Elite Mathematics
Edexcel International A Level

IAL MECHANICS 1 · WME01

WME01/01 January 2025 Worked Solutions

January 2025 paper rebuilt with the worked solution after each question.

7	2019–2026	Single-paper solutions
paper questions	18 exam sessions	checked by Dr Eslam



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PAST PAPER

WME01/01 January 2025

January 2025

7	75	1 h 30
questions	marks	exam time

Each question is followed by its worked solution and final answer.

WME01/01 JANUARY 2025

Question 1

8 marks | Forces

1. A particle of mass 2.5 kg moves on a smooth horizontal plane under the action of three horizontal forces, $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$, where

$$\mathbf{F}_1 = (6\mathbf{i} + 8\mathbf{j})\text{N}$$

$$\mathbf{F}_2 = (-16\mathbf{i} + 2\mathbf{j})\text{N}$$

$$\mathbf{F}_3 = (-2\mathbf{i} + 8\mathbf{j})\text{N}$$

(a) Find the magnitude of the acceleration of the particle.

(4)

A fourth force, $\mathbf{F}_4 = (p\mathbf{i} + p\mathbf{j})\text{N}$, where p is a constant, is added.

The resultant of the four forces acts in the direction of the vector $(7\mathbf{i} + 2\mathbf{j})$.

(b) Find the value of p.

(4)

WORKED SOLUTION

Question 1 · WME01/01 January 2025

1 Find the resultant of the first three forces

$\mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3 = (6\mathbf{i} + 8\mathbf{j}) + (-16\mathbf{i} + 2\mathbf{j}) + (-2\mathbf{i} + 8\mathbf{j}) = -12\mathbf{i} + 18\mathbf{j}$.

2 Apply Newtons second law

The mass is 2.5 kg, so $-12\mathbf{i} + 18\mathbf{j} = 2.5\mathbf{a}$. Hence $\mathbf{a} = -4.8\mathbf{i} + 7.2\mathbf{j}\ \text{m s}^{-2}$.

3 Find the magnitude of the acceleration

$|\mathbf{a}| = \sqrt{(-4.8)^2 + 7.2^2} = 8.653\ldots$, so the magnitude is $8.7\ \text{m s}^{-2}$ to 2 significant figures. Exactly, $|\mathbf{a}| = \dfrac{12\sqrt{13}}{5}$.

4 Add the fourth force

With $\mathbf{F}_4 = p\mathbf{i} + p\mathbf{j}$, the new resultant is $(p - 12)\mathbf{i} + (p + 18)\mathbf{j}$.

5 Use the given direction

The resultant acts in the direction $7\mathbf{i} + 2\mathbf{j}$, so $\dfrac{p - 12}{p + 18} = \dfrac{7}{2}$.

6 **Solve for p**

$2(p-12)=7(p+18)$, so $2p-24=7p+126$. Therefore $-150=5p$ and $p=-30$.

✓ **FINAL ANSWER**

$(a)\ |\mathbf{a}|=\dfrac{12\sqrt{13}}{5}\ \mathrm{m\,s^{-2}}\approx 8.7\ \mathrm{m\,s^{-2}}.\quad (b)\ p=-30.$

Question 2

11 marks | Kinematics Graphs

2. The fixed points A, B and C lie in a straight line on a horizontal road.

- At time $t = 0$, a motorbike passes through A with speed $5\,\text{m s}^{-1}$
- From A, the motorbike accelerates uniformly until it reaches B with a speed of $V\,\text{m s}^{-1}$
- The motorbike takes T_1 seconds to travel from A to B
- From B, the motorbike decelerates uniformly until it comes to rest at C
- The motorbike takes T_2 seconds to travel from B to C

(a) Sketch a speed-time graph for the motion of the motorbike as it moves from A to C.

(3)

The distance AB is 132 m and the distance BC is 136 m.

