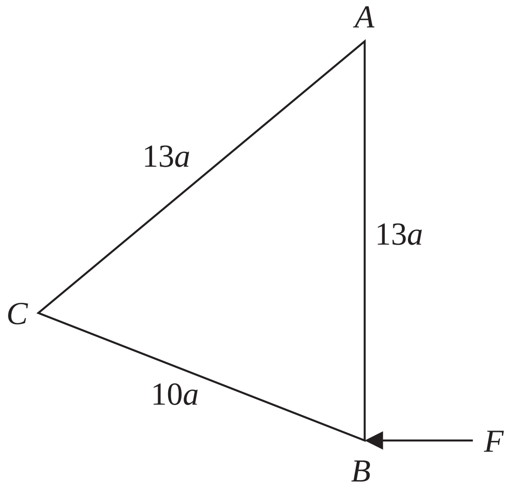

Figure 1

The uniform lamina ABC has sides $AB = AC = 13a$ and $BC = 10a$. The lamina is freely suspended from A. A horizontal force of magnitude F is applied to the lamina at B, as shown in Figure 1. The line of action of the force lies in the vertical plane containing the lamina. The lamina is in equilibrium with AB vertical. The weight of the lamina is W.

Find F in terms of W.

(5)

Leave blank

Question 2 continued

Q2

(Total 5 marks)

Leave blank

3. A car of mass 600 kg travels along a straight horizontal road with the engine of the car working at a constant rate of P watts. The resistance to the motion of the car is modelled as a constant force of magnitude R newtons. At the instant when the speed of the car is $15\,\text{m}\,\text{s}^{-1}$, the magnitude of the acceleration of the car is $0.2\,\text{m}\,\text{s}^{-2}$.

Later the same car travels up a straight road inclined at angle θ to the horizontal, where $\sin\theta = \frac{1}{20}$. The resistance to the motion of the car from non-gravitational forces is modelled as a constant force of magnitude R newtons. When the engine of the car is working at a constant rate of P watts, the car has a constant speed of $10\,\text{m}\,\text{s}^{-1}$.

Find the value of P.

(8)

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Question 3 continued

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Question 3 continued

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Question 3 continued

Q3

(Total 8 marks)

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4.

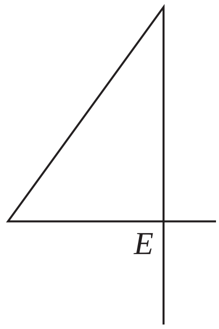

Figure 2

The number "4", shown in Figure 2, is a rigid framework made from three uniform rods, AB, BC and CD, where

$$AB = 6a,\ BC = 5a \text{ and } CD = 4a$$

The point E is on AB and CD, where $BE = 4a$, $CE = 3a$ and angle $CEB = 90°$

The three rods are all made from the same material and they all lie in the same plane.

The framework is suspended from B and hangs in equilibrium with BA at an angle θ to the downward vertical.

Find θ to the nearest degree.

(9)

Leave blank

Question 4 continued

Leave blank

Question 4 continued

Leave blank

Question 4 continued

(Total 9 marks)

Q4

Leave blank

5. At time t seconds, $t \geqslant 0$, a particle P has velocity $\mathbf{v}\,\text{m}\,\text{s}^{-1}$, where

$$\mathbf{v} = (5t^2 - 12t + 15)\mathbf{i} + (t^2 + 8t - 10)\mathbf{j}$$

When $t = 0$, P is at the origin O.

At time T seconds, P is moving in the direction of $(\mathbf{i} + \mathbf{j})$.

(a) Find the value of T.

(3)

When $t = 3$, P is at the point A.

(b) Find the magnitude of the acceleration of P as it passes through A.

(4)

(c) Find the position vector of A.

(4)

Leave blank

Question 5 continued

Q5

(Total 11 marks)

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6.

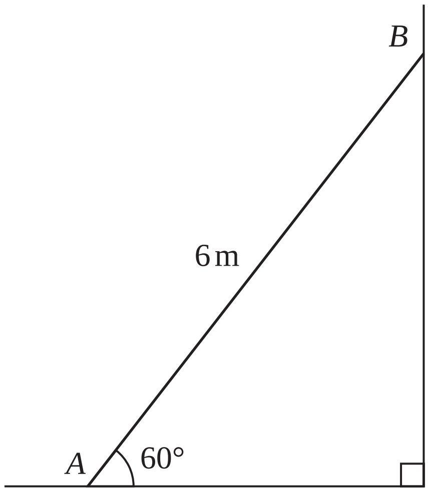

Figure 3

A ladder *AB* has length 6 m and mass 30 kg. The ladder rests in equilibrium at 60° to the horizontal with the end *A* on rough horizontal ground and the end *B* against a smooth vertical wall, as shown in Figure 3.

A man of mass 70 kg stands on the ladder at the point *C*, where *AC* = 2 m, and the ladder remains in equilibrium. The ladder is modelled as a uniform rod in a vertical plane perpendicular to the wall. The man is modelled as a particle.

(a) Find the magnitude of the force exerted on the ladder by the ground.

(6)

The man climbs further up the ladder. When he is at the point *D* on the ladder, the ladder is about to slip.

Given that the coefficient of friction between the ladder and the ground is 0.4

(b) find the distance *AD*.

(4)

(c) State how you have used the modelling assumption that the ladder is a rod.

(1)

Leave blank

Question 6 continued

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Question 6 continued

Leave blank

Question 6 continued

Q6

(Total 11 marks)

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7.

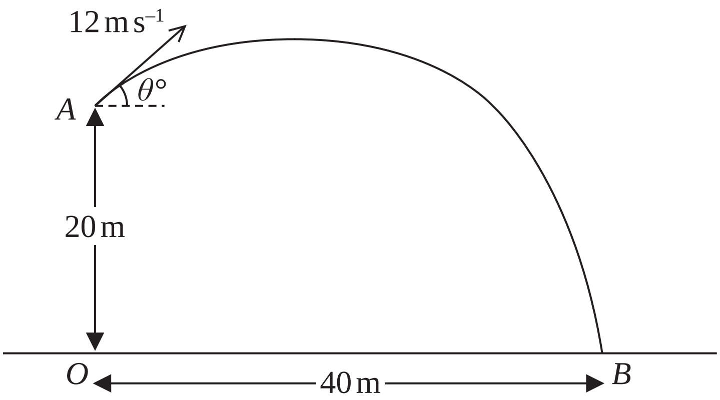

Figure 4

The fixed point A is 20 m vertically above the point O which is on horizontal ground. At time $t = 0$, a particle P is projected from A with speed 12 m s^{-1} at an angle $\theta°$ above the horizontal. The particle moves freely under gravity. At time $t = 5$ seconds, P strikes the ground at the point B, where $OB = 40$ m, as shown in Figure 4.

(a) By considering energy, find the speed of P as it hits the ground at B.

(4)

(b) Find the least speed of P as it moves from A to B.

(2)

(c) Find the length of time for which the speed of P is more than 10 m s^{-1}.

(6)

Leave blank

Question 7 continued

Leave blank

Question 7 continued

Leave blank

Question 7 continued

Q7

(Total 12 marks)

Leave blank

8. Two particles, A and B, have masses $3m$ and $4m$ respectively. The particles are moving towards each other along the same straight line on a smooth horizontal surface. The particles collide directly. Immediately after the collision, A and B are moving in the same direction with speeds $\frac{u}{3}$ and u respectively. In the collision, A receives an impulse of magnitude $8mu$.

(a) Find the coefficient of restitution between A and B.

(6)

When A and B collide they are at a distance d from a smooth vertical wall, which is perpendicular to their direction of motion. After the collision with A, particle B collides directly with the wall and rebounds so that there is a second collision between A and B. This second collision takes place at distance x from the wall.

Given that the coefficient of restitution between B and the wall is $\frac{1}{4}$

(b) find x in terms of d.

(6)

Leave blank

Question 8 continued

Leave blank

Question 8 continued

Leave blank

Question 8 continued

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Question 8 continued

Q8

(Total 12 marks)

TOTAL FOR PAPER: 75 MARKS

END

Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel International Advanced Level

Centre Number

Candidate Number

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).
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- 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 $g = 9.8\,\text{m s}^{-2}$, 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 8 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.
- Good luck with your examination.

Turn over ▶

Leave blank

1. A motorcyclist and his motorcycle have a combined mass of 480 kg.

The motorcyclist drives down a straight road that is inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{12}$, with the engine of the motorcycle working at 3.5 kW. The motorcycle is moving at a constant speed of $V\,\text{m s}^{-1}$. The resistance to the motion of the motorcycle is modelled as a constant force with magnitude $20V$ newtons.

Find the value of V.

(5)

Leave blank

Question 1 continued

Q1

(Total 5 marks)

Leave blank

2. A particle P of mass 1.5 kg moves under the action of a single force $\mathbf{F}$ newtons.

At time t seconds, $t \geqslant 0$, P has velocity $\mathbf{v}$ m s^{-1}, where

$$\mathbf{v} = (5t^2 - t^3)\mathbf{i} + (2t^3 - 8t)\mathbf{j}$$

(a) Find $\mathbf{F}$ when $t = 2$

(4)

At time $t = 0$, P is at the origin O.

(b) Find the position vector of P relative to O at the instant when P is moving in the direction of the vector $\mathbf{j}$

(4)

Leave blank

Question 2 continued

Q2

(Total 8 marks)

Leave blank

3.

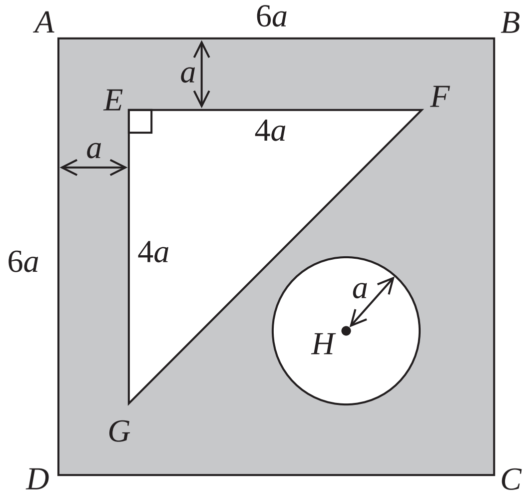

Figure 1

The uniform lamina *ABCD* is a square of side 6*a*. The template *T*, shown shaded in Figure 1, is formed by removing the right-angled triangle *EFG* and the circle, centre *H* and radius *a*, from the square lamina.

Triangle *EFG* has *EF* = *EG* = 4*a*, with *EF* parallel to *AB* and *EG* parallel to *AD*. The distance between *AB* and *EF* is *a* and the distance between *AD* and *EG* is *a*.

The point *H* lies on *AC* and the distance of *H* from *BC* is 2*a*.

(a) Show that the centre of mass of *T* is a distance $\dfrac{4(67-3\pi)}{3(28-\pi)}a$ from *AD*.

(5)

The template *T* is suspended from the ceiling by two light inextensible vertical strings. One string is attached to *T* at *A* and the other string is attached to *T* at *B* so that *T* hangs in equilibrium with *AB* horizontal.

The weight of *T* is *W*. The tension in the string attached to *T* at *B* is *kW*, where *k* is a constant.

(b) Find the value of *k*, giving your answer to 2 decimal places.

(3)

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Question 3 continued

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Question 3 continued

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Question 3 continued

Q3

(Total 8 marks)

Leave blank

4.

