Please check the examination details below before entering your candidate information

Candidate surname StemUp Model Solution | Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Monday 2 June 2025

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

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 ▶

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

Solutions relying entirely on calculator technology are not acceptable.

A particle P moves on the x-axis.
At time t seconds, $0 \leqslant t \leqslant 3$, the displacement of P relative to the origin is x metres where

$$x = 2t^4 - 14t^3 + \frac{45}{2}t^2 + 14t$$

(a) Verify that P is at instantaneous rest when $t = 2$

(3)

Given that this is the only value of t, in the interval $0 \leqslant t \leqslant 3$, for which P is at rest,

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

(2)

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

(3)

(a) $v = \frac{dx}{dt} = 8t^3 - 42t^2 + 45t + 14$

$t = 2$: $v = 8(8) - 42(4) + 45(2) + 14$

$= 64 - 168 + 90 + 14 = 0$

$v = 0$ when $t = 2$, so P is at instantaneous rest when $t = 2$

(b) $x = 2t^4 - 14t^3 + \frac{45}{2}t^2 + 14t$

$t = 0$: $x_0 = 0$

$t = 2$: $x_2 = 2(16) - 14(8) + \frac{45}{2}(4) + 14(2) = 32 - 112 + 90 + 28 = 38$

$t = 3$: $x_3 = 2(81) - 14(27) + \frac{45}{2}(9) + 14(3) = 162 - 378 + 202.5 + 42 = 28.5$

Total distance $= |x_2 - x_0| + |x_3 - x_2|$

$= |38 - 0| + |28.5 - 38| = 38 + 9.5$

Total distance $= \frac{95}{2}$ m (47.5 m)

(c) $a = \frac{dv}{dt} = 24t^2 - 84t + 45$

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Question 1 continued

$t = 1.5$: $a = 24(1.5)^2 - 84(1.5) + 45$

$= 54 - 126 + 45 = -27$

Magnitude of acceleration $= 27\ m\ s^{-2}$

(Total for Question 1 is 8 marks)

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2. [*In this question you may use, without proof, the formula for the centre of mass of a uniform sector of a circle.*]

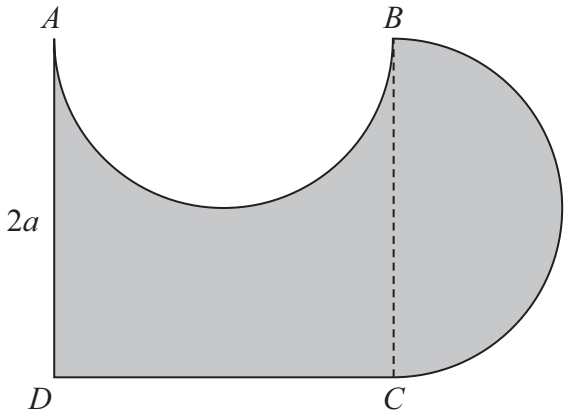


Figure 1

A uniform square lamina $ABCD$ has side $2a$.

A semicircular lamina, with diameter AB, is removed from the square lamina.

The semicircular lamina is then attached to BC to form the uniform lamina L shown shaded in Figure 1.

The centre of mass of L is a distance $\bar{x}$ from AD.

(a) Show that

$$\bar{x} = \frac{a}{24}(28 + 3\pi)$$

(5)

The lamina L has weight W.
A particle of weight kW is attached to L at D to form a loaded lamina.

The loaded lamina is now suspended by two light vertical strings with the first string attached at A and the second string attached at B.

The loaded lamina hangs freely in equilibrium with DC horizontal.

Given that the tension in the string attached at A is $4T$ and the tension in the string attached at B is T

(b) find the exact value of k.