(b) Find, in terms of V, an expression for

(i) T_1

(ii) T_2

(4)

Given that the motorbike takes 28 s to travel from A to C,

(c) find the value of V,

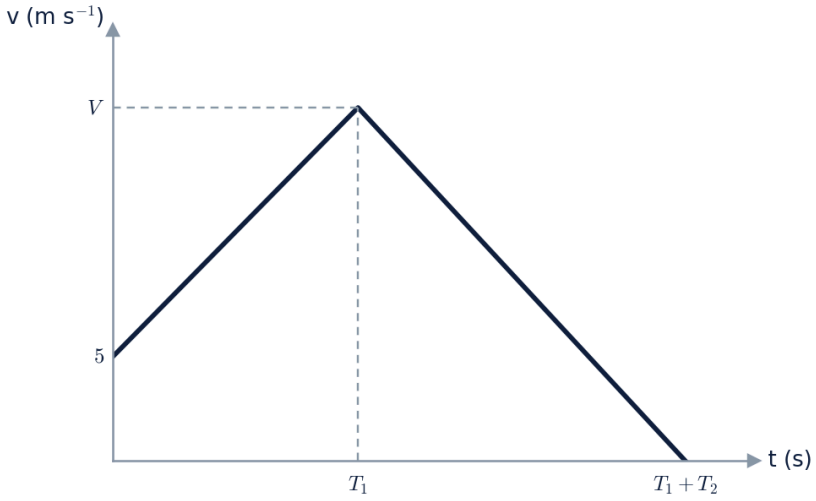
(2)

(d) find the deceleration of the motorbike.

(2)

1 **Sketch the speed-time graph**

The graph starts at speed 5 when $t = 0$, rises linearly to speed V at time T_1, then falls linearly to speed 0 at time $T_1 + T_2$.



2 **Use area from A to B**

The area under the first section is the distance $AB = 132$. Thus $\frac{1}{2}(5 + V)T_1 = 132$, so $T_1 = \frac{264}{V + 5}$.

3 **Use area from B to C**

The second section is a triangle of height V and base T_2. Since $BC = 136$, $\frac{1}{2}VT_2 = 136$, so $T_2 = \frac{272}{V}$.

4 **Use the total time**

The whole journey takes 28 s, so $\frac{264}{V + 5} + \frac{272}{V} = 28$.

5 **Solve for V**

Multiplying by $V(V + 5)$ gives $264V + 272(V + 5) = 28V(V + 5)$. This simplifies to $7V^2 - 99V - 340 = 0$, so $(V - 17)(7V + 20) = 0$. Since speed is positive, $V = 17$.

6 **Find the deceleration**

For the final section, $T_2 = \frac{272}{17} = 16$ s. The speed falls from 17 to 0, so the deceleration is $\frac{17}{16} = 1.0625\ \text{m s}^{-2}$.

FINAL ANSWER

$(b)(i)\ T_1 = \dfrac{264}{V+5}.\quad (b)(ii)\ T_2 = \dfrac{272}{V}.\quad (c)\ V = 17.\quad (d)\ \text{deceleration} = \dfrac{17}{16} = 1.0625\ \text{m s}^{-2}$

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Question 3

12 marks | Momentum, Impulse & Collisions

3.

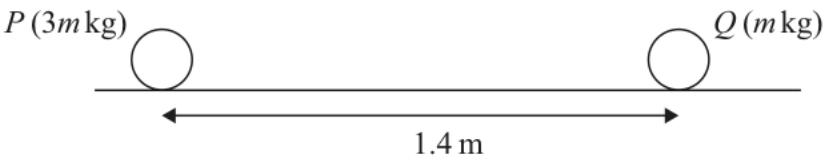


Figure 1

A particle P of mass $3m$ kg and a particle Q of mass m kg are at rest on a rough horizontal surface. The distance between P and Q is 1.4 m, as shown in Figure 1.

