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INTERNATIONAL A LEVEL MATHEMATICS • MECHANICS 1

Mechanics 1

Exam Questions by Topic

Pearson Edexcel International Advanced Level (WME01/01) • Calculator allowed • Take $g = 9.8 \text{ m s}^{-2}$

Multi-step exam questions at the difficulty of the real WME01 paper, with a full mark scheme

Chapters (tap a chapter to jump to it)	Qs	Marks	Page	My score
1 Mathematical Models in Mechanics Not examined on its own: modelling ideas are tested within Chapters 2 to 8	—	—	Not applicable	
2 Constant Acceleration Motion graphs, the suvat formulae, vertical motion under gravity	10	82	own PDF	
3 Vectors in Mechanics Resultants, velocity and position vectors, $\mathbf{r} = \mathbf{r}_0 + \mathbf{v}t$	10	81	2	
4 Dynamics of a Particle Moving in a Straight Line $F = ma$, connected particles, pulleys, lifts	10	82	own PDF	
5 Forces and Friction Resolving forces, friction, inclined planes	10	86	own PDF	
6 Momentum and Impulse Conservation of momentum, impulse	10	81	own PDF	
7 Statics of a Particle Equilibrium, limiting friction	10	82	own PDF	
8 Moments Beams and rods, tilting, non-uniform rods	10	82	own PDF	

[Full mark scheme](#)

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CHAPTER 3 • KEY SKILLS

3

Vectors in Mechanics

Specification M1: Vectors • 10 questions • 81 marks • about 97 minutes

1 Magnitude and direction

$|a\mathbf{i} + b\mathbf{j}| = \sqrt{a^2 + b^2}$. For the angle, draw the vector and use $\tan \theta = \frac{b}{a}$ on the right-angled triangle.

2 Bearings

Measured clockwise from north ($\mathbf{j}$), three figures. $4\mathbf{i} - 3\mathbf{j}$ points south of east: $90^\circ + 36.9^\circ = 127^\circ$

3 Adding vectors

Add the $\mathbf{i}$ and $\mathbf{j}$ parts, or draw a triangle with the vectors top to tail and use the sine and cosine rules.

4 Parallel vectors

Parallel to $2\mathbf{i} - \mathbf{j}$ means a multiple of it: $x\mathbf{i} + y\mathbf{j} = \lambda(2\mathbf{i} - \mathbf{j})$, so $\frac{x}{2} = \frac{y}{-1}$

5 Speed and velocity

Speed = $|\mathbf{v}|$. Speed 26 in the direction $5\mathbf{i} - 12\mathbf{j}$: $\mathbf{v} = \frac{26}{13}(5\mathbf{i} - 12\mathbf{j})$

6 Position at time t

$\mathbf{r} = \mathbf{r}_0 + \mathbf{v}t$, where $\mathbf{r}_0$ is the position when $t = 0$. From $t = 1$ to $t = 9$ is 8 seconds, not 9.

7 Relative position

$\vec{AB} = \mathbf{r}_B - \mathbf{r}_A$ and $AB = |\vec{AB}|$. Particles collide only if *both* components agree at the same t .

8 Direction conditions

Due north of O : $\mathbf{i}$ part = 0. North-east of O : the $\mathbf{i}$ and $\mathbf{j}$ parts are equal and positive.

9 Least distance

AB^2 is a quadratic in t : complete the square (or differentiate) to find the least value and when it happens.

Skills map every skill above is tested at least once; interleaved skills come from GCSE or other chapters

Skill	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Marks	6	6	6	6	6	10	10	10	10	11
1 Magnitude and direction	•		•			•	•	•	•	
2 Bearings	•	•				•	•	•	•	•
3 Adding vectors		•	•						•	
4 Parallel vectors			•							
5 Speed and velocity				•				•	•	
6 Position at time t	•			•	•	•	•	•		•
7 Relative position					•	•	•			•
8 Direction conditions	•			•			•	•	•	
9 Least distance										•
Interleaved: trigonometry: sine and cosine rules (P1)		•							•	
Interleaved: quadratics, completing the square, simultaneous equations (P1)					•	•				•
Interleaved: speed, distance and time (Chapter 2)				•		•	•		•	

Exam difficulty. Questions 1 to 5 check each skill on its own. Questions 6 to 10 are multi-step questions built like the last questions on a real WME01 paper, where one part leads into the next and skills from different topics are combined.

Must learn. Draw a diagram with north marked. Give velocities in $\mathbf{i}, \mathbf{j}$ form and speeds as magnitudes, bearings as three figures, and times as clock times when the question uses them.



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1. [In this question, $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors directed due east and due north respectively, and position vectors are given relative to a fixed origin O .]