(5)

(a) Take moments about AD (distances from AD):

Square: mass ratio $4a^2$, distance a

Semicircle removed: mass ratio $\frac{\pi a^2}{2}$, distance a

Semicircle attached: mass ratio $\frac{\pi a^2}{2}$, distance $2a + \frac{4a}{3\pi}$

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Question 2 continued

Lamina L: mass ratio $4a^2 - \frac{\pi a^2}{2} + \frac{\pi a^2}{2} = 4a^2$, distance $\bar{x}$

$$4a^2(a) - \frac{\pi a^2}{2}(a) + \frac{\pi a^2}{2}\left(2a + \frac{4a}{3\pi}\right) = 4a^2\bar{x}$$

$$4a^3 - \frac{\pi a^3}{2} + \pi a^3 + \frac{2a^3}{3} = 4a^2\bar{x}$$

$$\frac{14a^3}{3} + \frac{\pi a^3}{2} = 4a^2\bar{x}$$

$$\bar{x} = \frac{a}{4}\left(\frac{14}{3} + \frac{\pi}{2}\right) = \frac{a}{4} \times \frac{28 + 3\pi}{6}$$

$$\bar{x} = \frac{a}{24}(28 + 3\pi) \quad \text{as required}$$

(b) With DC horizontal, A is vertically above D, B above C.
Weight W acts at distance $\bar{x}$ from AD; kW acts at D (on line AD).

M(A): $T \times 2a = W \times \bar{x} + kW \times 0$

$$2aT = W \times \frac{a}{24}(28 + 3\pi)$$

$$T = \frac{W(28 + 3\pi)}{48}$$

R(↑): $4T + T = W + kW$

$$5T = W + kW$$

$$\frac{5W(28 + 3\pi)}{48} = W(1 + k)$$

$$k = \frac{140 + 15\pi}{48} - 1 = \frac{140 + 15\pi - 48}{48}$$

$$k = \frac{92 + 15\pi}{48}$$

Question 2 continued

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Question 2 continued

(Total for Question 2 is 10 marks)

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

The point A is on horizontal ground.

A ball is projected from A with velocity $(8\mathbf{i} + 14\mathbf{j})\,\text{m s}^{-1}$

The motion of the ball is modelled as that of a particle moving freely under gravity.

(a) Find the maximum possible height of the ball above the ground.

(2)

(b) Find the speed of the ball 2.4 s after leaving A.

(3)

The point B is also on the horizontal ground.

The point C is 3 m vertically above B.

After the ball reaches its maximum height, the ball passes through the point C.

(c) Find the distance AB.

(5)

(a) Vertically: $u = 14$, $v = 0$, $a = -9.8$ $(-g)$, $s = h$

$v^2 = u^2 + 2as$: $0 = 14^2 + 2(-9.8)h$

$h = \frac{196}{19.6} = 10$

Maximum height = 10 m

(b) Horizontal component of velocity = 8 (constant)

Vertical component: $v = u + at = 14 - 9.8(2.4) = 14 - 23.52 = -9.52$

Speed $= \sqrt{(8^2 + (-9.52)^2)} = \sqrt{(64 + 90.6304)} = \sqrt{154.6304}$

$= 12.4350...$

Speed = 12.4 m s^{-1}

(c) Vertically, from A to C: $s = 3$, $u = 14$, $a = -9.8$

$s = ut + \frac{1}{2}at^2$: $3 = 14t - \frac{1}{2}(9.8)t^2$

$4.9t^2 - 14t + 3 = 0$

$t = \frac{14 \pm \sqrt{(14^2 - 4(4.9)(3))}}{2(4.9)} = \frac{14 \pm \sqrt{137.2}}{9.8}$

$t = 0.23336...$ or $t = 2.6237...$

C is reached after the maximum height ($t = \frac{14}{9.8} = 1.43$ s), so $t = 2.6237...$

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Question 3 continued

Horizontally: $AB = 8t = 8 \times 2.6237... = 20.989...$

$AB = 21$ m (21.0 m)

Question 3 continued

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Question 3 continued

(Total for Question 3 is 10 marks)

4. The combined mass of a cyclist and her cycle is 70 kg.

The cyclist travels on a straight horizontal road with constant acceleration $0.4\,\text{m s}^{-2}$

The resistance to the motion is modelled as a constant force of magnitude 30 N.

(a) Using this model, find the rate at which the cyclist is working, at the instant when her speed is $5\,\text{m s}^{-1}$

(4)

The cyclist travels in a straight line **down** a hill from a point A to a point B, where $AB = 250\,\text{m}$

- at the instant she passes A, her speed is $5\,\text{m s}^{-1}$ and she **stops** pedalling
- at the instant she passes B, her speed is $8\,\text{m s}^{-1}$
- the resistance to the motion is modelled as a constant force of magnitude 30 N

(b) Use this model with the work-energy principle to find the change in vertical height from A to B.