An impulse of magnitude λ N s is now applied to P in the direction PQ. Immediately after the impulse is applied, the speed of P is $5\,\text{m s}^{-1}$

(a) Find λ in terms of m.

(2)

Immediately before P collides with Q, the speed of P is $2.5\,\text{m s}^{-1}$ The coefficient of friction between P and the surface is μ

(b) Find the value of μ

(7)

Immediately after P collides with Q, the speed of Q is $2.1\,\text{m s}^{-1}$

(c) Find the speed of P immediately after the collision.

(3)

WORKED SOLUTION

Question 3 · WME01/01 January 2025

1 **Use impulse to find lambda**

P starts from rest and immediately after the impulse has speed $5\ \text{m s}^{-1}$. Since the mass of P is $3m$, $\lambda = 3m(5-0) = 15m$.

2 **Find the acceleration before collision**

Between the impulse and the collision, P slows from 5 to $2.5\ \text{m s}^{-1}$ over 1.4 m. Using $v^2 = u^2 + 2as$: $(2.5)^2 = 5^2 + 2a(1.4)$.

3 **Calculate the acceleration**

$6.25 = 25 + 2.8a$, so $a = \dfrac{-18.75}{2.8} = -6.696\ldots\ \text{m s}^{-2}$.

4 **Connect friction to acceleration**

On the horizontal surface, $R = 3mg$ and friction is $F = \mu R = 3\mu mg$. This friction is opposite the motion, so $-3\mu mg = 3ma$ and therefore $a = -\mu g$.

5 **Find mu**

$\mu = \dfrac{-a}{g} = \dfrac{6.696\ldots}{9.8} = 0.683\ldots$, so $\mu = 0.68$ to 2 significant figures.

6 **Use momentum in the collision**

Immediately before collision, P has speed 2.5 and Q is at rest. Immediately after, Q has speed 2.1 and P has speed v. Conservation of momentum gives $3m(2.5) + m(0) = 3mv + m(2.1)$.

7 **Find the speed after collision**

$7.5 = 3v + 2.1$, so $3v = 5.4$ and $v = 1.8\ \mathrm{m\,s^{-1}}$.

✓ **FINAL ANSWER**

$(a)\ \lambda = 15m.$ $(b)\ \mu = 0.68$ or $0.683.$ (c) speed of $\mathrm{P} = 1.8\ \mathrm{m\,s^{-1}}$.

Question 4

10 marks | Moments

4.

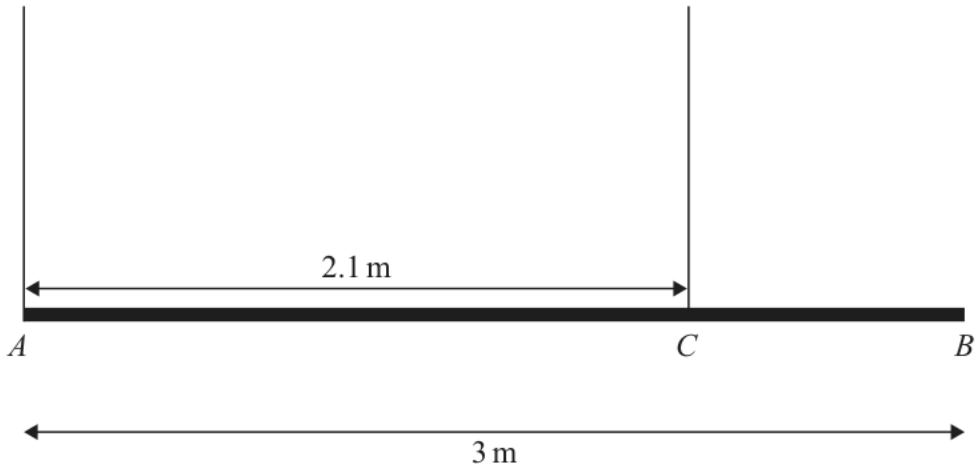


Figure 2

A uniform rod AB has length 3 m and weight W newtons.
The rod is suspended by two light vertical ropes.
One rope is attached to the rod at A and the other rope is attached to the rod at C, where $AC = 2.1$ m.