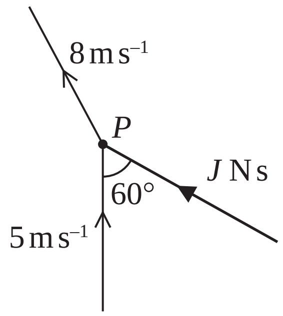

Figure 2

A particle P of mass 0.3 kg is moving with speed 5 m s^{-1} along a straight line on a smooth horizontal plane. The particle receives a horizontal impulse of magnitude J N s. The speed of P immediately after receiving the impulse is 8 m s^{-1}. The angle between the direction of motion of P before it receives the impulse and the direction of the impulse is 60°, as shown in Figure 2.

Find the value of J.

(6)

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Question 4 continued

Q4

(Total 6 marks)

Leave blank

5.

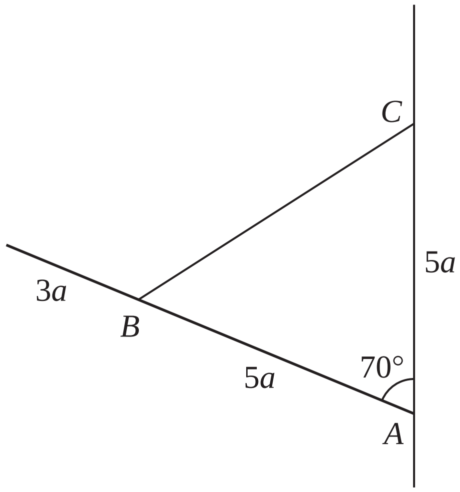

Figure 3

A uniform rod, of length $8a$ and mass M, has one end freely hinged to a fixed point A on a vertical wall. One end of a light inextensible string is attached to the rod at the point B, where $AB = 5a$. The other end of the string is attached to the wall at the point C, where $AC = 5a$ and C is vertically above A. The rod rests in equilibrium in a vertical plane perpendicular to the wall with angle $BAC = 70°$, as shown in Figure 3.

(a) Find, in terms of M and g, the tension in the string.

(3)

The magnitude of the force acting on the rod at A is λMg, where λ is a constant.

(b) Find, to 2 significant figures, the value of λ.

(6)

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Question 5 continued

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Question 5 continued

Leave blank

Question 5 continued

Q5

(Total 9 marks)

6.

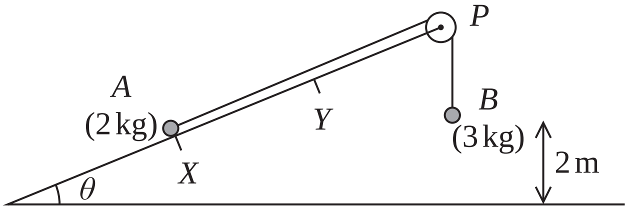

Figure 4

Two particles, A and B, of mass 2 kg and 3 kg respectively, are connected by a light inextensible string. Particle A is held at rest at the point X on a fixed rough ramp that is inclined at an angle θ to the horizontal, where $\tan\theta = \frac{5}{12}$. The string passes over a small smooth pulley P that is fixed at the top of the ramp. Particle B hangs vertically below P, 2 m above the ground, as shown in Figure 4.

The particles are released from rest with the string taut so that A moves up the ramp and the section of the string from A to P is parallel to a line of greatest slope of the ramp. The coefficient of friction between A and the ramp is $\frac{3}{8}$

Air resistance is ignored.

(a) Find the potential energy lost by the system as A moves 2 m up the ramp.
(3)

(b) Find the work done against friction as A moves 2 m up the ramp.
(4)

When B hits the ground, B is brought to rest by the impact and does not rebound and A continues to move up the ramp.

(c) Use the work-energy principle to find the speed of B at the instant before it hits the ground.
(4)

Particle A comes to instantaneous rest at the point Y on the ramp, where $XY = (2 + d)$ m.

(d) Use the work-energy principle to find the value of d.
(4)

Leave blank

Question 6 continued

Leave blank

Question 6 continued

Leave blank

Question 6 continued

Q6

(Total 15 marks)

Leave blank

7. [*In this question, the unit vectors* **i** *and* **j** *are in a vertical plane,* **i** *being horizontal and* **j** *being vertically upwards.*]

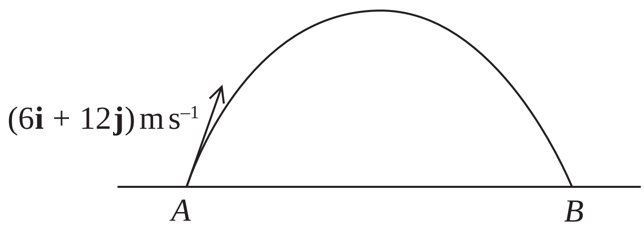

Figure 5

A small ball is projected with velocity (6**i** + 12**j**) m s^{-1} from a fixed point *A* on horizontal ground. The ball hits the ground at the point *B*, as shown in Figure 5. The motion of the ball is modelled as a particle moving freely under gravity.

(a) Find the distance *AB*.

(4)

When the height of the ball above the ground is more than *h* metres, the speed of the ball is less than 10 m s^{-1}

(b) Find the smallest possible value of *h*.

(4)

When the ball is at the point *C* on its path, the direction of motion of the ball is perpendicular to the direction of motion of the ball at the instant before it hits the ground at *B*.

(c) Find, in terms of **i** and **j**, the velocity of the ball when it is at *C*.

(3)

Leave blank

Question 7 continued

Leave blank

Question 7 continued

Leave blank

Question 7 continued

Q7

(Total 11 marks)

8. Particles A, B and C, of masses $2m$, m and $3m$ respectively, lie at rest in a straight line on a smooth horizontal plane with B between A and C. Particle A is projected towards particle B with speed $2u$ and collides directly with B.

The coefficient of restitution between each pair of particles is e.

(a) (i) Show that the speed of B immediately after the collision with A is $\frac{4}{3}u(1 + e)$

(ii) Find the speed of A immediately after the collision with B.

(7)

At the instant when A collides with B, particle C is projected with speed u towards B so that B and C collide directly.

(b) Show that there will be a second collision between A and B.

(6)

Leave blank

Question 8 continued

Leave blank

Question 8 continued

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Question 8 continued

Leave blank

Question 8 continued

Q8

(Total 13 marks)

TOTAL FOR PAPER: 75 MARKS

END

Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

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

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- Whenever a numerical value of g is required, take $g = 9.8\,\text{m s}^{-2}$, and give your answer to either 2 significant figures or 3 significant figures.

Information

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- There are 8 questions in this question paper. The total mark for this paper is 75.
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1.

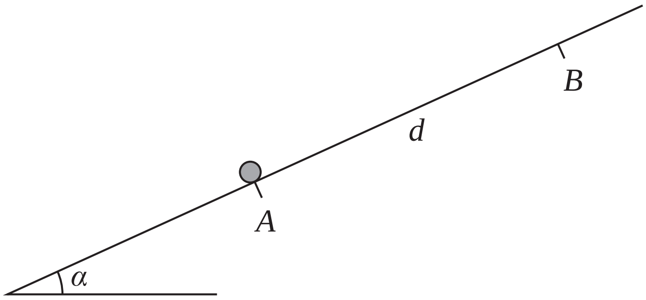

Figure 1

A particle of mass m is held at rest at a point A on a rough plane.

The plane is inclined at an angle α to the horizontal, where $\tan\alpha = \frac{5}{12}$

The coefficient of friction between the particle and the plane is $\frac{1}{5}$

The points A and B lie on a line of greatest slope of the plane, with B above A, and $AB = d$, as shown in Figure 1.

The particle is pushed up the line of greatest slope from A to B.

(a) Show that the work done against friction as the particle moves from A to B is $\frac{12}{65}mgd$

(3)

The particle is then held at rest at B and released.

(b) Use the work-energy principle to find, in terms of g and d, the speed of the particle at the instant it reaches A.

(4)

Leave blank

Question 1 continued

Q1

(Total 7 marks)

Leave blank

2. A vehicle of mass 450 kg is moving on a straight road that is inclined at angle θ to the horizontal, where $\sin\theta = \frac{1}{15}$

At the instant when the vehicle is moving **down** the road at $12\,\mathrm{m\,s^{-1}}$

- the engine of the vehicle is working at a rate of P watts
- the **acceleration** of the vehicle is $0.5\,\mathrm{m\,s^{-2}}$
- the resistance to the motion of the vehicle is modelled as a constant force of magnitude R newtons

At the instant when the vehicle is moving **up** the road at $12\,\mathrm{m\,s^{-1}}$

- the engine of the vehicle is working at a rate of $2P$ watts
- the **deceleration** of the vehicle is $0.5\,\mathrm{m\,s^{-2}}$
- the resistance to the motion of the vehicle from non-gravitational forces is modelled as a constant force of magnitude R newtons

Find the value of P.

(8)

Leave blank

Question 2 continued

Leave blank

Question 2 continued

Leave blank

Question 2 continued

Q2

(Total 8 marks)

Leave blank

3. A particle P moves on the x-axis.

At time $t = 0$, P is instantaneously at rest at O.

At time t seconds, $t > 0$, the x coordinate of P is given by

$$x = 2t^{\frac{7}{2}} - 14t^{\frac{5}{2}} + \frac{56}{3}t^{\frac{3}{2}}$$

Find

(a) the non-zero values of t for which P is at instantaneous rest **(3)**

(b) the total distance travelled by P in the interval $0 \leqslant t \leqslant 4$ **(3)**

(c) the acceleration of P when $t = 4$ **(3)**

Leave blank

Question 3 continued

Q3

(Total 9 marks)

Leave blank

4. A particle P of mass 0.75 kg is moving with velocity $4\mathbf{i}\,\mathrm{m\,s^{-1}}$ when it receives an impulse $\mathbf{J}$ N s. Immediately after P receives the impulse, the speed of P is $8\,\mathrm{m\,s^{-1}}$

Given that $\mathbf{J} = c(-\mathbf{i} + 2\mathbf{j})$, where c is a constant, find the two possible values of c.

(6)

Leave blank

Question 4 continued

Q4

(Total 6 marks)

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5.

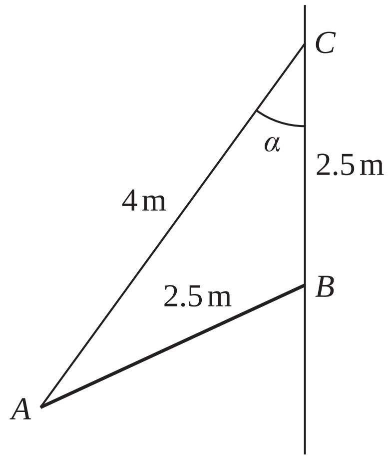

Figure 2

A pole AB has length 2.5 m and weight 70 N.
The pole rests with end B against a rough vertical wall. One end of a cable of length 4 m is attached to the pole at A. The other end of the cable is attached to the wall at the point C.
The point C is vertically above B and BC = 2.5 m.
The angle between the cable and the wall is α, as shown in Figure 2.
The pole is in a vertical plane perpendicular to the wall.
The cable is modelled as a light inextensible string and the pole is modelled as a uniform rod.

Given that $\tan\alpha = \frac{3}{4}$

(a) show that the tension in the cable is 56 N.

(4)

Given also that the pole is in limiting equilibrium,

(b) find the coefficient of friction between the pole and the wall.

(6)

Leave blank

Question 5 continued

Leave blank

Question 5 continued

Leave blank

Question 5 continued

Q5

(Total 10 marks)

Leave blank

6. Two particles, A and B, are moving in opposite directions along the same straight line on a smooth horizontal surface when they collide directly.
The mass of A is $2m$ and the mass of B is $3m$.

