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

Thursday 23 October 2025

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 ▶

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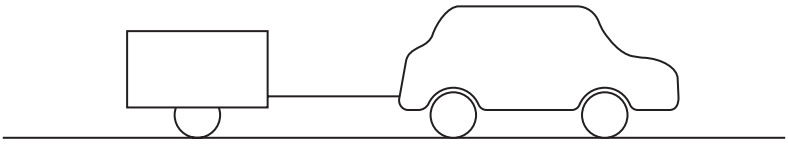


Figure 1

A car of mass 500 kg is towing a trailer of mass 150 kg along a straight horizontal road. The trailer is attached to the car by a towbar, as shown in Figure 1.

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

The towbar is modelled as a light rod.

The resistance to the motion of the car is modelled as a constant force of magnitude 350 N.

The resistance to the motion of the trailer is modelled as a constant force of magnitude 200 N.

The engine of the car is working at a constant rate of 10.5 kW.

At the instant when the car and the trailer are moving with speed $14\,\text{m s}^{-1}$, the acceleration of the car is $a\,\text{m s}^{-2}$ and the tension in the towbar is T newtons.

Using the model,

(a) find the value of a,

(4)

(b) find the value of T.

(3)

(a) Driving force $F = \frac{P}{v} = \frac{10\,500}{14} = 750$ N

N2L for car and trailer together:

$F - 350 - 200 = (500 + 150)a$

$750 - 550 = 650a$

$a = \frac{200}{650} = \frac{4}{13} = 0.30769...$

$a = 0.31$

(b) N2L for the trailer:

$T - 200 = 150a = 150 \times \frac{4}{13}$

$T = 200 + \frac{600}{13} = \frac{3200}{13} = 246.153...$

$T = 246$

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Question 1 continued

(Total for Question 1 is 7 marks)

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

A particle P of mass 2 kg is moving on a smooth horizontal plane with velocity $4\mathbf{i}\,\text{m s}^{-1}$

The particle receives a horizontal impulse of magnitude $\sqrt{29}$ Ns.

Immediately **after** receiving the impulse, the velocity of P is $(3\mathbf{i} + \lambda\mathbf{j})\,\text{m s}^{-1}$, where λ is a positive constant.

(a) Find the value of λ

(4)

(b) Find the size of the angle between the direction of motion of P immediately **before** receiving the impulse and the direction of the impulse.

(3)

(a) Impulse = change in momentum:

$I = 2(3i + \lambda j) - 2(4i) = -2i + 2\lambda j$

$|I| = \sqrt{29} \Rightarrow (-2)^2 + (2\lambda)^2 = 29$

$4 + 4\lambda^2 = 29 \Rightarrow \lambda^2 = \frac{25}{4}$

$\lambda = 2.5 \quad (\lambda > 0)$

(b) $I = -2i + 5j$, direction of motion before: i

$\cos\theta = \frac{4i \cdot (-2i + 5j)}{4 \times \sqrt{29}} = \frac{-8}{4\sqrt{29}} = \frac{-2}{\sqrt{29}}$

$\theta = 111.801...°$

Angle = 112°

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Question 2 continued

(Total for Question 2 is 7 marks)

3. [*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 Q is moving on a smooth horizontal plane.

At time t seconds, $t \geqslant 0$, the position vector of Q, relative to a fixed origin, is $\mathbf{r}$ metres and the velocity of Q is $\mathbf{v}\,\text{m s}^{-1}$

It is given that $\mathbf{v} = (2t + 3)\mathbf{i} + (t^2 - 5t - 15)\mathbf{j}$

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

(2)

When $t = 1$, $\mathbf{r} = 6\mathbf{i} - 2\mathbf{j}$

(b) Find an exact expression for $\mathbf{r}$ in terms of t, $\mathbf{i}$ and $\mathbf{j}$

(4)

When $t = T$, particle Q is moving in the direction of the vector $5\mathbf{i} - 3\mathbf{j}$

(c) Find the exact speed of Q when $t = T$

(5)

(a) $a = \frac{dv}{dt} = 2i + (2t - 5)j$

$t = 4$: $a = 2i + (8 - 5)j = (2i + 3j)\ m\ s^{-2}$

(b) $r = \int v\,dt = (t^2 + 3t + A)i + \left(\frac{1}{3}t^3 - \frac{5}{2}t^2 - 15t + B\right)j$

$t = 1$, $r = 6i - 2j$:

i: $1 + 3 + A = 6 \Rightarrow A = 2$

j: $\frac{1}{3} - \frac{5}{2} - 15 + B = -2 \Rightarrow B = -2 + 15 + \frac{5}{2} - \frac{1}{3} = \frac{91}{6}$