The rod is in equilibrium in a horizontal position, as shown in Figure 2.

The tension in the rope at C is 350 N.

(a) Show that $W = 490$

(3)

A particle P of weight 210 N is attached to the rod at a distance d metres from A.
The tension in the rope at C is now 600 N.
The rod remains in equilibrium in a horizontal position.

(b) Find the value of d.

(3)

Particle P is removed from the rod.
A particle Q of weight X newtons is now attached at B.
The rod remains in equilibrium in a horizontal position and is now on the point of tilting.

(c) Find the value of X.

(4)

1 Use moments to find W

Take moments about A. The rope at C is 2.1 m from A and the weight of the uniform rod acts at its midpoint, 1.5 m from A. Hence $350(2.1) = W(1.5)$.

2 Show W is 490

$735 = 1.5W$, so $W = 490$ N.

3 Set up moments with particle P

When P is attached, the tension at C is 600 N. Taking moments about A:
$600(2.1) = 490(1.5) + 210d$.

4 Find d

$1260 = 735 + 210d$, so $525 = 210d$ and $d = 2.5$.

5 Use the tilting condition

When Q is attached at B and the rod is on the point of tilting, the rope at A is just slack. The rod is about to tilt about C.

6 Find X

Take moments about C. The rod weight acts $2.1 - 1.5 = 0.6$ m to the left of C, and Q acts $3 - 2.1 = 0.9$ m to the right. Thus $490(0.6) = X(0.9)$, so $X = \dfrac{980}{3}$ N.

FINAL ANSWER

$(a)\ W = 490.$ $(b)\ d = 2.5.$ $(c)\ X = \dfrac{980}{3}\ \text{N} \approx 327\ \text{N}.$

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Question 5

7 marks | Working with Vectors

5. [*In this question* **i** *and* **j** *are horizontal perpendicular unit vectors and position vectors are given relative to a fixed origin.*]

In a game, a ball B is rolled across a horizontal surface towards a fixed target.
The ball is modelled as a particle moving with constant velocity.

At time $t = 1$ s, the position vector of B is $(-2\mathbf{i} + 5\mathbf{j})$ m.
At time $t = 9$ s, the position vector of B is $(10\mathbf{i} - 3\mathbf{j})$ m.

(a) Find the velocity of the ball.

(3)

The position vector of the target is $(13\mathbf{i} - 5\mathbf{j})$ m.

(b) Use the model to find the distance of B from the target at time $t = 7$ s.

(4)

WORKED SOLUTION

Question 5 · WME01/01 January 2025

1 Find the displacement over 8 seconds

From $t = 1$ to $t = 9$, the displacement is $(10\mathbf{i} - 3\mathbf{j}) - (-2\mathbf{i} + 5\mathbf{j}) = 12\mathbf{i} - 8\mathbf{j}$.

2 Find the velocity

The time interval is 8 seconds, so $\mathbf{v} = \dfrac{12\mathbf{i} - 8\mathbf{j}}{8} = 1.5\mathbf{i} - \mathbf{j}\ \text{m s}^{-1}$.

3 Find the position at t=7

Time $t = 7$ is 6 seconds after $t = 1$. Therefore $\mathbf{r}_B(7) = (-2\mathbf{i} + 5\mathbf{j}) + 6(1.5\mathbf{i} - \mathbf{j}) = 7\mathbf{i} - \mathbf{j}$.

4 Find the vector from B to the target

The target has position vector $13\mathbf{i} - 5\mathbf{j}$. The vector from the ball to the target is $(13\mathbf{i} - 5\mathbf{j}) - (7\mathbf{i} - \mathbf{j}) = 6\mathbf{i} - 4\mathbf{j}$.