Immediately **after** the collision, A and B are moving in opposite directions with the same speed v.
In the collision, A receives an impulse of magnitude $5mv$.

(a) Find the coefficient of restitution between A and B.

(6)

After the collision with A, particle B strikes a smooth fixed vertical wall and rebounds. The wall is perpendicular to the direction of motion of the particles.
The coefficient of restitution between B and the wall is f.

As a result of its collision with A and with the wall, the total kinetic energy lost by B is E.
As a result of its collision with B, the kinetic energy lost by A is $2E$.

(b) Find the value of f.

(4)

Leave blank

Question 6 continued

Leave blank

Question 6 continued

Leave blank

Question 6 continued

Q6

(Total 10 marks)

Leave blank

7. In this question you may use, without proof, the formula for the centre of mass of a uniform sector of a circle, as given in the formulae book.

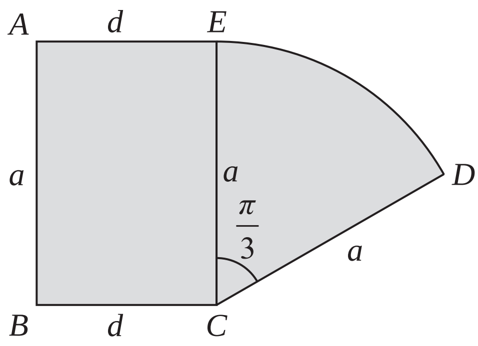

Figure 3

The uniform lamina *ABCDE*, shown shaded in Figure 3, is formed by joining a rectangle to a sector of a circle.

- The rectangle *ABCE* has $AB = EC = a$ and $AE = BC = d$
- The sector *CDE* has centre *C* and radius *a*
- Angle $ECD = \frac{\pi}{3}$ radians

The centre of mass of the lamina lies on *EC*.

(a) Show that $a = \sqrt{3}d$

(4)

The lamina is freely suspended from *B* and hangs in equilibrium with *BC* at an angle β radians to the downward vertical.

(b) Find the value of β

(7)

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Question 7 continued

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Question 7 continued

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Question 7 continued

(Total 11 marks)

Q7

Leave blank

8.

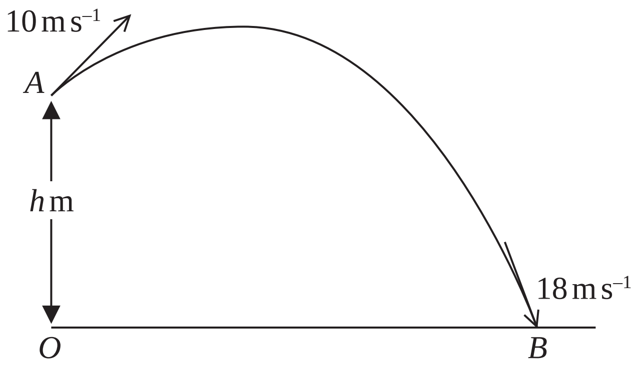

Figure 4

The fixed point A is h metres vertically above the point O that is on horizontal ground. At time $t = 0$, a particle P is projected from A with speed $10\,\text{m}\,\text{s}^{-1}$. The particle moves freely under gravity. At time $t = 2.5$ seconds, P strikes the ground at the point B. At the instant when P strikes the ground, the speed of P is $18\,\text{m}\,\text{s}^{-1}$, as shown in Figure 4.

(a) By considering energy, find the value of h.

(3)

(b) Find the distance OB.

(5)

As P moves from A to B, the speed of P is less than or equal to $8\,\text{m}\,\text{s}^{-1}$ for T seconds.

(c) Find the value of T

(6)

Leave blank

Question 8 continued

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Question 8 continued

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Question 8 continued

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Question 8 continued

Q8

(Total 14 marks)

TOTAL FOR PAPER IS 75 MARKS

END

Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

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.

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Information

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- There are 7 questions in this question paper. The total mark for this paper is 75.
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Advice

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- 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 ▶

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1. A particle of mass 0.5 kg is moving with velocity $(2\mathbf{i} + 4\mathbf{j})\,\text{m s}^{-1}$ when it receives an impulse of $(-4\mathbf{i} + 6\mathbf{j})\,\text{N s}$.

(a) Find the speed of the particle immediately after it receives the impulse.

(5)

(b) Find the size of the angle between the direction of motion of the particle immediately before it receives the impulse and the direction of motion of the particle immediately after it receives the impulse.

(3)

Leave blank

Question 1 continued

Q1

(Total 8 marks)

Leave blank

2. A car of mass 600 kg tows a trailer of mass 200 kg up a hill along a straight road that is inclined at angle θ to the horizontal, where $\sin\theta = \frac{1}{20}$. The trailer is attached to the car by a light inextensible towbar. The resistance to the motion of the car from non-gravitational forces is modelled as a constant force of magnitude 150 N. The resistance to the motion of the trailer from non-gravitational forces is modelled as a constant force of magnitude 300 N.

When the engine of the car is working at a constant rate of P kW the car and the trailer have a constant speed of 15 m s^{-1}

(a) Find the value of P.

(5)

Later, at the instant when the car and the trailer are travelling up the hill with a speed of 20 m s^{-1}, the towbar breaks. When the towbar breaks the trailer is at the point X. The trailer continues to travel up the hill before coming to instantaneous rest at the point Y. The resistance to the motion of the trailer from non-gravitational forces is again modelled as a constant force of magnitude 300 N.

(b) Use the work-energy principle to find the distance XY.

(4)

Leave blank

Question 2 continued

Leave blank

Question 2 continued

Leave blank

Question 2 continued

Q2

(Total 9 marks)

Leave blank

3. A particle P of mass 0.25 kg is moving on a smooth horizontal surface under the action of a single force, **F** newtons.

At time t seconds $(t \geqslant 0)$, the velocity $\mathbf{v}\,\mathrm{m\,s^{-1}}$ of P is given by

$$\mathbf{v} = (6\sin 3t)\,\mathbf{i} + (1 + 2\cos t)\,\mathbf{j}$$

(a) Find **F** in terms of t.

(3)

At time $t = 0$, the position vector of P relative to a fixed point O is $(4\mathbf{i} - \sqrt{3}\mathbf{j})\,\mathrm{m}$.

(b) Find the position vector of P relative to O when P is first moving parallel to the vector **i**.

(6)

Leave blank

Question 3 continued

Leave blank

Question 3 continued

Leave blank

Question 3 continued

Q3

(Total 9 marks)

Leave blank

4. Two small balls, A and B, are moving in opposite directions along the same straight line on smooth horizontal ground. The mass of A is $2m$ and the mass of B is $3m$.
The balls collide directly. Immediately before the collision, the speed of A is $2u$ and the speed of B is u. The coefficient of restitution between A and B is e, where $e > 0$

By modelling the balls as particles,

(a) show that the speed of B immediately after the collision is $\frac{1}{5}u(1 + 6e)$.

(6)

After the collision with ball A, ball B hits a smooth fixed vertical wall which is perpendicular to the direction of motion of B.

The coefficient of restitution between B and the wall is $\frac{5}{7}$

Ball B rebounds from the wall and there is a second direct collision between A and B.

(b) Find the range of possible values of e.

(4)

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Question 4 continued

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Question 4 continued

Leave blank

Question 4 continued

Q4

(Total 10 marks)

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5.

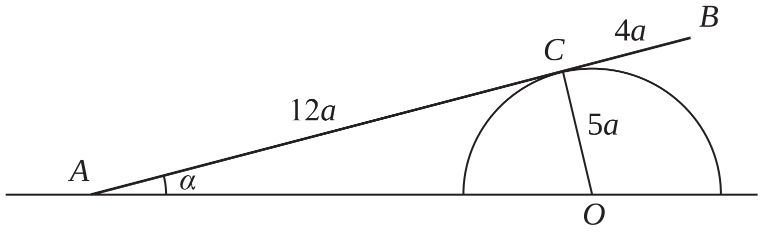

Figure 1

A smooth solid hemisphere is fixed with its flat surface in contact with rough horizontal ground. The hemisphere has centre O and radius $5a$.
A uniform rod AB, of length $16a$ and weight W, rests in equilibrium on the hemisphere with end A on the ground. The rod rests on the hemisphere at the point C, where $AC = 12a$ and angle $CAO = \alpha$, as shown in Figure 1.

Points A, C, B and O all lie in the same vertical plane.

(a) Explain why $AO = 13a$

(1)

The normal reaction on the rod at C has magnitude kW

(b) Show that $k = \frac{8}{13}$

(3)

The resultant force acting on the rod at A has magnitude R and acts upwards at $\theta°$ to the horizontal.

(c) Find

(i) an expression for R in terms of W

(ii) the value of θ

(8)

Leave blank

Question 5 continued

Leave blank

Question 5 continued

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Question 5 continued

Q5

(Total 12 marks)

Leave blank

6. [*The centre of mass of a semicircular arc of radius r is* $\frac{2r}{\pi}$ *from the centre.*]

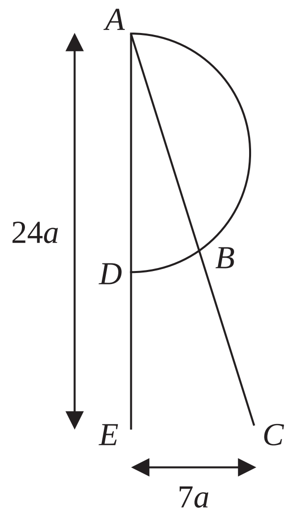

Figure 2

Uniform wire is used to form the framework shown in Figure 2.

In the framework,

- ABC is straight and has length $25a$
- ADE is straight and has length $24a$
- ABD is a semicircular arc of radius $7a$
- $EC = 7a$
- angle $AEC = 90°$
- the points A, B, C, D and E all lie in the same plane

The distance of the centre of mass of the framework from AE is d.

(a) Show that $d = \dfrac{53}{2(7+\pi)}a$

(4)

The framework is freely suspended from A and hangs in equilibrium with AC at angle $\alpha°$ to the downward vertical.

(b) Find the value of α.

(7)

Leave blank

Question 6 continued

Leave blank

Question 6 continued

Leave blank

Question 6 continued

Q6

(Total 11 marks)

Leave blank

7. A particle P is projected from a fixed point O on horizontal ground. The particle is projected with speed u at an angle α above the horizontal. At the instant when the horizontal distance of P from O is x, the vertical distance of P above the ground is y.
The motion of P is modelled as that of a particle moving freely under gravity.

(a) Show that $y = x\tan\alpha - \dfrac{gx^2}{2u^2}\left(1 + \tan^2\alpha\right)$

(6)

A small ball is projected from the fixed point O on horizontal ground. The ball is projected with speed $20\,\text{m s}^{-1}$ at angle $\theta°$ above the horizontal. A vertical pole AB, of height $2\,\text{m}$, stands on the ground with $OA = 10\,\text{m}$, as shown in Figure 3.

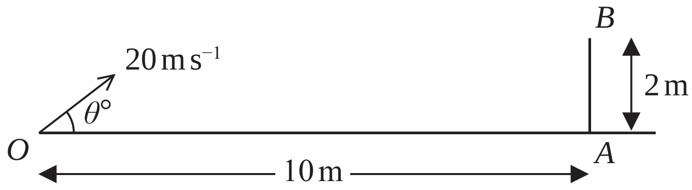

Figure 3

The ball is modelled as a particle moving freely under gravity and the pole is modelled as a rod.
The path of the ball lies in the vertical plane containing O, A and B.

Using the model,

(b) find the range of values of θ for which the ball will pass over the pole.