$r = (t^2 + 3t + 2)i + \left(\frac{1}{3}t^3 - \frac{5}{2}t^2 - 15t + \frac{91}{6}\right)j$

(c) v parallel to $5i - 3j \Rightarrow \frac{2T + 3}{5} = \frac{T^2 - 5T - 15}{-3}$

$-3(2T + 3) = 5(T^2 - 5T - 15)$

$-6T - 9 = 5T^2 - 25T - 75$

$5T^2 - 19T - 66 = 0$

$(5T + 11)(T - 6) = 0 \Rightarrow T = 6 \quad (T \geq 0)$

$v = (2 \times 6 + 3)i + (36 - 30 - 15)j = 15i - 9j$

(check: $15i - 9j = 3(5i - 3j)$, correct direction)

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Question 3 continued

speed = $\sqrt{(15^2 + (-9)^2)} = \sqrt{(225 + 81)} = \sqrt{306}$

Speed = $\sqrt{306} = 3\sqrt{34}$ m s^{-1}

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Question 3 continued

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Question 3 continued

(Total for Question 3 is 11 marks)

4. In this question you may assume, without proof, that the distance of the centre of mass of a uniform semicircular lamina of radius r from its diameter is $\frac{4r}{3\pi}$

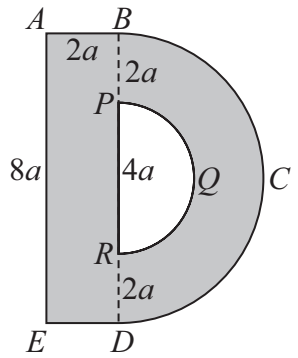


Figure 2

The uniform lamina $ABDE$ is a rectangle with $AB = 2a$ and $AE = 8a$.

The uniform lamina BCD is a semicircle with diameter $BD = 8a$.

The points P and R lie on BD with $BP = RD = 2a$.

The uniform lamina PQR is a semicircle with diameter $PR = 4a$.

The mass per unit area of the lamina $ABDE$ is equal to the mass per unit area of the lamina BCD.

The uniform template $ABCDE$, shown shaded in Figure 2, is formed by joining the lamina $ABDE$ to the lamina BCD and removing the lamina PQR.

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

(a) Show that $d = \frac{32a}{3(8+3\pi)}$

(5)

The template is free to rotate in a vertical plane about a smooth horizontal axis through B and hangs freely in equilibrium with BD at an angle $\phi°$ to the downward vertical.

(b) Find the value of ϕ.

(3)

The weight of the template is $15W$. A particle of weight kW is attached to the template at E.

The template is again free to rotate in a vertical plane about a smooth horizontal axis through B. The template is held in equilibrium, with BD vertical, by a horizontal force of magnitude W which is applied to the template at E and acts towards D.

(c) Find the value of k.

(4)

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Question 4 continued

(a) Distances measured from BD, positive towards C.

	ABDE	BCD	PQR	Template
Area	$16a^2$	$\frac{1}{2}\pi(4a)^2 = 8\pi a^2$	$\frac{1}{2}\pi(2a)^2 = 2\pi a^2$	$16a^2 + 6\pi a^2$
Mass ratio	16	8π	2π	$16 + 6\pi$
Distance	$-a$	$\frac{4(4a)}{3\pi} = \frac{16a}{3\pi}$	$\frac{4(2a)}{3\pi} = \frac{8a}{3\pi}$	d

Moments about BD:

$$16(-a) + 8\pi \times \frac{16a}{3\pi} - 2\pi \times \frac{8a}{3\pi} = (16 + 6\pi)d$$

$$-16a + \frac{128a}{3} - \frac{16a}{3} = (16 + 6\pi)d$$

$$\frac{64a}{3} = (16 + 6\pi)d$$

$$d = \frac{64a}{3(16 + 6\pi)} = \frac{32a}{3(8 + 3\pi)} \quad \text{as required}$$

(b) By symmetry G is 4a from B measured along BD.

Hanging from B, BG is vertical:

$$\tan\phi^\circ = \frac{d}{4a} = \frac{32a}{3(8 + 3\pi) \times 4a} = \frac{8}{3(8 + 3\pi)} = 0.15304\ldots$$

$\phi = 8.700\ldots$

$\phi = 8.7$

(c) B above D with BD vertical. E is 8a below B and 2a from BD (on the A side).

G is d from BD on the C side.

M(B): $15W \times d = kW \times 2a + W \times 8a$

$$15W \times \frac{32a}{3(8 + 3\pi)} = 2akW + 8aW$$

$$\frac{160}{8 + 3\pi} = 2k + 8$$

$$2k = \frac{160 - 64 - 24\pi}{8 + 3\pi} \Rightarrow k = \frac{48 - 12\pi}{8 + 3\pi} = 0.59116\ldots$$

$k = 0.591$

Question 4 continued

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Question 4 continued

(Total for Question 4 is 12 marks)

5.