(5)

The cyclist travels **up** a hill from a point C to a point D, where $CD = 200\,\text{m}$.

- she travels from C to D with constant speed, $8\,\text{m s}^{-1}$
- she travels in a straight line at 5° to the horizontal
- the resistance to the motion from non-gravitational forces is modelled as a constant force of magnitude 30 N

(c) Use this model to find the total work done by the cyclist as she moves from C to D.

(3)

(a) Let the driving force be D N.

N2L: $D - 30 = 70 \times 0.4$

$D = 30 + 28 = 58$ N

$P = Dv = 58 \times 5$

Rate of working = 290 W

(b) Let the vertical height lost from A to B be H m.

KE gained $= \frac{1}{2} \times 70 \times 8^2 - \frac{1}{2} \times 70 \times 5^2 = 2240 - 875 = 1365$ J

Work done against resistance $= 30 \times 250 = 7500$ J

Work-energy: loss in PE = gain in KE + work done against resistance

$70gH = \frac{1}{2} \times 70 \times 8^2 - \frac{1}{2} \times 70 \times 5^2 + 250 \times 30$

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Question 4 continued

$686H = 1365 + 7500 = 8865$

$H = \frac{8865}{686} = 12.922...$

Change in vertical height = 12.9 m (B is 12.9 m below A)

(c) Constant speed, so no change in KE.

Gain in PE = $70g \times 200 \sin 5° = 11957.8...$ J

Work done against resistance = $30 \times 200 = 6000$ J

Total work done by cyclist = $70g(200 \sin 5°) + (30 \times 200)$

$= 11957.8... + 6000 = 17957.8...$

Total work done = 18000 J (18 kJ)

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Question 4 continued

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Question 4 continued

(Total for Question 4 is 12 marks)

5. A particle P of mass 0.5 kg is moving with velocity $6\mathbf{i}\,\text{m s}^{-1}$ in the xy plane.

The particle receives an impulse $(a\mathbf{i} + b\mathbf{j})\,\text{N s}$, where a and b are constants.

As a result of the impulse, the direction of motion of P is deflected through 45°

The impulse has magnitude $\frac{3\sqrt{2}}{2}\,\text{N s}$.

Find the two possible impulses, giving your answers in terms of **i** and **j**.

(8)

Deflected through 45°, so the velocity after the impulse is

$v = \lambda i \pm \lambda j \quad (\lambda > 0)$

Impulse = change in momentum:

$ai + bj = 0.5v - 0.5(6i) = 0.5(\lambda i \pm \lambda j) - 3i$

$ai + bj = (0.5\lambda - 3)i \pm 0.5\lambda j$

Magnitude of impulse:

$\frac{3\sqrt{2}}{2} = \sqrt{((0.5\lambda - 3)^2 + (0.5\lambda)^2)}$

$\frac{9}{2} = 0.25\lambda^2 - 3\lambda + 9 + 0.25\lambda^2$

$0.5\lambda^2 - 3\lambda + 4.5 = 0$

$\lambda^2 - 6\lambda + 9 = 0$

$(\lambda - 3)^2 = 0 \quad \Rightarrow \quad \lambda = 3$

$a = 0.5(3) - 3 = -\frac{3}{2}, \quad b = \pm 0.5(3) = \pm\frac{3}{2}$

Impulses: $-\frac{3}{2}i + \frac{3}{2}j$ N s or $-\frac{3}{2}i - \frac{3}{2}j$ N s

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Question 5 continued

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Question 5 continued

(Total for Question 5 is 8 marks)

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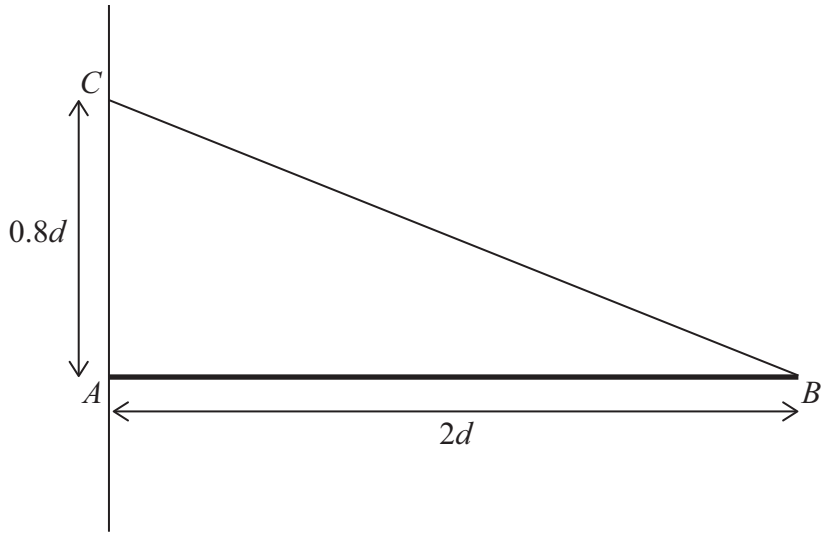


