M1 Vectors: exam questions

10 questions · 44 marks · full mark schemes

Name _____ Date _____ Score / 44

- Position, velocity and force vectors in i, j form; magnitude and direction; r = r_0 + vt for constant velocity; resultant forces.
- Try every question before you look at the mark schemes. They start after the questions: M marks for method, A marks for accuracy, B marks for a correct result on its own.
- Online, with more practice: alevelmathrevision.com/alevel-frontend/units/m1/vectors-questions

1. **2 marks · warm-up**

Particle B has initial position vector $(-\mathbf{i} + 7\mathbf{j})$ m and constant velocity $(3\mathbf{i} + 2\mathbf{j})$ m s^{-1}. Particle C has initial position vector $(11\mathbf{i} + \mathbf{j})$ m and constant velocity $(-\mathbf{i} + 4\mathbf{j})$ m s^{-1}. The particles collide when $t = 3$. Find the position vector of the point where they collide.

2. **3 marks · warm-up**

A particle moves with a constant velocity of $(5\mathbf{i} + 12\mathbf{j})$ m s^{-1}. Find the distance it travels in 4 seconds.

3. **3 marks · standard**

A particle Q moves with a speed of 10 m s^{-1} in the direction of the vector $3\mathbf{i} - 4\mathbf{j}$. Find its velocity vector.

4. 4 marks · standard

A particle moves with constant acceleration $\mathbf{a} = (-2\mathbf{i} + 3\mathbf{j})\ \text{m s}^{-2}$. At $t = 0$, its velocity is $(10\mathbf{i} - 4\mathbf{j})\ \text{m s}^{-1}$. Find the time t when the particle is moving parallel to the $\mathbf{j}$ vector.

5. 5 marks · standard

At time t seconds, a particle P has position vector $\big((-6 + 3t)\mathbf{i} + (9 - 4t)\mathbf{j}\big)$ m relative to a fixed origin O.

(a) Show that $OP^2 = 25t^2 - 108t + 117$. [2]

(b) Find the least distance of P from O, and the value of t at which it occurs. [3]

6. 6 marks · standard

A particle P of mass 0.8 kg moves under the action of a single constant force $\mathbf{F}$ newtons. At time $t = 0$ the velocity of P is $(4\mathbf{i} - 3\mathbf{j})$ m s^{-1}, and at time $t = 5$ s the velocity of P is $(-6\mathbf{i} + 12\mathbf{j})$ m s^{-1}.

(a) Find the acceleration of P. [2]

(b) Find $\mathbf{F}$. [2]

(c) Find the magnitude of $\mathbf{F}$. [2]

7. 2 marks · harder

Ship A travels with velocity $(4\mathbf{i} - 3\mathbf{j})\ \text{km h}^{-1}$; ship B travels $(-\mathbf{i} + \mathbf{j})\ \text{km h}^{-1}$. Find the velocity of A relative to B.

8. 5 marks · harder

Two forces $\mathbf{F}_1 = (a\mathbf{i} - 3\mathbf{j})\ \text{N}$ and $\mathbf{F}_2 = (4\mathbf{i} + b\mathbf{j})\ \text{N}$ act on a particle. The resultant force has a magnitude of $13\ \text{N}$ and acts in the direction of the vector $5\mathbf{i} - 12\mathbf{j}$. Find the values of a and b.

9. 6 marks · harder

[In this question $\mathbf{i}$ is a horizontal unit vector and $\mathbf{j}$ is a unit vector vertically upwards. Take $g = 9.8$ m s^{-2}.]

A particle of mass m kg is in equilibrium under the action of its weight and three forces $(4\mathbf{i} + 7\mathbf{j})$ N, $(-9\mathbf{i} + 5\mathbf{j})$ N and $p\mathbf{i}$ N.

(a) Find the value of p and the value of m. [4]

(b) The force $(-9\mathbf{i} + 5\mathbf{j})$ N is removed. The other forces are unchanged. Find the magnitude of the acceleration of the particle. [2]

10. **8 marks · harder**

A particle P of mass 0.5 kg is moving with velocity $(6\mathbf{i} - 2\mathbf{j})$ m s^{-1} when $t = 0$. From $t = 0$, P is acted on by a single constant force $(-1.5\mathbf{i} + 2\mathbf{j})$ N.

(a) Find the acceleration of P. [2]

(b) Find the velocity of P at time t seconds. [1]

(c) Find the time at which P is moving parallel to $\mathbf{j}$, and its speed at that time. [3]

(d) Find the value of t when P is moving in the direction of the vector $(\mathbf{i} + \mathbf{j})$. [2]

Answers and worked solutions

Question 1

2 marks

1. M1 for substituting the collision time $t = 3$ into either $\mathbf{r}_B$ or $\mathbf{r}_C$.
2. A1 for calculating the correct position vector: $(8\mathbf{i} + 13\mathbf{j})$ m.

Question 2

3 marks

1. M1 for finding the speed: $\sqrt{5^2 + 12^2} = 13$ m s^{-1}.
2. M1 for using distance = speed × time: 13×4.
3. A1 for calculating 52 m.