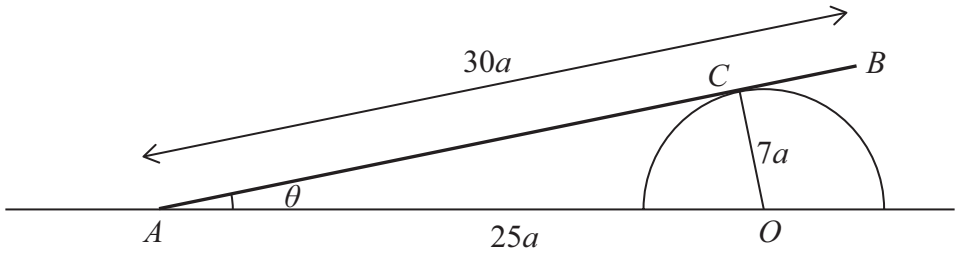


Figure 3

A smooth solid hemisphere is fixed with its plane face in contact with rough horizontal ground. The hemisphere has centre O and radius $7a$

A uniform rod AB, of length $30a$ and weight W, rests in limiting equilibrium on the hemisphere with end A on the ground. The rod is in contact with the hemisphere at the point C. The rod is at an angle θ to the ground, as shown in Figure 3.

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

Given that $AO = 25a$

(a) show that $AC = 24a$

(1)

(b) Show that the magnitude of the normal reaction on the rod at C is $\frac{3}{5}W$

(3)

The coefficient of friction between the rod and the ground at A is μ

(c) Find the value of μ

(6)

(a) AC is a tangent to the hemisphere, so OC is perpendicular to AC.

$AC = \sqrt{((25a)^2 - (7a)^2)} = \sqrt{(625a^2 - 49a^2)} = \sqrt{(576a^2)} = 24a$ as required

(b) $\cos\theta = \frac{24a}{25a} = \frac{24}{25}$, $\sin\theta = \frac{7}{25}$. N = reaction at C

M(A): $N \times 24a = W \times 15a \cos\theta$

$24aN = 15aW \times \frac{24}{25}$

$N = \frac{15}{25}W = \frac{3}{5}W$ as required

(c) N acts along OC, so its components are N cos θ upwards and N sin θ towards A.

At A: normal reaction R upwards, friction F horizontally towards O.

R(↑): $R + N\cos\theta = W$

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Question 5 continued

$R = W - \frac{3}{5}W \times \frac{24}{25} = W - \frac{72}{125}W = \frac{53}{125}W$

$R(\rightarrow)$: $F = N \sin\theta = \frac{3}{5}W \times \frac{7}{25} = \frac{21}{125}W$

Limiting equilibrium: $F = \mu R$

$\frac{21}{125}W = \mu \times \frac{53}{125}W$

$\mu = \frac{21}{53} = 0.39622...$

$\mu = \frac{21}{53}$ (0.396)

Question 5 continued

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Question 5 continued

(Total for Question 5 is 10 marks)

6. Two particles, P of mass $9m$ and Q of mass $3m$, are at rest on a smooth horizontal surface.

Particle P is projected with speed $4u$ towards Q and P collides with Q.

The coefficient of restitution between the particles is e.

(a) Show that the speed of Q immediately after the collision is $3u(1 + e)$.

(5)

The total kinetic energy lost in the collision between P and Q is kmu^2

Given that $e = \frac{2}{3}$

(b) find the value of k.

(4)

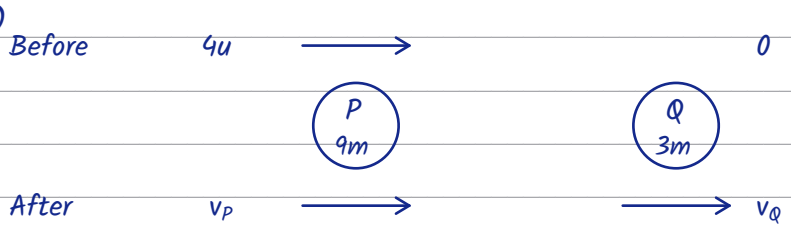
After being struck by P, particle Q goes on to hit a fixed vertical wall. The wall is perpendicular to the direction of motion of Q.

In the collision with the wall, Q receives an impulse of magnitude $21mu$.

(c) Find the coefficient of restitution between Q and the wall.