Figure 2

A uniform rod AB has mass m and length $2d$.

The rod is held in equilibrium in a horizontal position, with the end A against a rough vertical wall, by a light inextensible string.

One end of the string is attached to the rod at B.

The other end of the string is attached to the wall at the point C, where $AC = 0.8d$ and C is vertically above A, as shown in Figure 2.

A particle of mass km is attached at B and the rod AB remains in equilibrium in a horizontal position.

The particle, rod and string are in a vertical plane perpendicular to the wall.

(a) Show that the tension in the string is

$$\frac{mg\sqrt{29}}{4}(2k+1)$$

(4)

The resultant force acting on the rod at A makes an angle θ with the horizontal.

(b) Given that $\tan\theta = \frac{1}{8}$, find the exact value of k.

(6)

(a) Let α be the angle between the string and the wall (angle ACB).

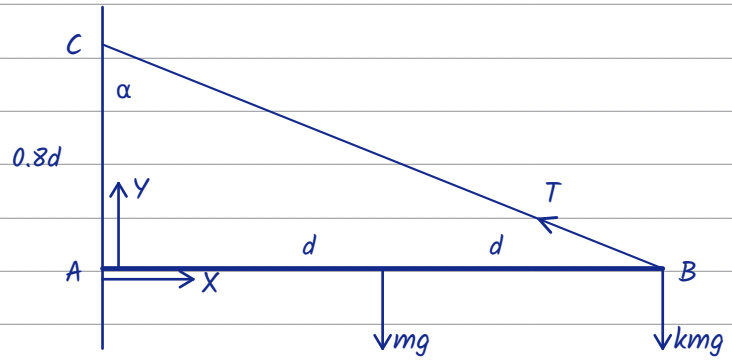
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Question 6 continued



$\tan\alpha = \frac{2d}{0.8d} = \frac{5}{2}$, $BC = \sqrt{((2d)^2 + (0.8d)^2)} = \frac{\sqrt{29}}{5}d$

$\cos\alpha = \frac{2}{\sqrt{29}}$, $\sin\alpha = \frac{5}{\sqrt{29}}$

M(A): $T\cos\alpha \times 2d = mg \times d + kmg \times 2d$

$T \times \frac{2}{\sqrt{29}} \times 2d = mgd(1 + 2k)$

$T = \frac{\sqrt{29}\, mg(1 + 2k)}{4}$

$T = \frac{mg\sqrt{29}}{4}(2k + 1)$ as required

(b) Let the force at A have components X (horizontal, away from the wall) and Y (vertically upwards).

R(→): $X = T\sin\alpha = \frac{mg\sqrt{29}}{4}(2k + 1) \times \frac{5}{\sqrt{29}} = \frac{5mg}{4}(2k + 1)$

R(↑): $Y + T\cos\alpha = mg + kmg$

$Y = mg(1 + k) - \frac{mg\sqrt{29}}{4}(2k + 1) \times \frac{2}{\sqrt{29}} = mg(1 + k) - \frac{mg}{2}(2k + 1)$

$Y = \frac{mg}{2}$

$\tan\theta = \frac{Y}{X} = \frac{1}{8}$: $\frac{mg}{2} \div \frac{5mg(2k + 1)}{4} = \frac{1}{8}$

Question 6 continued

$\frac{2}{5(2k+1)} = \frac{1}{8} \Rightarrow 5(2k+1) = 16$

$10k = 11$

$k = \frac{11}{10}$

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Question 6 continued

(Total for Question 6 is 10 marks)

7.