A particle P moves with constant velocity $(4\mathbf{i} - 3\mathbf{j}) \text{ m s}^{-1}$. At time $t = 0$, P passes through the point with position vector $(-10\mathbf{i} + 18\mathbf{j}) \text{ m}$.

- (a) Find the direction of motion of P , giving your answer as a bearing to the nearest degree.

(2)

- (b) Write down the position vector of P at time t seconds.

(1)

- (c) Find the value of t when P is due east of O , and the distance of P from O at this time.

(3)

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Question 1 continued

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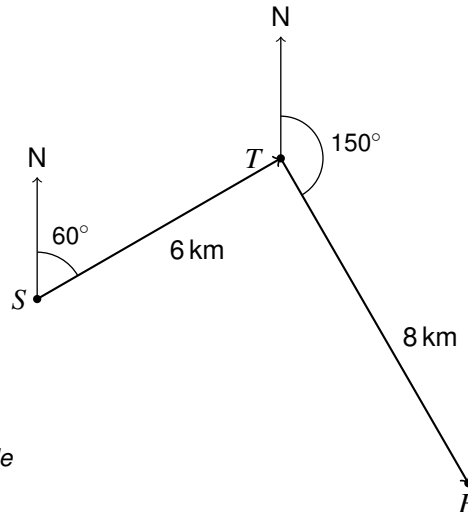
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2.

**Figure 1**

A hiker walks 6 km in a straight line from her start point S on a bearing of 060° to the point T . She then walks 8 km in a straight line on a bearing of 150° to the point F , as shown in Figure 1.

(a) Find the distance SF . (3)

(b) Find the bearing of F from S , giving your answer to the nearest degree. (3)



Question 2 continued

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3. A small robot moves across a horizontal floor. It first moves with displacement $\mathbf{a} = (3\mathbf{i} + 4\mathbf{j})$ m and then with displacement $\mathbf{b} = (p\mathbf{i} - 6\mathbf{j})$ m, where p is a constant.
- (a) Find the angle between $\mathbf{a}$ and the vector $\mathbf{i}$, giving your answer in degrees to one decimal place. (2)

The resultant displacement $\mathbf{a} + \mathbf{b}$ is parallel to the vector $(2\mathbf{i} - \mathbf{j})$.

- (b) Find the value of p . (3)
- (c) Find the magnitude of the resultant displacement. (1)

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4. [In this question, $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors directed due east and due north respectively, and position vectors are given relative to a fixed origin O .]

A ship moves with constant speed 26 km h^{-1} in the direction of the vector $(5\mathbf{i} - 12\mathbf{j})$. At 09:00 the ship is at the point with position vector $(-20\mathbf{i} + 60\mathbf{j}) \text{ km}$.

- (a) Find the velocity of the ship in the form $(x\mathbf{i} + y\mathbf{j}) \text{ km h}^{-1}$ (2)
- (b) Find the position vector of the ship t hours after 09:00 (1)
- (c) Find the time of day at which the ship is due east of O , and its distance from O at this time. (3)

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5. [In this question, $\mathbf{i}$ and $\mathbf{j}$ are perpendicular horizontal unit vectors, and position vectors are given relative to a fixed origin O .]

Two particles A and B move on a smooth horizontal plane with constant velocities $(2\mathbf{i} + \mathbf{j}) \text{ m s}^{-1}$ and $(-\mathbf{i} + 4\mathbf{j}) \text{ m s}^{-1}$ respectively. At time $t = 0$, A is at the point with position vector $(\mathbf{i} + 2\mathbf{j}) \text{ m}$ and B is at the point with position vector $(7\mathbf{i} - 4\mathbf{j}) \text{ m}$.

- (a) Write down the position vectors of A and B at time t seconds.

(2)

- (b) Show that A and B collide, and find the position vector of the point where they collide.

(4)

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6. [In this question, $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors directed due east and due north respectively, and position vectors are given relative to a fixed origin O .]

Two ships A and B are moving with constant velocities. The velocity of A is $(4\mathbf{i} + 3\mathbf{j}) \text{ km h}^{-1}$ and the velocity of B is $(p\mathbf{i} + q\mathbf{j}) \text{ km h}^{-1}$. At 14:00, A is at the point with position vector $(2\mathbf{i} - 3\mathbf{j}) \text{ km}$ and B is at the point with position vector $(12\mathbf{i} + 7\mathbf{j}) \text{ km}$.

- (a) Find the speed of A .

(1)

At time t hours after 14:00, $\vec{AB} = [(10 - 6t)\mathbf{i} + (10 - 8t)\mathbf{j}] \text{ km}$

- (b) Find the value of p and the value of q .

(4)

- (c) Find the two times of day at which the ships are $2\sqrt{10} \text{ km}$ apart.