(3)

(a)



CLM: $9m(4u) = 9mv_P + 3mv_Q \Rightarrow 12u = 3v_P + v_Q$ (1)

NEL: $v_Q - v_P = e(4u) \Rightarrow v_P = v_Q - 4ue$ (2)

Substitute (2) into (1): $12u = 3v_Q - 12ue + v_Q$

$4v_Q = 12u + 12ue$

$v_Q = 3u(1 + e)$ as required

(b) $e = \frac{2}{3}$: $v_Q = 3u\left(1 + \frac{2}{3}\right) = 5u$, $v_P = 5u - 4u \times \frac{2}{3} = \frac{7u}{3}$

KE lost $= \frac{1}{2}(9m)(4u)^2 - \frac{1}{2}(9m)\left(\frac{7u}{3}\right)^2 - \frac{1}{2}(3m)(5u)^2$

$= 72mu^2 - 24.5mu^2 - 37.5mu^2$

$= 10mu^2$

$k = 10$

(c) Q hits the wall with speed $5u$ and rebounds with speed $5uf$,

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Question 6 continued

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

Impulse = change in momentum: $21mu = 3m(5uf - (-5u))$

$21mu = 15muf + 15mu$

$15f = 6$

$f = \frac{2}{5}$

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Question 6 continued

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Question 6 continued

(Total for Question 6 is 12 marks)

7.



Figure 4

A rough straight ramp is fixed at an angle α to horizontal ground, where $\tan\alpha = \frac{5}{12}$

The point A is at the bottom of the ramp and the point B is at the top of the ramp. Points A and B are on a line of greatest slope of the ramp, with $AB = 5\,\text{m}$, as shown in the sketch in Figure 4.

A particle of mass 0.5 kg is projected up the ramp from A, along the line AB, with speed $U\,\text{m s}^{-1}$. At the instant when it reaches B, the speed of the particle is $26\,\text{m s}^{-1}$

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

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

(3)

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

(4)

After leaving the ramp at B, the particle moves freely under gravity.

The particle is above the level of B for T seconds.

(c) Find the value of T.

(3)

The particle hits the ground for the first time at the point C.

(d) Find the distance AC.

(6)

(a) $\tan\alpha = \frac{5}{12} \Rightarrow \sin\alpha = \frac{5}{13}, \cos\alpha = \frac{12}{13}$

$R = 0.5g\cos\alpha = 0.5 \times 9.8 \times \frac{12}{13} = \frac{6g}{13}$

$F = \mu R = \frac{1}{3} \times \frac{6g}{13} = \frac{2g}{13}$ $(= 1.5077\ldots)$

Work done against friction $= F \times S = \frac{10g}{13} = 7.538\ldots$

Work done = 7.54 J

(b) Work-energy principle from A to B:

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Question 7 continued

Initial KE = final KE + gain in GPE + work done against friction

$$\frac{1}{2}(0.5)U^2 = \frac{1}{2}(0.5)(26)^2 + 0.5 \times 9.8 \times 5 \sin\alpha + \frac{10g}{13}$$

$$0.25U^2 = 169 + 9.4230\ldots + 7.5384\ldots = 185.961\ldots$$

$$U^2 = 743.846\ldots \Rightarrow U = 27.273\ldots$$

$$U = 27.3$$

(c) At B: vertical component $= 26 \sin\alpha = 26 \times \frac{5}{13} = 10\ m\ s^{-1}$,

horizontal component $= 26 \cos\alpha = 26 \times \frac{12}{13} = 24\ m\ s^{-1}$

Back to the level of B ($s = 0$): $0 = 10T - \frac{1}{2}(9.8)T^2$

$$T = \frac{20}{9.8} = 2.0408\ldots$$

$$T = 2.04$$

(d) Height of B above the ground $= 5 \sin\alpha = \frac{25}{13}\ m$

Vertical motion from B to the ground (up positive):

$$-\frac{25}{13} = 10t - \frac{1}{2}(9.8)t^2$$

$$4.9t^2 - 10t - \frac{25}{13} = 0$$

$$t = \frac{10 + \sqrt{(10^2 + 4 \times 4.9 \times 1.9230\ldots)}}{9.8}$$

$$t = \frac{10 + 11.734\ldots}{9.8} = 2.2177\ldots$$

Horizontal distance from B to C: $X = 24t = 24 \times 2.2177\ldots = 53.227\ldots$

Horizontal distance from A to B $= 5 \cos\alpha = \frac{60}{13} = 4.6153\ldots$

$$AC = 4.6153\ldots + 53.227\ldots = 57.842\ldots$$

$$AC = 57.8\ m$$

Question 7 continued

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Question 7 continued

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Question 7 continued

Question 7 continued

(Total for Question 7 is 16 marks)

TOTAL FOR PAPER IS 75 MARKS

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