Figure 3

Three particles, P, Q and R, lie at rest on a smooth horizontal surface.

The particles are in a straight line with Q between P and R, as shown in Figure 3.

The mass of P is $2m$, the mass of Q is $3m$ and the mass of R is $5m$.

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

Particle P is projected with speed $2u$ towards Q and they collide.

(a) Show that the speed of Q immediately after the collision is

$$\frac{4u}{5}(e+1)$$

(5)

In the collision, the direction of motion of P is reversed.

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

(3)

In the collision, the magnitude of the impulse exerted on Q by P is $\frac{108}{25}mu$

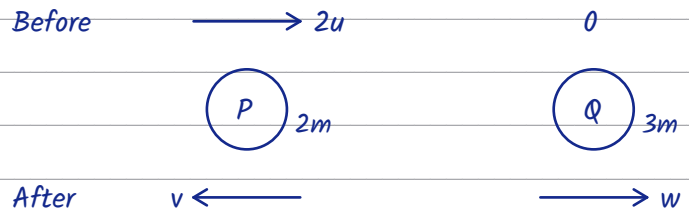
(c) Show that $e = \frac{4}{5}$

(3)

(d) Determine, with clear reasoning, whether there will be a second collision between P and Q.

(6)

(a)



Take the direction P → Q as positive. P rebounds with speed v, Q moves with speed w.

CLM: $2m(2u) = 2m(-v) + 3m(w) \Rightarrow 4u = -2v + 3w$ (1)

NEL: $w + v = e(2u) \Rightarrow v = 2eu - w$ (2)

Substitute (2) into (1): $4u = -2(2eu - w) + 3w = -4eu + 5w$

$5w = 4u + 4eu$

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Question 7 continued

$w = \frac{4u}{5}(e + 1)$ as required

(b) $v = 2eu - \frac{4u}{5}(e + 1) = \frac{10eu - 4eu - 4u}{5}$

$v = \frac{2u}{5}(3e - 2)$

Direction of P reversed $\Rightarrow$ $v > 0$: $3e - 2 > 0 \Rightarrow e > \frac{2}{3}$

Also $0 \leqslant e \leqslant 1$, so $\frac{2}{3} < e \leqslant 1$

(c) Impulse on Q = change in momentum of Q:

$\frac{108mu}{25} = 3m \times \frac{4u}{5}(e + 1)$

$e + 1 = \frac{108}{25} \times \frac{5}{12} = \frac{9}{5}$

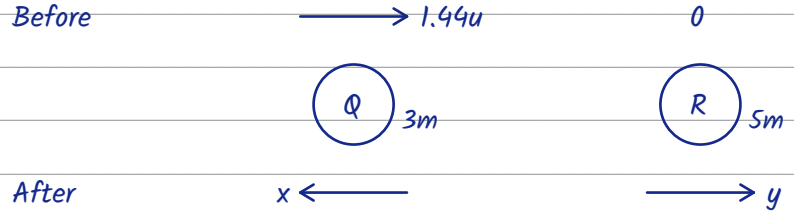
$e = \frac{4}{5}$ as required

(d) After the first collision, with $e = \frac{4}{5}$:

speed of P = $v = \frac{2u}{5}(3 \times \frac{4}{5} - 2) = \frac{2u}{5} \times \frac{2}{5} = \frac{4u}{25} = 0.16u$ (away from Q)

speed of Q = $w = \frac{4u}{5} \times \frac{9}{5} = \frac{36u}{25} = 1.44u$ (towards R)

Q then collides with R.



CLM: $3m(1.44u) = 3m(-x) + 5m(y) \Rightarrow 4.32u = -3x + 5y$ (3)

Question 7 continued

NEL: $x + y = \frac{4}{5}(1.44u) = 1.152u \Rightarrow y = 1.152u - x$ (4)

Substitute (4) into (3): $4.32u = -3x + 5.76u - 5x$

$8x = 1.44u \Rightarrow x = 0.18u$

So after colliding with R, Q moves back towards P with speed 0.18u, while P is moving in the same direction with speed 0.16u. Since 0.18u > 0.16u, Q is moving faster than P and will catch it up, so there will be a second collision between P and Q.

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Question 7 continued

Question 7 continued

(Total for Question 7 is 17 marks)

TOTAL FOR PAPER IS 75 MARKS

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