(3)

Given that $\theta = 40$ and that the ball first hits the ground at the point C

(c) find the speed of the ball at the instant it passes over the pole,

(5)

(d) find the distance OC.

(2)

Leave blank

Question 7 continued

Leave blank

Question 7 continued

Leave blank

Question 7 continued

Leave blank

Question 7 continued

Q7

(Total 16 marks)

TOTAL FOR PAPER IS 75 MARKS

END

Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

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.
- 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 8 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 ▶

Leave blank

1. At time t seconds, $t \geqslant 0$, a particle P has position vector $\mathbf{r}$ metres with respect to a fixed origin O, where

$$\mathbf{r} = (t^3 - 8t)\mathbf{i} + \left(\frac{1}{3}t^3 - t^2 + 2t\right)\mathbf{j}$$

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

(5)

At time T seconds, $T \geqslant 0$, P is moving in the direction of $(2\mathbf{i} + \mathbf{j})$

(b) Find the value of T

(3)

Leave blank

Question 1 continued

Q1

(Total 8 marks)

Leave blank

2.

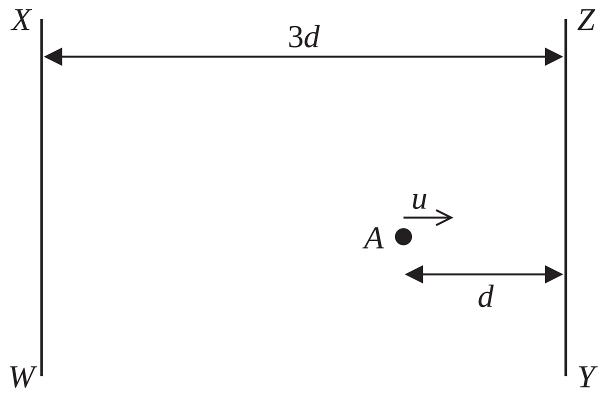

Figure 1

The point A lies on a smooth horizontal floor between two fixed smooth parallel vertical walls WX and YZ, as shown in the plan view in Figure 1.
The distance between WX and YZ is $3d$.
The distance of A from YZ is d.
A particle is projected from A along the floor with speed u towards YZ in a direction perpendicular to YZ.

The coefficient of restitution between the particle and each wall is $\frac{2}{3}$

The time taken for the particle to move from A, bounce off each wall once and return to A for the **first** time is T_1

(a) Find T_1 in terms of d and u.

(5)

The ball returns to A for the first time after bouncing off each wall once.
The further time taken for the particle to move from A, bounce off each wall once and return to A for the **second** time is T_2

(b) Find T_2 in terms of d and u.

(1)

Leave blank

Question 2 continued

Q2

(Total 6 marks)

Leave blank

3. A particle P of mass 0.5 kg is moving with velocity $\lambda(\mathbf{i} + \mathbf{j})\,\mathrm{m\,s^{-1}}$ when P receives an impulse of magnitude $\sqrt{\frac{5}{2}}$ N s

Immediately after P receives the impulse, the velocity of P is $4\mathbf{i}\,\mathrm{m\,s^{-1}}$
Given that λ is a constant, find the two possible values of λ

(6)

Leave blank

Question 3 continued

Q3

(Total 6 marks)

Leave blank

4. A truck of mass 900 kg is moving along a straight horizontal road with the engine of the truck working at a constant rate of P watts. The resistance to the motion of the truck is modelled as a constant force of magnitude R newtons.
At the instant when the speed of the truck is $15\,\text{m}\,\text{s}^{-1}$, the deceleration of the truck is $0.2\,\text{m}\,\text{s}^{-2}$

Later the same truck is moving down a straight road inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{30}$. The resistance to the motion of the truck is again modelled as a constant force of magnitude R newtons. The engine of the truck is again working at a constant rate of P watts.
At the instant when the speed of the truck is $12\,\text{m}\,\text{s}^{-1}$, the acceleration of the truck is $0.4\,\text{m}\,\text{s}^{-2}$

Find the value of R.

(8)

Leave blank

Question 4 continued

Leave blank

Question 4 continued

Leave blank

Question 4 continued

Q4

(Total 8 marks)

Leave blank

5.

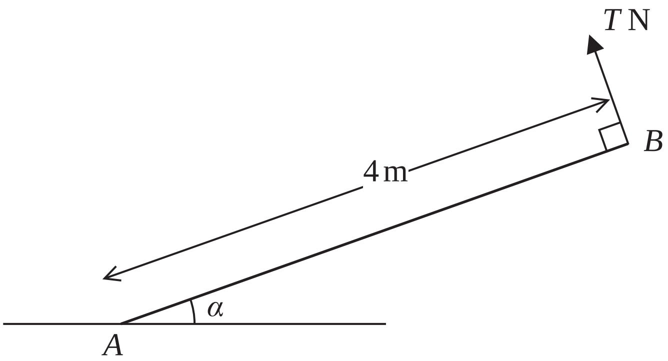

Figure 2

A uniform rod AB has length 4 m and weight 50 N.
The rod has its end A on rough horizontal ground. The rod is held in equilibrium at an angle α to the ground by a light inextensible cable attached to the rod at B, as shown in Figure 2. The cable and the rod lie in the same vertical plane and the cable is perpendicular to the rod. The tension in the cable is T newtons.

Given that $\sin\alpha = \frac{3}{5}$

(a) show that $T = 20$

(3)

Given also that the rod is in limiting equilibrium,

(b) find the value of the coefficient of friction between the rod and the ground.

(6)

Leave blank

Question 5 continued

Leave blank

Question 5 continued

Leave blank

Question 5 continued

Q5

(Total 9 marks)

Leave blank

6. Two particles, P and Q, are moving in opposite directions along the same straight line on a smooth horizontal surface so that the particles collide directly.
The mass of P is km and the mass of Q is m.
Immediately before the collision, the speed of P is x and the speed of Q is y.
Immediately after the collision, P and Q are moving in the same direction, the speed of P is v and the speed of Q is $2v$.

The coefficient of restitution between P and Q is $\frac{1}{5}$

The magnitude of the impulse received by Q in the collision is $5mv$

(a) Find (i) y in terms of v

(ii) x in terms of v

(iii) the value of k

(9)

(b) Find, in terms of m and v, the total kinetic energy lost in the collision between P and Q.

(3)

Leave blank

Question 6 continued

Leave blank

Question 6 continued

Leave blank

Question 6 continued

Q6

(Total 12 marks)

Leave blank

7.

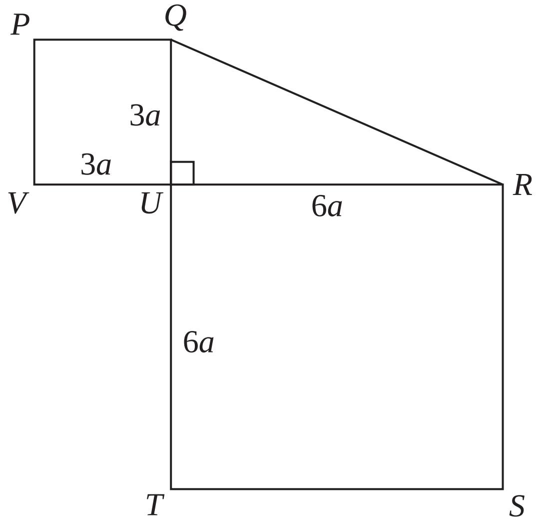

Figure 3

The template shown in Figure 3 is formed by joining together three separate laminas. All three laminas lie in the same plane.

- *PQUV* is a uniform square lamina with sides of length $3a$
- *URST* is a uniform square lamina with sides of length $6a$
- *QRU* is a uniform triangular lamina with $UQ = 3a$, $UR = 6a$ and angle $QUR = 90°$

The mass per unit area of *PQUV* is k, where k is a constant.
The mass per unit area of *URST* is k.
The mass per unit area of *QRU* is $2k$.

The distance of the centre of mass of the template from *QT* is d.

(a) Show that $d = \dfrac{29}{14}a$

(5)

The template is freely suspended from the point Q and hangs in equilibrium with QR at $\theta°$ to the downward vertical.

(b) Find the value of θ

(7)

Leave blank

Question 7 continued

Leave blank

Question 7 continued

Leave blank

Question 7 continued

Q7

(Total 12 marks)

Leave blank

8.

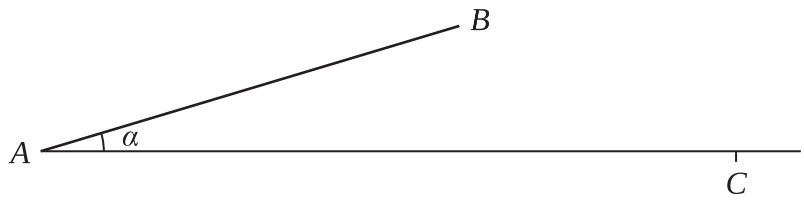

Figure 4

Figure 4 shows a rough ramp fixed to horizontal ground.

The ramp is inclined at angle α to the ground, where $\tan\alpha = \frac{1}{6}$

The point A is on the ground at the bottom of the ramp.
The point B is at the top of the ramp.
The line AB is a line of greatest slope of the ramp and $AB = 4\,\text{m}$.

A particle P of mass 3 kg is projected with speed $U\,\text{m}\,\text{s}^{-1}$ from A directly towards B.

The coefficient of friction between the particle and the ramp is $\frac{3}{4}$

(a) Find the work done against friction as P moves from A to B.

(4)

Given that at the instant P reaches the point B, the speed of P is $5\,\text{m}\,\text{s}^{-1}$

(b) use the work-energy principle to find the value of U.

(4)

The particle leaves the ramp at B, and moves freely under gravity until it hits the ground at the point C.

(c) Find the horizontal distance from B to C.

(6)

Leave blank

Question 8 continued

Leave blank

Question 8 continued

Leave blank

Question 8 continued

Leave blank

Question 8 continued

Q8

(Total 14 marks)

TOTAL FOR PAPER IS 75 MARKS

END

Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

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

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- 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 $g = 9.8\,\text{m s}^{-2}$, 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 8 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. A truck of mass 1500 kg is moving on a straight horizontal road.
The engine of the truck is working at a constant rate of 30 kW.
The resistance to the motion of the truck is modelled as a constant force of magnitude R newtons.
At the instant when the truck is moving at a speed of $20\,\mathrm{m\,s^{-1}}$, the acceleration of the truck is $0.6\,\mathrm{m\,s^{-2}}$

(a) Find the value of R.

(4)

Later on, the truck is moving up a straight road that is inclined at an angle α to the horizontal, where $\sin\alpha = \frac{1}{8}$

The resistance to the motion of the truck from non-gravitational forces is modelled as a constant force of magnitude 500 N.
The engine of the truck is again working at a constant rate of 30 kW.
At the instant when the speed of the truck is $V\,\mathrm{m\,s^{-1}}$, the deceleration of the truck is $0.2\,\mathrm{m\,s^{-2}}$

(b) Find the value of V

(4)

Question 1 continued

(Total for Question 1 is 8 marks)

2. A particle P of mass 0.5 kg is moving with velocity $(5\mathbf{i} + 3\mathbf{j})\,\text{m s}^{-1}$

The particle receives an impulse $(-2\mathbf{i} + \lambda\mathbf{j})\,\text{N s}$, where λ is a constant.

Immediately after receiving the impulse, the velocity of P is $(x\mathbf{i} + y\mathbf{j})\,\text{m s}^{-1}$

The kinetic energy gained by P as a result of receiving the impulse is 22 J.

Find the possible values of λ.

(7)

Question 2 continued

(Total for Question 2 is 7 marks)

3.