(3)

- (d) Find the bearing of B from A at the later of these two times, giving your answer to the nearest degree.

(2)



Question 6 continued

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Question 6 continued

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7. [In this question, $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors directed due east and due north respectively, and position vectors are given relative to a fixed origin O .]

A boat leaves a harbour at O at 12:00 and moves with constant velocity $(6\mathbf{i} + 8\mathbf{j}) \text{ km h}^{-1}$. At 13:30 the boat changes direction and then moves with constant velocity $(-4\mathbf{i} + 3\mathbf{j}) \text{ km h}^{-1}$. A lighthouse L is at the point with position vector $(5\mathbf{i} + 18\mathbf{j}) \text{ km}$.

- (a) Find the speed of the boat before 13:30 (1)
- (b) Find the position vector of the boat at 13:30 (2)
- (c) Find the position vector of the boat s hours after 13:30 (2)
- (d) Find the time of day at which the boat is due west of L , and its distance from L at that time. (3)
- (e) Find the bearing of L from the boat at 13:30, giving your answer to the nearest degree. (2)



Question 7 continued

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8. [In this question, $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors directed due east and due north respectively, and position vectors are given relative to a fixed origin O .]

A puck moves in a straight line with constant velocity across a smooth horizontal ice rink. At time $t = 2$ seconds the puck is at the point with position vector $(-3\mathbf{i} + 5\mathbf{j})$ m and at time $t = 5$ seconds it is at the point with position vector $(12\mathbf{i} + 11\mathbf{j})$ m.

- (a) Find the velocity of the puck. (2)
- (b) Find the speed of the puck and its direction of motion as a bearing, to the nearest degree. (3)
- (c) Find the position vector of the puck at time t seconds. (2)
- (d) Find the time at which the puck is north-east of O . (2)
- (e) Find the distance of the puck from O at this time. (1)



Question 8 continued

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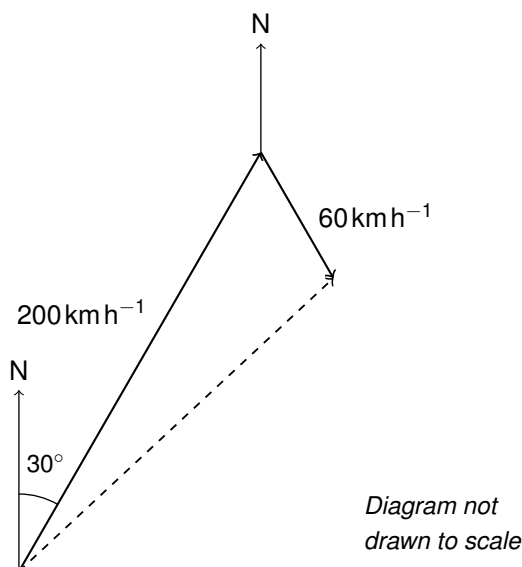


Figure 2

[In this question, $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors directed due east and due north respectively.]

An aircraft is flying with a speed of 200 km h^{-1} relative to the air, heading on a bearing of 030° . A wind is blowing at 60 km h^{-1} towards the bearing 150° . The velocity of the aircraft over the ground is the sum of these two velocities, shown by the dashed line in Figure 2.

(a) Find the speed of the aircraft over the ground.

(3)

(b) Find the bearing of the direction in which the aircraft is moving over the ground, to the nearest degree.

(3)

The pilot now changes heading, keeping a speed of 200 km h^{-1} relative to the air, so that the aircraft moves due east over the ground. The wind is unchanged.

(c) Find the new heading of the aircraft as a bearing, to the nearest degree, and its new speed over the ground.

(4)



Question 9 continued

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Question 9 continued

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10. [In this question, $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors directed due east and due north respectively, and position vectors are given relative to a fixed origin O .]

Two ships A and B move with constant velocities $(\mathbf{i} + 3\mathbf{j}) \text{ km h}^{-1}$ and $(4\mathbf{i} - 3\mathbf{j}) \text{ km h}^{-1}$ respectively. At 12:00, A is at the point with position vector $(5\mathbf{i} + 2\mathbf{j}) \text{ km}$ and B is at the point with position vector $(-13\mathbf{i} + 23\mathbf{j}) \text{ km}$.

- (a) Show that both ships pass through the point X with position vector $(7\mathbf{i} + 8\mathbf{j}) \text{ km}$, and explain why they do not collide. (3)
- (b) Show that, t hours after 12:00, $AB^2 = 45(t^2 - 8t + 17)$ (3)
- (c) Find the least distance between the ships and the time of day at which it occurs. (3)
- (d) Find the bearing of B from A at this time, to the nearest degree. (2)



Question 10 continued

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