5 Find the distance

The distance is $\sqrt{6^2 + (-4)^2} = \sqrt{52} = 2\sqrt{13}\ \text{m}$, which is about $7.2\ \text{m}$.

FINAL ANSWER

$(a)\ \mathbf{v} = 1.5\mathbf{i} - \mathbf{j}\ \text{m s}^{-1}$. $(b)\ \text{distance} = 2\sqrt{13}\ \text{m} \approx 7.2\ \text{m}$.

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Question 6

12 marks | Resolving Forces, Inclined Planes

6.

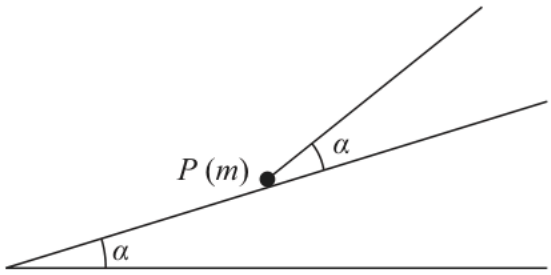


Figure 3

A particle P of mass m is held in equilibrium on a fixed rough inclined plane by a light inextensible string.

The plane is inclined at an angle α to the horizontal, where $\alpha < 45°$
The string is inclined to the plane at angle α, as shown in Figure 3.

The string lies in a vertical plane that contains a line of greatest slope of the inclined plane.

When the tension in the string is $0.75\,mg$, P is on the point of moving up the plane.

(a) Find an expression for the magnitude of the frictional force acting on P, giving your answer in terms of m, g and α.

(3)

The coefficient of friction between P and the plane is $\frac{1}{2}$

(b) Show that

$$\tan\alpha = \frac{2}{5}$$

(6)

The string breaks.

(c) Determine whether P remains at rest. You must justify your reasoning.

(3)

WORKED SOLUTION

Question 6 · WME01/01 January 2025

1 **Resolve parallel to the plane**

P is on the point of moving up the plane, so friction acts down the plane. The tension has component $0.75mg\cos\alpha$ up the plane, and the weight component is $mg\sin\alpha$ down the plane.

2 **Find the frictional force**

For equilibrium parallel to the plane, $0.75mg\cos\alpha = mg\sin\alpha + F$. Hence $F = 0.75mg\cos\alpha - mg\sin\alpha$.

3 **Resolve perpendicular to the plane**

The string has a component away from the plane, so $R = mg\cos\alpha - 0.75mg\sin\alpha$.

4 **Use the coefficient of friction**

Given $\mu = \frac{1}{2}$, limiting friction gives $F = \frac{1}{2}R$. Therefore $0.75mg\cos\alpha - mg\sin\alpha = \frac{1}{2}(mg\cos\alpha - 0.75mg\sin\alpha)$.

5 **Show the tangent result**

Divide by mg and collect terms: $0.75\cos\alpha - \sin\alpha = 0.5\cos\alpha - 0.375\sin\alpha$. Thus $0.25\cos\alpha = 0.625\sin\alpha$, so $\tan\alpha = \frac{0.25}{0.625} = \frac{2}{5}$.

6 **Check what happens when the string breaks**

Without the string, $R = mg\cos\alpha$ and the maximum friction is $\frac{1}{2}mg\cos\alpha$. The component of weight down the plane is $mg\sin\alpha$.

7 **Compare friction with the downslope component**

Since $\tan\alpha = \frac{2}{5} < \frac{1}{2}$, we have $mg\sin\alpha < \frac{1}{2}mg\cos\alpha$. The available friction is large enough to hold P, so P remains at rest.

✓ **FINAL ANSWER**

$(a)\ F = 0.75mg\cos\alpha - mg\sin\alpha.$ $(b)\ \tan\alpha = \frac{2}{5}.$ $(c)\ P$ remains at rest.

Question 7

15 marks | Newton's Second Law

7.