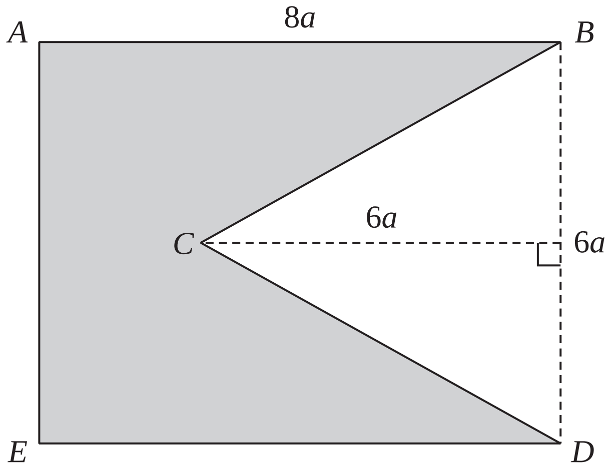

Figure 1

The uniform lamina *ABDE* is in the shape of a rectangle with $AB = 8a$ and $BD = 6a$.
The triangle *BCD* is isosceles and has base $6a$ and perpendicular height $6a$.
The template *ABCDE*, shown shaded in Figure 1, is formed by removing the triangular lamina *BCD* from the lamina *ABDE*.

(a) Show that the centre of mass of the template is $\frac{14}{5}a$ from *AE*.

(5)

The template is freely suspended from *A* and hangs in equilibrium with *AB* at an angle of $\theta°$ to the downward vertical.

(b) Find the value of θ, giving your answer to the nearest whole number.

(3)

Question 3 continued

Question 3 continued

Question 3 continued

(Total for Question 3 is 8 marks)

4. [*In this question, the perpendicular unit vectors* **i** *and* **j** *are in a horizontal plane*.]

A particle Q of mass 1.5 kg is moving on a smooth horizontal plane under the action of a single force **F** newtons. At time t seconds $(t \geqslant 0)$, the position vector of Q, relative to a fixed point O, is **r** metres and the velocity of Q is **v** m s^{-1}
It is given that

$$\mathbf{v} = (3t^2 + 2t)\mathbf{i} + (t^3 + kt)\mathbf{j}$$

where k is a constant.

Given that when $t = 2$ particle Q is moving in the direction of the vector $\mathbf{i} + \mathbf{j}$

(a) show that $k = 4$

(2)

(b) find the magnitude of **F** when $t = 2$

(4)

Given that $\mathbf{r} = 3\mathbf{i} + 4\mathbf{j}$ when $t = 0$

(c) find **r** when $t = 2$

(4)

Question 4 continued

(Total for Question 4 is 10 marks)

5.

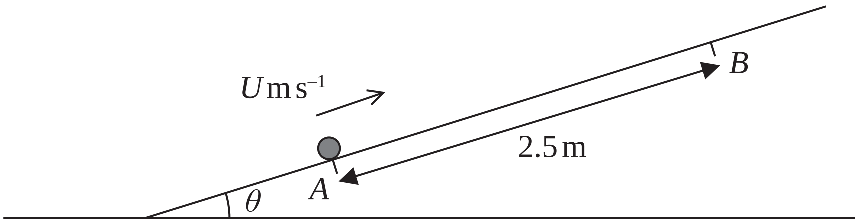

Figure 2

A rough straight ramp is fixed to horizontal ground. The ramp is inclined at an angle θ to the horizontal, where $\tan\theta = \frac{5}{12}$

The points A and B are on a line of greatest slope of the ramp, with $AB = 2.5\,\text{m}$ and B above A, as shown in Figure 2.

A package of mass 1.5 kg is projected up the ramp from A with speed $U\,\text{m s}^{-1}$ and first comes to instantaneous rest at B.

The coefficient of friction between the package and the ramp is $\frac{2}{7}$

The package is modelled as a particle.

(a) Find the work done against friction as the package moves from A to B.

(3)

(b) Use the work–energy principle to find the value of U.

(4)

After coming to instantaneous rest at B, the package slides back down the slope.

(c) Use the work–energy principle to find the speed of the package at the instant it returns to A.

(3)

Question 5 continued

Question 5 continued

Question 5 continued

(Total for Question 5 is 10 marks)

6.

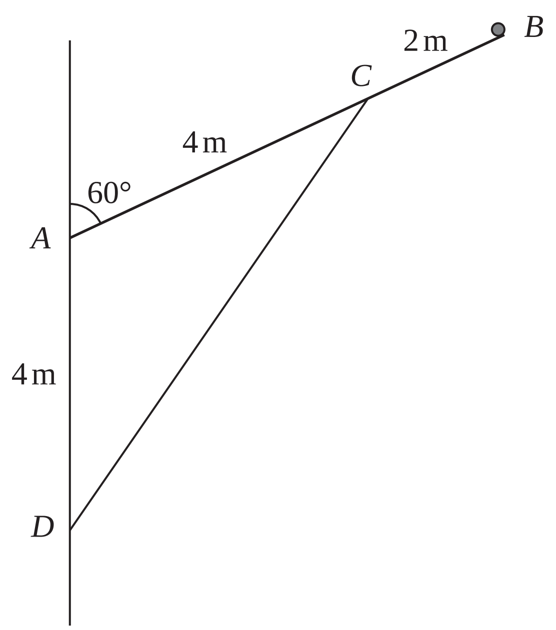

Figure 3

A uniform pole AB, of weight 50 N and length 6 m, has a particle of weight W newtons attached at its end B. The pole has its end A freely hinged to a vertical wall.
A light rod holds the particle and pole in equilibrium with the pole at 60° to the wall.
One end of the light rod is attached to the pole at C, where $AC = 4$ m.
The other end of the light rod is attached to the wall at the point D.
The point D is vertically below A with $AD = 4$ m, as shown in Figure 3.

The pole and the light rod lie in a vertical plane which is perpendicular to the wall.

The pole is modelled as a rod.

Given that the thrust in the light rod is $60\sqrt{3}$ N,

(a) show that $W = 15$

(4)

(b) find the magnitude of the resultant force acting on the pole at A.

(6)

Question 6 continued

Question 6 continued

Question 6 continued

(Total for Question 6 is 10 marks)

7. Particle P has mass $3m$ and particle Q has mass km. The particles are moving towards each other on the same straight line on a smooth horizontal surface.
The particles collide directly.
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 u and the speed of Q is v.

The direction of motion of P is unchanged by the collision.

(a) Show that $v = \frac{(3 - 3k)}{k} u$

(3)

(b) Find, in terms of m and u, the magnitude of the impulse received by Q in the collision.

(2)

The coefficient of restitution between P and Q is e.

Given that $v \neq u$

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

(5)

Question 7 continued

Question 7 continued

Question 7 continued

(Total for Question 7 is 10 marks)

8. A particle P is projected from a fixed point O. The particle is projected with speed $u\,\text{m}\,\text{s}^{-1}$ at angle α above the horizontal. The particle moves freely under gravity. At the instant when the horizontal distance of P from O is x metres, P is y metres vertically above the level of O.

(a) Show that $y = x\tan\alpha - \dfrac{gx^2}{2u^2}\left(1 + \tan^2\alpha\right)$

(6)

A small ball is projected from a fixed point A with speed $U\,\text{m}\,\text{s}^{-1}$ at $\theta°$ above the horizontal.
The point B is on horizontal ground and is vertically below the point A, with $AB = 20\,\text{m}$.
The ball hits the ground at the point C, where $BC = 30\,\text{m}$, as shown in Figure 4.

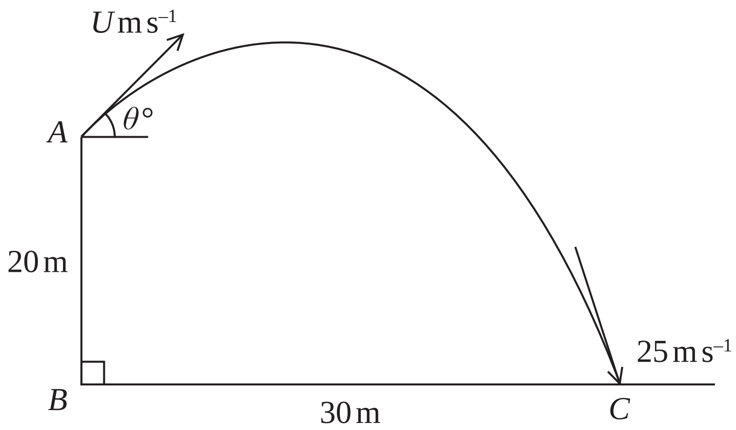

Figure 4

The speed of the ball immediately before it hits the ground is $25\,\text{m}\,\text{s}^{-1}$
The motion of the ball is modelled as that of a particle moving freely under gravity.

(b) Use the principle of conservation of mechanical energy to find the value of U.

(3)

(c) Find the value of θ

(3)

Question 8 continued

Question 8 continued

Question 8 continued

Question 8 continued

(Total for Question 8 is 12 marks)

TOTAL FOR PAPER IS 75 MARKS

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 25 May 2023

Morning (Time: 1 hour 30 minutes)

Paper reference **WME02/01**

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.
- 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 $g = 9.8 \text{ m s}^{-2}$, 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. A particle P of mass 0.3 kg is moving with velocity $5\mathbf{i}\ \mathrm{m\,s^{-1}}$

The particle receives an impulse $\mathbf{I}$ N s.

Immediately after receiving the impulse, the velocity of P is $(7\mathbf{i} + 7\mathbf{j})\ \mathrm{m\,s^{-1}}$

(a) Find the magnitude of $\mathbf{I}$

(4)

(b) Find the angle between the direction of $\mathbf{I}$ and the direction of motion of P immediately before receiving the impulse.

(3)

Question 1 continued

(Total for Question 1 = 7 marks)

2. [*In this question, the perpendicular unit vectors* **i** *and* **j** *are in a horizontal plane.*]

In this question you must show all stages of your working.
Solutions relying on calculator technology are not acceptable.

A particle P is moving on a smooth horizontal plane.

At time t seconds $(t \geqslant 0)$, the position vector of P, relative to a fixed point O, is $\mathbf{r}$ metres and the velocity of P is $\mathbf{v}\ \mathrm{m\,s^{-1}}$ where

$$\mathbf{v} = (4t^2 - 5t)\mathbf{i} + (-10t - 12)\mathbf{j}$$

When $t = 0$, $\mathbf{r} = 2\mathbf{i} + 6\mathbf{j}$

(a) Find $\mathbf{r}$ when $t = 2$

(4)

When $t = T$ particle P is moving in the direction of the vector $\mathbf{i} - 2\mathbf{j}$

(b) Find the value of T

(3)

(c) Find the exact magnitude of the acceleration of P when $t = 2.5$

(3)

Question 2 continued

Question 2 continued

Question 2 continued

(Total for Question 2 = 10 marks)

3.