Question 3

3 marks

1. M1 for finding the magnitude of the direction vector: $\sqrt{3^2 + (-4)^2} = 5$.
2. M1 for finding the required scaling factor for the velocity: $10/5 = 2$.
3. A1 for computing the final vector: $2(3\mathbf{i} - 4\mathbf{j}) = (6\mathbf{i} - 8\mathbf{j})$ m s^{-1}.

Question 4

4 marks

1. M1 for establishing the general velocity equation: $\mathbf{v} = \mathbf{u} + \mathbf{a}t = (10 - 2t)\mathbf{i} + (-4 + 3t)\mathbf{j}$.
2. M1 for identifying the condition for moving parallel to $\mathbf{j}$, which is setting the $\mathbf{i}$ component to zero.
3. M1 for creating the equation: $10 - 2t = 0$.
4. A1 for calculating $t = 5$ s.

Question 5

5 marks

Answer: (b) $0.6\ m$ when $t = 2.16$

(a) $OP^2 = (3t - 6)^2 + (9 - 4t)^2$ **M1**

$= 9t^2 - 36t + 36 + 16t^2 - 72t + 81 = 25t^2 - 108t + 117$ **A1** (cso)

(b) $25t^2 - 108t + 117 = 25(t - 2.16)^2 + 0.36$ (or any complete method for the minimum) **M1**

$t = 2.16$ **A1**

Least distance $\sqrt{0.36} = 0.6\ m$ **A1**

Question 6

6 marks

Answer: (a) $(-2\mathbf{i} + 3\mathbf{j})\ ms^{-2}$ (b) $(-1.6\mathbf{i} + 2.4\mathbf{j})\ N$ (c) 2.88 N

(a) $(-6\mathbf{i} + 12\mathbf{j}) = (4\mathbf{i} - 3\mathbf{j}) + 5\mathbf{a}$ **M1**

$\mathbf{a} = (-2\mathbf{i} + 3\mathbf{j})\ ms^{-2}$ **A1**

(b) $\mathbf{F} = 0.8\mathbf{a}$ **M1**

$(-1.6\mathbf{i} + 2.4\mathbf{j})\ N$ **A1**

(c) $\sqrt{1.6^2 + 2.4^2}$ **M1**

2.88 N (awrt) **A1**

Question 7

2 marks

Answer: $5\mathbf{i} - 4\mathbf{j}$

$\mathbf{v}_A - \mathbf{v}_B = (4\mathbf{i} - 3\mathbf{j}) - (-\mathbf{i} + \mathbf{j})$ **M1**

$= (5\mathbf{i} - 4\mathbf{j})$ km h^{-1} **A1**

Answer: $5\mathbf{i} - 4\mathbf{j}$

Question 8

5 marks

1. M1 for identifying that a vector in the direction of $5\mathbf{i} - 12\mathbf{j}$ with magnitude 13 is exactly $5\mathbf{i} - 12\mathbf{j}$ (since $\sqrt{5^2 + (-12)^2} = 13$).
2. M1 for setting up the resultant force expression: $\mathbf{F}_{\text{net}} = \mathbf{F}_1 + \mathbf{F}_2 = (a + 4)\mathbf{i} + (b - 3)\mathbf{j}$.
3. M1 for equating the components: $a + 4 = 5$ and $b - 3 = -12$.
4. A1 for finding $a = 1$.
5. A1 for finding $b = -9$.

Question 9

6 marks

Answer: (a) $p = 5$, $m = 1.22$ (b) 8.41 m s^{-2}

(a) $\mathbf{i}$: $4 - 9 + p = 0$ **M1**

$p = 5$ **A1**

$\mathbf{j}$: $7 + 5 - 9.8m = 0$ **M1**

$m = \dfrac{12}{9.8} = 1.2$ or 1.22 **A1**

(b) Resultant $= (9\mathbf{i} - 5\mathbf{j})\ N$ and $\sqrt{106} = ma$ **M1**

$a = 8.4$ or $8.41\ ms^{-2}$ **A1**

Note: as $g = 9.8$ is used, answers are given to 2 or 3 significant figures. Use the unrounded $m = \frac{60}{49}$ in (b); 8.44, from the rounded $m = 1.22$, is A0 (premature approximation).

Question 10

8 marks

Answer: (a) $(-3\mathbf{i} + 4\mathbf{j})\ ms^{-2}$ (c) $t = 2$, 6 m s^{-1} (d) $t = \frac{8}{7}$

(a) $(-1.5\mathbf{i} + 2\mathbf{j}) = 0.5\mathbf{a}$ **M1**

$\mathbf{a} = (-3\mathbf{i} + 4\mathbf{j})\ ms^{-2}$ **A1**

(b) $\mathbf{v} = (6 - 3t)\mathbf{i} + (-2 + 4t)\mathbf{j}$ **B1ft**

(c) $6 - 3t = 0$ **M1**

$t = 2$ **A1**

$\mathbf{v} = 6\mathbf{j}$, speed 6 m s^{-1} **A1**

(d) $6 - 3t = -2 + 4t$ (components equal and positive) **M1**

$t = \frac{8}{7}$ $(= 1.14)$ **A1**

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