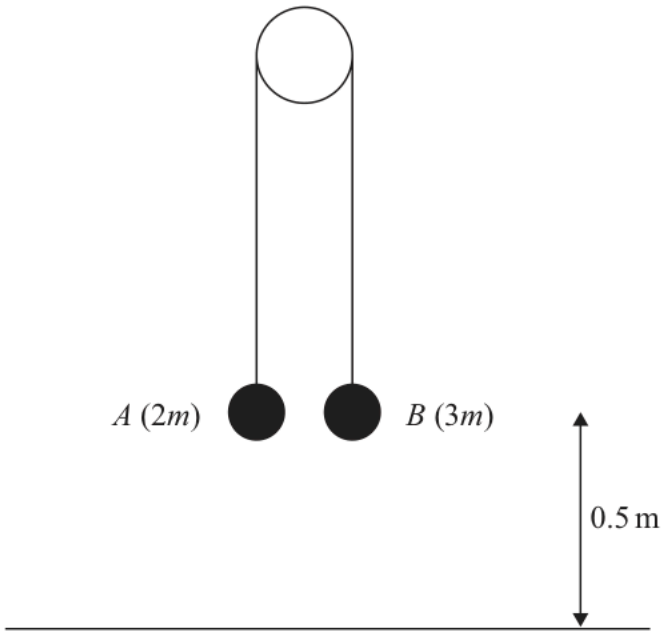


Figure 4

One end of a light inextensible string is attached to a particle A of mass $2m$.
The other end is attached to a particle B of mass $3m$.
The string passes over a small smooth fixed pulley.
The string is taut and both straight parts of the string are vertical.
Both particles are held at a distance 0.5 m above a horizontal surface, as shown in Figure 4.

The system is released from rest and B moves downwards.

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

(5)

(b) Find the speed of B at the instant it strikes the surface.

(4)

In the subsequent motion, A does not reach the pulley and B does not rebound after it strikes the surface.

(c) Find the time from the instant when the system is released from rest to the instant when A first reaches a height of 1.06 m above the surface.

(6)

1 Write the equations of motion

B moves down and A moves up with the same acceleration a. For A: $T - 2mg = 2ma$. For B: $3mg - T = 3ma$.

2 Find the acceleration

Adding the two equations gives $mg = 5ma$, so $a = \dfrac{g}{5}$.

3 Find the tension

Use $T - 2mg = 2ma$: $T = 2mg + 2m\left(\dfrac{g}{5}\right) = \dfrac{12mg}{5}$.

4 Find the speed when B hits the surface

B starts from rest and moves 0.5 m with acceleration $g/5$. Using $v^2 = u^2 + 2as$,
$v^2 = 2\left(\dfrac{g}{5}\right)(0.5) = \dfrac{g}{5} = 1.96$.

5 Calculate the impact speed

$v = \sqrt{1.96} = 1.4\ \mathrm{m\,s^{-1}}$.

6 Find the first time interval

The time until B hits the surface is found from $0.5 = \dfrac{1}{2}\left(\dfrac{g}{5}\right)t_1^2$. With $g = 9.8$,
$t_1 = \dfrac{5}{7} = 0.714285\ldots$ s.

7 Find the extra time after B stops

After B hits the surface, A continues upwards freely under gravity. It is then at height 1.00 m and must rise another 0.06 m with initial speed $1.4\ \mathrm{m\,s^{-1}}$. So $0.06 = 1.4t_2 - 4.9t_2^2$.

8 Find the total time

Solving $0.06 = 1.4t_2 - 4.9t_2^2$ gives the first positive time $t_2 = 0.0525\ldots$ s. Therefore the total time is $0.714285\ldots + 0.0525\ldots = 0.767$ s.

FINAL ANSWER

$(a)\ T = \dfrac{12mg}{5}$. $\quad (b)\ v = 1.4\ \mathrm{m\,s^{-1}}$. $\quad (c)\ t = 0.767$ s approximately.