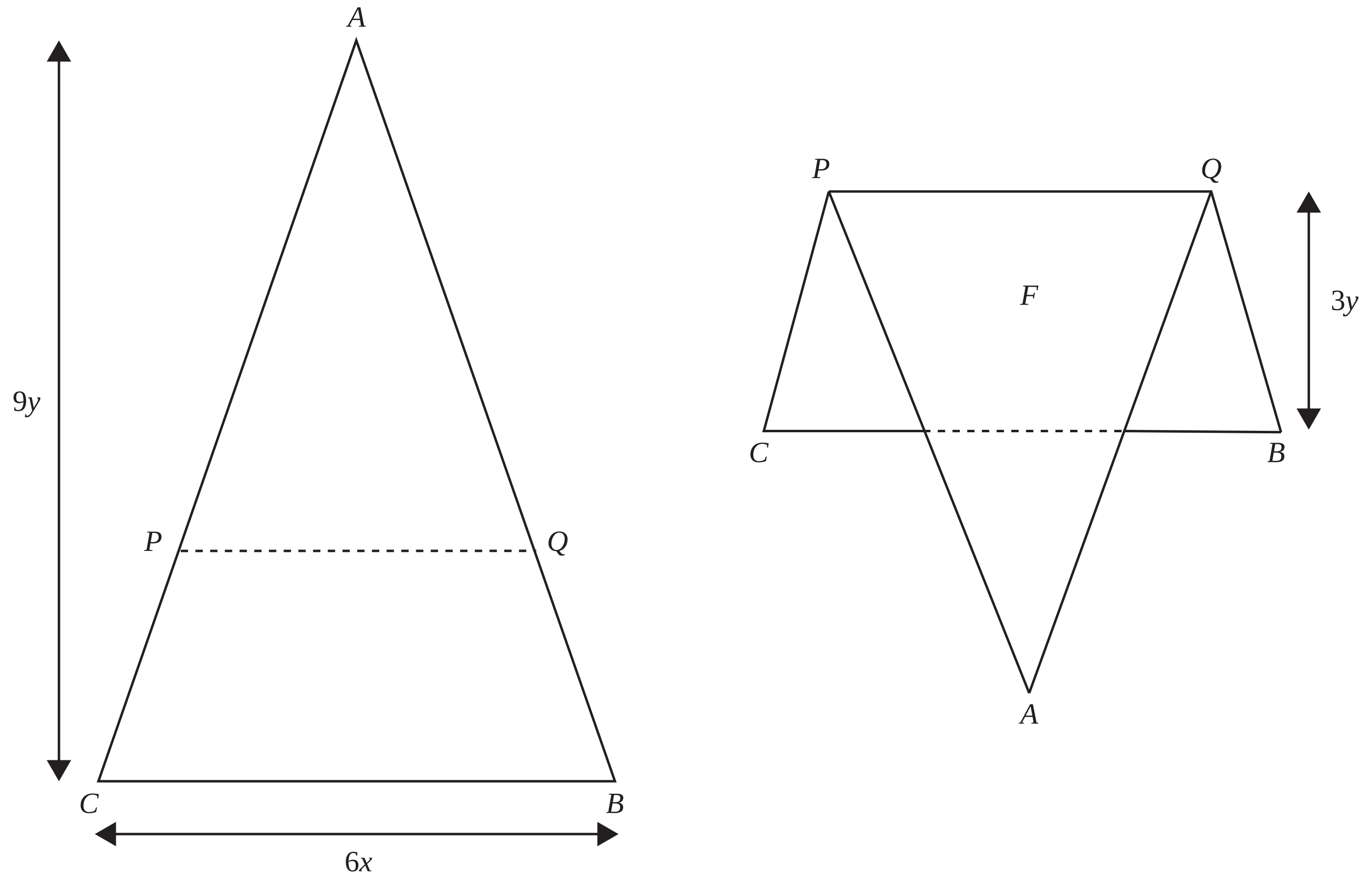

Figure 1

The uniform triangular lamina ABC, shown in Figure 1, has height $9y$, base $BC = 6x$, and $AB = AC$

The points P and Q are such that $AP : PC = AQ : QB = 2 : 1$

The lamina is folded along PQ to form the folded lamina F

The distance of the centre of mass of F from PQ is d

(a) Show that $d = \frac{16}{9}y$

(5)

The folded lamina is suspended from P and hangs freely in equilibrium with PQ at an angle α to the downward vertical.

Given that $\tan\alpha = \frac{64}{81}$

(b) find x in terms of y

(3)

Question 3 continued

Question 3 continued

Question 3 continued

(Total for Question 3 = 8 marks)

4. A particle P of mass $3m$ and a particle Q of mass $5m$ are moving towards each other along the same straight line on a smooth horizontal surface. The particles collide directly.

Immediately **before** the collision, the speed of P is u and the speed of Q is ku.

Immediately **after** the collision, the speed of P is $2v$ and the speed of Q is v.

The direction of motion of each particle is reversed by the collision.

In the collision, P receives an impulse of magnitude $15mv$.

(a) Show that $u = 3v$.

(3)

(b) Find the value of k.

(3)

The coefficient of restitution between P and Q is e.

(c) Find the value of e.

(3)

The total kinetic energy lost in the collision is λmv^2

(d) Find the value of λ.

(3)

Question 4 continued

Question 4 continued

Question 4 continued

(Total for Question 4 = 12 marks)

5.

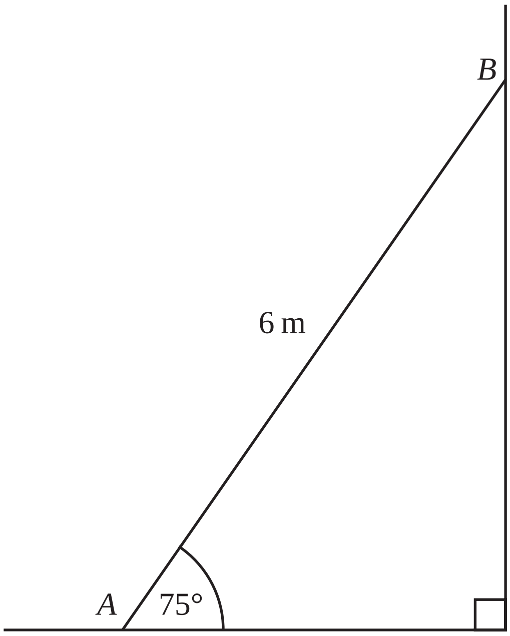

Figure 2

A uniform beam *AB*, of mass 15 kg and length 6 m, rests with end *A* on rough horizontal ground. The end *B* of the beam rests against a rough vertical wall.

The beam is inclined at 75° to the ground, as shown in Figure 2.

The coefficient of friction between the beam and the wall is 0.2

The coefficient of friction between the beam and the ground is μ

The beam is modelled as a uniform rod which lies in a vertical plane perpendicular to the wall.

The beam rests in limiting equilibrium.

(a) Find the magnitude of the normal reaction between the beam and the wall at *B*.

(5)

(b) Find the value of μ

(6)

Question 5 continued

Question 5 continued

Question 5 continued

(Total for Question 5 = 11 marks)

6. A van of mass 900 kg is moving along a straight horizontal road.

The resistance to the motion of the van is modelled as a constant force of magnitude 600 N.

The engine of the van is working at a constant rate of 24 kW.

At the instant when the speed of the van is $V\ \mathrm{m\,s^{-1}}$, the acceleration of the van is $2\ \mathrm{m\,s^{-2}}$

(a) Find the value of V

(4)

Later on, the van is towing a trailer of mass 700 kg up a straight road inclined at an angle θ to the horizontal, where $\sin\theta = \dfrac{1}{14}$

The trailer is attached to the van by a towbar, as shown in Figure 3.

The towbar is parallel to the direction of motion of the van and the trailer.

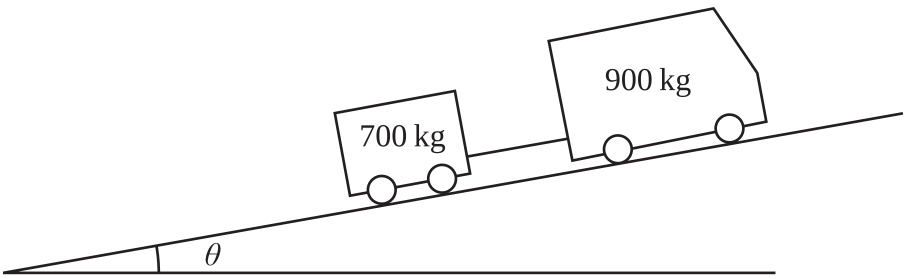

Figure 3

The resistance to the motion of the van from non-gravitational forces is modelled as a constant force of magnitude 600 N.

The resistance to the motion of the trailer from non-gravitational forces is modelled as a constant force of magnitude 550 N.

The towbar is modelled as a light rod.

The engine of the van is working at a constant rate of 24 kW.

(b) Find the acceleration of the van at the instant when the van and the trailer are moving with speed $8\ \mathrm{m\,s^{-1}}$

(4)

At the instant when the van and the trailer are moving up the road at $9\ \mathrm{m\,s^{-1}}$, the towbar breaks. The trailer continues to move in a straight line up the road until it comes to instantaneous rest.

The distance moved by the trailer as it slows from a speed of $9\ \mathrm{m\,s^{-1}}$ to instantaneous rest is d metres.

(c) Use the work-energy principle to find the value of d.

(4)

Question 6 continued

Question 6 continued

Question 6 continued

(Total for Question 6 = 12 marks)

7. [*In this question, the perpendicular unit vectors* **i** *and* **j** *are in a vertical plane with* **i** *being horizontal and* **j** *being vertically upwards.*]

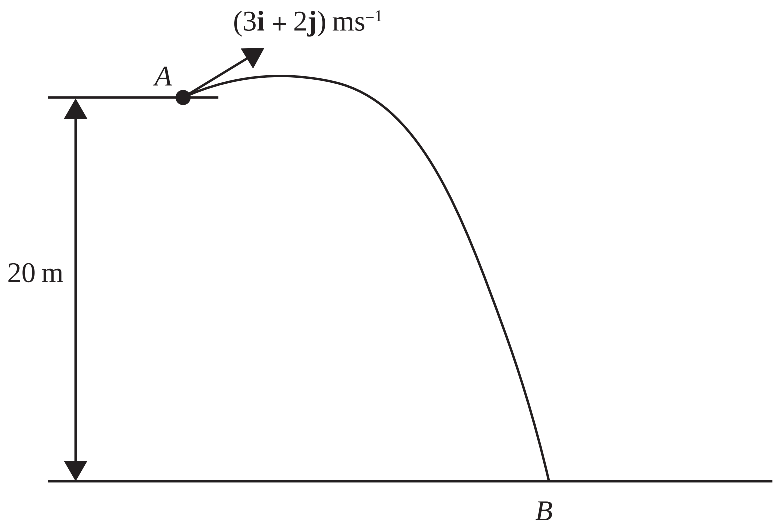

Figure 4

A small ball is projected with velocity $(3\mathbf{i} + 2\mathbf{j})\,\mathrm{m\,s^{-1}}$ from the fixed point A.

The point A is 20 m above horizontal ground.

The ball hits the ground at the point B, as shown in Figure 4.

The ball is modelled as a particle moving freely under gravity.

(a) By considering energy, find the speed of the ball at the instant immediately before it hits the ground.

(3)

(b) Find the direction of motion of the ball at the instant immediately before it hits the ground.

(3)

(c) Find the time taken for the ball to travel from A to B.

(3)

At the instant when the direction of motion of the ball is perpendicular to $(3\mathbf{i} + 2\mathbf{j})$ the ball is h metres above the ground.

(d) Find the value of h.

(6)

Question 7 continued

Question 7 continued

Question 7 continued

Question 7 continued

(Total for Question 7 = 15 marks)

TOTAL FOR PAPER IS 75 MARKS

END

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)

Question 1 continued

(Total for Question 1 is 7 marks)

2.

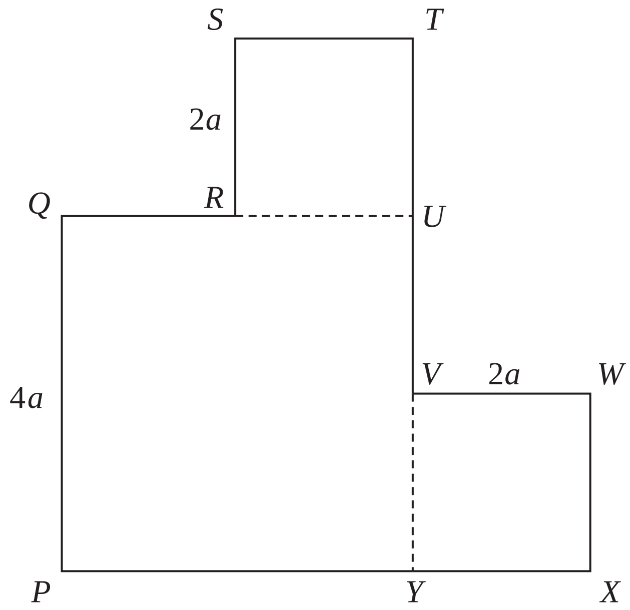

Figure 1

Figure 1 shows a template where

- *PQUY* is a uniform square lamina with sides of length 4*a*
- *RSTU* is a uniform square lamina with sides of length 2*a*
- *VWXY* is a uniform square lamina with sides of length 2*a*
- 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

Question 2 continued

(Total for Question 2 is 14 marks)

3.

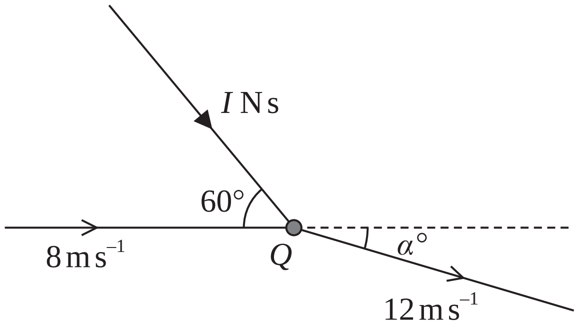

Figure 2

A particle Q of mass 0.25 kg is moving in a straight line on a smooth horizontal surface with speed $8\,\text{m}\,\text{s}^{-1}$ 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 $12\,\text{m}\,\text{s}^{-1}$

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.*]

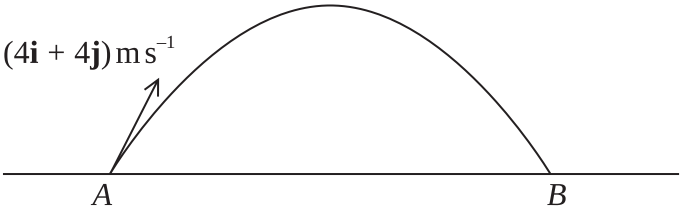

Figure 3

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 $6\,\text{m s}^{-1}$

(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 $8\,\text{m s}^{-1}$

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 $7\,\text{m s}^{-1}$

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)

Question 5 continued

Question 5 continued

Question 5 continued

(Total for Question 5 is 13 marks)

6.

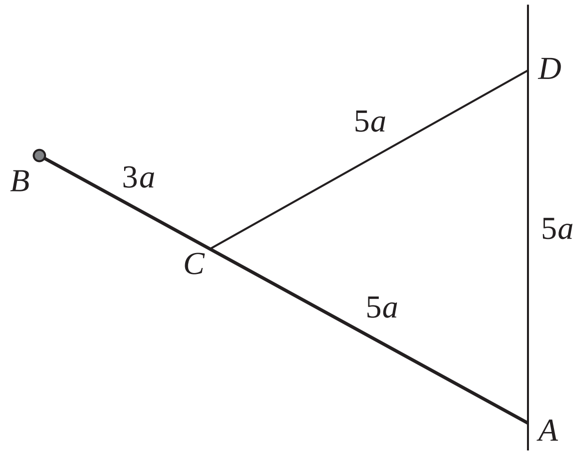

Figure 4

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

Question 7 continued

Question 7 continued

(Total for Question 7 is 14 marks)

TOTAL FOR PAPER IS 75 MARKS

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 11 January 2024

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

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- 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 $g = 9.8\,\text{m s}^{-2}$, 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 8 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. A particle P moves along a straight line. The fixed point O is on the line. At time t seconds, $t > 0$, the displacement of P from O is x metres, where

$$x = 2t^3 - 21t^2 + 60t$$

Find

(a) the values of t for which P is instantaneously at rest

(4)

(b) the distance travelled by P in the interval $1 \leqslant t \leqslant 3$

(2)

(c) the magnitude of the acceleration of P at the instant when $t = 3$

(2)

Question 1 continued

(Total for Question 1 is 8 marks)

2. [*In this question,* **i** *and* **j** *are horizontal perpendicular unit vectors.*]

A particle Q of mass 0.5 kg is moving on a smooth horizontal surface. Particle Q is moving with velocity $(3\mathbf{i} + \mathbf{j})\,\text{m s}^{-1}$ when it receives an impulse of $(2\mathbf{i} + 5\mathbf{j})\,\text{N s}$.

(a) Find the speed of Q immediately after receiving the impulse.

(4)

As a result of receiving the impulse, the direction of motion of Q is turned through an angle $\theta°$

(b) Find the value of θ

(2)

Question 2 continued

(Total for Question 2 is 6 marks)

3.

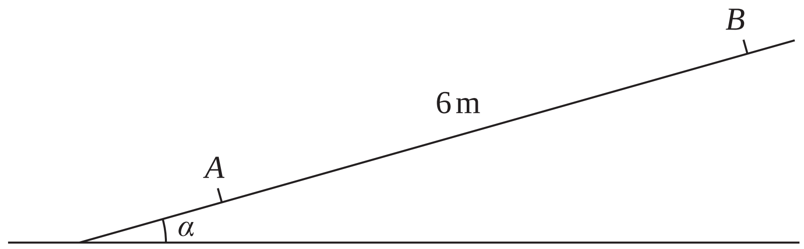

Figure 1

A rough ramp is fixed to horizontal ground.

The ramp is inclined to the horizontal at an angle α, where $\sin\alpha = \frac{3}{7}$

The line AB is a line of greatest slope of the ramp, with B above A and $AB = 6$ m, as shown in Figure 1.

A block P of mass 2 kg is pushed, with constant speed, in a straight line up the slope from A to B. The force pushing P acts parallel to AB.

The coefficient of friction between P and the ramp is $\frac{1}{3}$

The block is modelled as a particle and air resistance is negligible.

(a) Use the model to find the **total** work done in pushing the block from A to B.

(5)

The block is now held at B and released from rest.

(b) Use the model and the work-energy principle to find the speed of the block at the instant it reaches A.

(4)

Question 3 continued

Question 3 continued

Question 3 continued

(Total for Question 3 is 9 marks)

4.

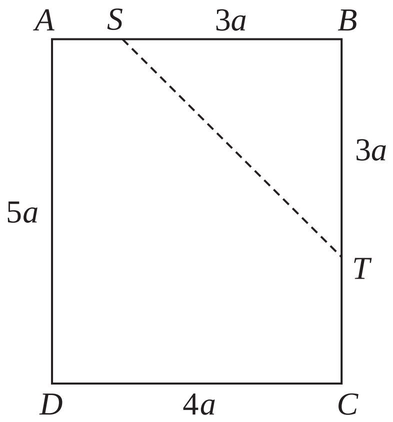

Figure 2

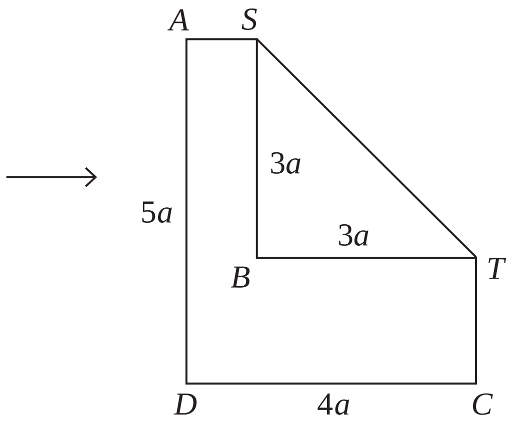

Figure 3

The uniform rectangular lamina $ABCD$, shown in Figure 2, has $DC = 4a$ and $AD = 5a$

The points S on AB and T on BC are such that $SB = BT = 3a$

The lamina is folded along ST to form the folded lamina L, shown in Figure 3.

The distance of the centre of mass of L from AD is d.

(a) Show that $d = \frac{71}{40}a$

(5)

The weight of L is $4W$. A particle of weight W is attached to L at C.

The folded lamina L is freely suspended from S.

A force of magnitude F, acting parallel to DC, is applied to L at D so that AD is vertical.

(b) Find F in terms of W

(4)

Question 4 continued

Question 4 continued

Question 4 continued

(Total for Question 4 is 9 marks)

5.

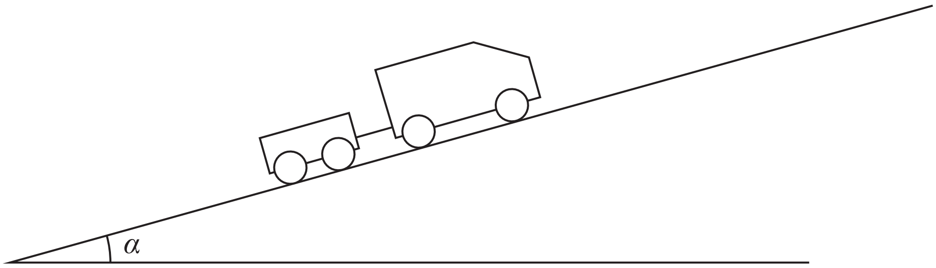

Figure 4

A van of mass 600 kg is moving up a straight road inclined at an angle α to the horizontal, where $\sin\alpha = \frac{1}{14}$. The van is towing a trailer of mass 200 kg. The trailer is attached to the van by a rigid towbar which is parallel to the direction of motion of the van and the trailer, as shown in Figure 4.

The resistance to the motion of the van from non-gravitational forces is modelled as a constant force of magnitude 250 N.

The resistance to the motion of the trailer from non-gravitational forces is modelled as a constant force of magnitude 150 N.

The towbar is modelled as a light rod.

At the instant when the speed of the van is $16\,\text{m}\,\text{s}^{-1}$, the engine of the van is working at a rate of 10 kW.

(a) Find the deceleration of the van at this instant.

(5)

(b) Find the tension in the towbar at this instant.

(4)

Question 5 continued

Question 5 continued

Question 5 continued

(Total for Question 5 is 9 marks)

6.

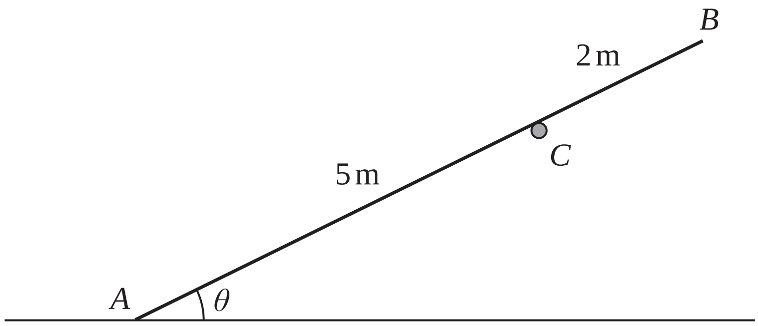

Figure 5

A uniform beam AB, of weight 40 N and length 7 m, rests with end A on rough horizontal ground.

The beam rests on a smooth horizontal peg at C, with $AC = 5$ m, as shown in Figure 5.

The beam is inclined at an angle θ to the ground, where $\sin\theta = \frac{3}{5}$

The beam is modelled as a rod that lies in a vertical plane perpendicular to the peg.

The normal reaction between the beam and the peg at C has magnitude P newtons.

Using the model,

(a) show that $P = 22.4$

(3)

(b) find the magnitude of the resultant force acting on the beam at A.

(6)

Question 6 continued

Question 6 continued

Question 6 continued

(Total for Question 6 is 9 marks)

7. Particle P has mass m and particle Q has mass $5m$.

The particles are moving in the same direction 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 $6u$ and the speed of Q is u.

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

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

The coefficient of restitution between P and Q is e.

(a) Find the complete range of possible values of e.

(7)

Given that $e = \frac{3}{5}$

(b) find the total kinetic energy lost in the collision between P and Q.

(4)

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 a second collision between P and Q,

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

(3)

Question 7 continued

Question 7 continued

Question 7 continued

(Total for Question 7 is 14 marks)

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

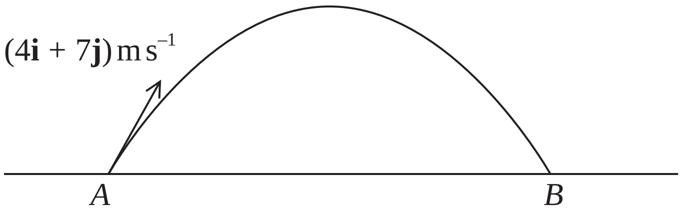

Figure 6

The fixed points A and B lie on horizontal ground.

At time $t = 0$, a particle P is projected from A with velocity $(4\mathbf{i} + 7\mathbf{j})\,\text{m s}^{-1}$

Particle P moves freely under gravity and hits the ground at B, as shown in Figure 6.

(a) Find the distance AB.

(4)

The speed of P is less than $5\,\text{m s}^{-1}$ for an interval of length T seconds.

(b) Find the value of T

(3)

At the instant when the direction of motion of P is perpendicular to the initial direction of motion of P, the particle is h metres above the ground.

(c) Find the value of h.

(4)

Question 8 continued

Question 8 continued

(Total for Question 8 is 11 marks)

TOTAL FOR PAPER IS 75 MARKS

Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Friday 31 May 2024

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

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- 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

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  – *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.

1. [*In this question,* **i** *and* **j** *are horizontal perpendicular unit vectors.*]

A particle A has mass 2 kg and a particle B has mass 3 kg. The particles are moving on a smooth horizontal plane when they collide.

Immediately before the collision, the velocity of A is $5\mathbf{j}\,\mathrm{m\,s^{-1}}$ and the velocity of B is $(3\mathbf{i} - \mathbf{j})\,\mathrm{m\,s^{-1}}$

Immediately after the collision, the velocity of A is $(3\mathbf{i} + 2\mathbf{j})\,\mathrm{m\,s^{-1}}$

(a) Find the total kinetic energy of the two particles before the collision.

(3)

(b) Find, in terms of **i** and **j**, the impulse received by A in the collision.

(2)

Given that, in the collision, the impulse of A on B is equal and opposite to the impulse of B on A,

(c) find the velocity of B immediately after the collision.

(3)

Question 1 continued

(Total for Question 1 is 8 marks)

2. **In this question you must show all stages of your working.**

Solutions relying on calculator technology are not acceptable.

A particle P is moving in a straight line.

At time t seconds, the speed, $v\,\text{m s}^{-1}$, of P is given by the continuous function

$$v = \begin{cases} \sqrt{2t+1} & 0 \leqslant t \leqslant k \\ \dfrac{3}{4}t & t > k \end{cases}$$

where k is a constant.

(a) Show that $k = 4$, explaining your method carefully.

(3)

(b) Find the acceleration of P when $t = 1.5$

(3)

At time $t = 0$, P passes through the point O

(c) Find the distance of P from O when $t = 8$

(7)

Question 2 continued

(Total for Question 2 is 13 marks)

3.

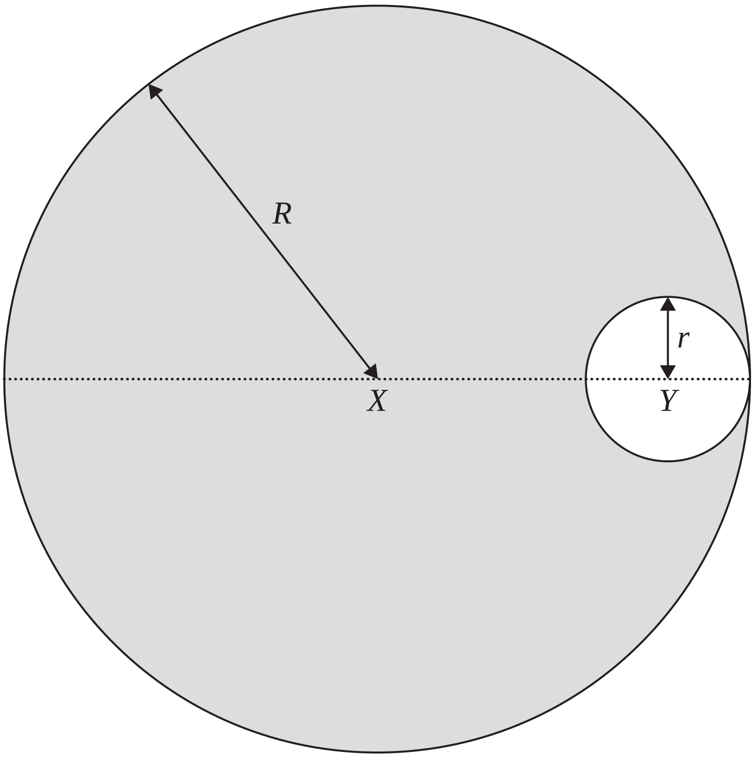

Figure 1

A uniform circular disc C has centre X and radius R.

A disc with centre Y and radius r, where $0 < r < R$ and $XY = R - r$, is removed from C to form the template shown shaded in Figure 1.

The centre of mass of the template is a distance kr from X.

(a) Show that $r = \dfrac{k}{1-k}R$

(4)

(b) Hence find the range of possible values of k.

(2)

The point P is on the outer edge of the template and PX is perpendicular to XY.

The template is freely suspended from P and hangs in equilibrium.

Given that $k = \dfrac{4}{9}$

(c) find the angle that XY makes with the vertical.

(3)

The mass of the template is M.

(d) Find, in terms of M, the mass of the lightest particle that could be attached to the template so that it would hang in equilibrium from P with XY horizontal.

(3)

Question 3 continued

Question 3 continued

Question 3 continued

(Total for Question 3 is 12 marks)

4. A rough plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{3}{4}$

A particle P of mass m is held at rest at a point A on the plane.

The particle is then projected with speed u up a line of greatest slope of the plane and comes to instantaneous rest at the point B.

The coefficient of friction between the particle and the plane is $\frac{1}{7}$

(a) Show that the magnitude of the frictional force acting on the particle, as it moves from A to B, is $\frac{4mg}{35}$

(2)

Given that $u = \sqrt{10ag}$, use the work–energy principle

(b) to find AB in terms of a,

(4)

(c) to find, in terms of a and g, the speed of P when it returns to A.

(4)

Question 4 continued

Question 4 continued

Question 4 continued

(Total for Question 4 is 10 marks)

5. A particle P of mass m and a particle Q of mass $2m$ are at rest on a smooth horizontal plane.

Particle P is projected with speed u along the plane towards Q and the particles collide. The coefficient of restitution between the particles is e.

As a result of the collision, the direction of motion of P is reversed.

(a) Find, in terms of u and e, the speed of P after the collision.

(6)

After the collision, Q goes on to hit a vertical wall which is fixed at right angles to the direction of motion of Q. The coefficient of restitution between Q and the wall is $\frac{1}{3}$

Given that there is a second collision between P and Q

(b) find the full range of possible values of e.

(5)

Question 5 continued

Question 5 continued

Question 5 continued

(Total for Question 5 is 11 marks)

6.

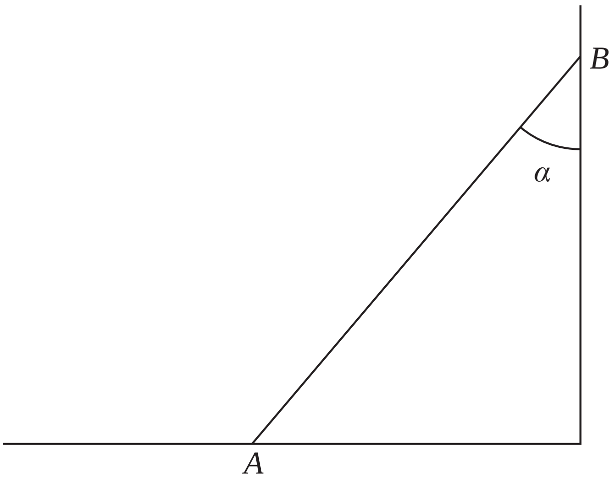

Figure 2

A uniform rod, *AB*, of mass *m* and length 2*a*, rests in limiting equilibrium with its end *A* on rough horizontal ground and its end *B* against a smooth vertical wall.
The vertical plane containing the rod is at right angles to the wall.
The rod is inclined to the wall at an angle α, as shown in Figure 2.

The coefficient of friction between the rod and the ground is $\frac{1}{3}$

(a) Show that $\tan\alpha = \frac{2}{3}$

(6)

With the rod in the same position, a horizontal force of magnitude *kmg* is applied to the rod at *A*, towards the wall. The line of action of this force is at right angles to the wall.

The rod remains in equilibrium.

(b) Find the largest possible value of *k*.

(4)

Question 6 continued

Question 6 continued

Question 6 continued

(Total for Question 6 is 10 marks)

7. [*In this question, the unit vectors* **i** *and* **j** *are in a vertical plane,* **i** *being horizontal and* **j** *being vertically upwards.*]

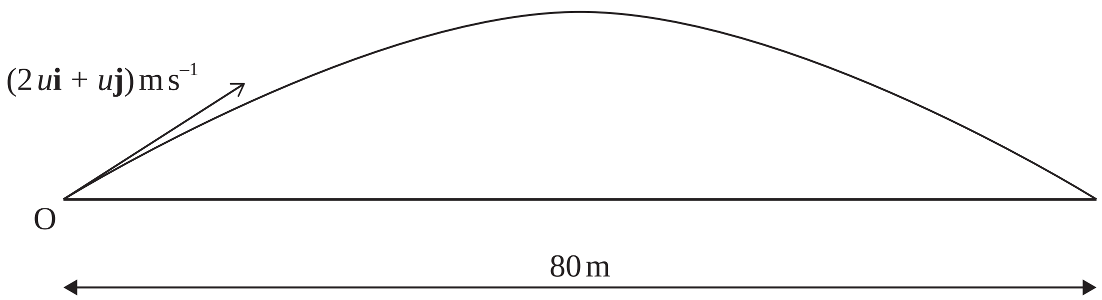

Figure 3

A golf ball is hit from a point O on horizontal ground and is modelled as a particle moving freely under gravity. The initial velocity of the ball is $(2u\mathbf{i} + u\mathbf{j})\,\mathrm{m\,s^{-1}}$
The ball first hits the horizontal ground at a point which is 80 m from O, as shown in Figure 3.

Use the model to

(a) show that $u = 14$

(6)

(b) find the total time, while the ball is in the air, for which the speed of the ball is greater than $7\sqrt{17}\ \mathrm{m\,s^{-1}}$

(5)

Question 7 continued

Question 7 continued

(Total for Question 7 is 11 marks)

TOTAL FOR PAPER IS 75 MARKS