A-LEVEL MATHS (EDEXCEL 9MA0) · PURE YEAR 2 · CHAPTER 12: VECTORS · A* EXAM PRACTICE

Hints online, answers free with an account:
mathswariz.uk/worksheets/a-level-pure-year-2-chapter-12-a-star/

# Vectors: A* questions

87 marks

Date


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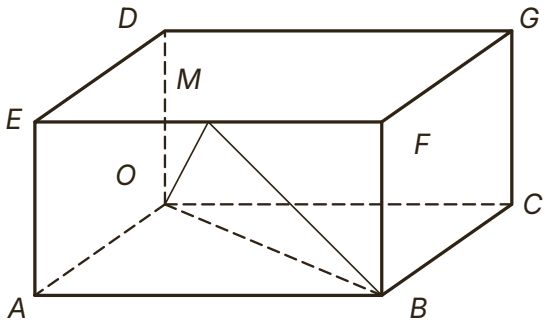
## X A* exam questions

A to A*

Extended Edexcel-style questions. Show every step. The hints are at the end of the sheet. Use one at a time.

**X1** $OABCDEFG$ is a cuboid. $O$ is the origin and $A$, $B$ and $C$ are $(6, 0, 0)$, $(6, 8, 0)$ and $(0, 8, 0)$. The points $D$, $E$, $F$ and $G$ are $4$ units directly above $O$, $A$, $B$ and $C$. $M$ is the midpoint of $EF$.

**(a)** Show that triangle $OMB$ has a right angle at $M$. [3 marks]




**(b)** Find angle $MOB$. Give your answer to $1$ decimal place. [2 marks]

Answer angle $MOB = \ldots^\circ$



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**(c)** The point $P$ lies on the line through $O$ and $M$, and $P$ is not $O$. Given that $BP = BO$, find the coordinates of $P$. [4 marks]

Answer $P = (\ldots, \ldots, \ldots)$

**(d)** Explain why $M$ is the midpoint of $OP$. [2 marks]

**Total for X1: 11 marks**


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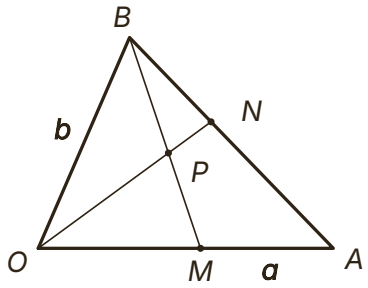
**X2** In triangle $OAB$, $\overrightarrow{OA} = \mathbf{a}$ and $\overrightarrow{OB} = \mathbf{b}$, where $\mathbf{a}$ and $\mathbf{b}$ are not parallel. $M$ is the point on $OA$ with $OM : MA = 2 : 1$. $N$ is the point on $AB$ with $AN : NB = 3 : 1$. The lines $ON$ and $BM$ meet at $P$. Find the ratios $OP : PN$ and $BP : PM$. [9 marks]




not to scale

Answer $OP : PN = \ldots$ , $BP : PM = \ldots$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**X3** The points $A$ and $B$ are $(1, -2, 4)$ and $(3, -1, 2)$. The point $C$ is $(9 - p,\ p - 1,\ 2 - 2p)$, where $p$ is a constant.

**(a)** Given that $A$, $B$ and $C$ are collinear, find $p$ and the ratio $AB : BC$. [4 marks]

Answer $p = \ldots$ , $AB : BC = \ldots$

**(b)** Instead, $|\overrightarrow{BC}| = 3\sqrt{6}$. Find the two possible values of $p$. [4 marks]

Answer $p = \ldots$ or $p = \ldots$


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**(c)** For the case $p = -1$, show that $\cos ABC = -\dfrac{\sqrt{6}}{6}$. [3 marks]

**(d)** Hence find the exact area of triangle $ABC$ when $p = -1$. [2 marks]

Answer area $= \ldots$

**Total for X3: 13 marks**


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**X4** A particle $P$ of mass $2$ kg is acted on by its weight and by three forces, in newtons: $\mathbf{F}_1 = 3\mathbf{i} - 2\mathbf{j} + 5\mathbf{k}$, $\mathbf{F}_2 = p\mathbf{i} + 4\mathbf{j} + q\mathbf{k}$ and $\mathbf{F}_3 = -\mathbf{i} + r\mathbf{j} + 8.6\mathbf{k}$. The unit vectors $\mathbf{i}$ and $\mathbf{j}$ are horizontal and $\mathbf{k}$ is vertically upwards. Take $g = 9.8$ m s$^{-2}$. The particle is in equilibrium.

**(a)** Find $p$, $q$ and $r$. [4 marks]

Answer $p = \ldots$, $q = \ldots$, $r = \ldots$

**(b)** The force $\mathbf{F}_2$ is removed. Find the acceleration of $P$ and its magnitude. [3 marks]

Answer $\mathbf{a} = \ldots$, $|\mathbf{a}| = \ldots$


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**(c)** When $\mathbf{F}_2$ is removed, $P$ is at rest at the origin. Explain why $P$ then moves in a straight line. Find the distance $P$ moves in the next $3$ seconds, and the angle between its direction of motion and the downward vertical. [5 marks]

Answer distance $= \ldots$ m, angle $= \ldots^\circ$

**Total for X4: 12 marks**


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**X5** Two ships $S$ and $T$ move with constant velocities. Their position vectors, in km, at time $t$ hours after noon are $\mathbf{r}_S = (\mathbf{i} + 2\mathbf{j}) + t(3\mathbf{i} + 4\mathbf{j})$ and $\mathbf{r}_T = 12\mathbf{i} + t(-\mathbf{i} + 7\mathbf{j})$, where $\mathbf{i}$ points east and $\mathbf{j}$ points north.

**(a)** Find the speed of $S$ and the bearing on which $S$ sails. [3 marks]

Answer speed $= \ldots$ , bearing $= \ldots$

**(b)** Show that the distance $d$ km between the ships at time $t$ satisfies $d^2 = 25t^2 - 100t + 125$. [3 marks]


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**(c)** Hence find the least distance between the ships and the time at which it occurs. [3 marks]

Answer least distance $= \ldots$ km at $\ldots$

**(d)** The ships can talk by radio when they are at most $13$ km apart. For how long after noon can they talk? [3 marks]

Answer $\ldots$ hours

**Total for X5: 12 marks**


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**X6** A particle of mass $0.5$ kg moves in a horizontal plane under a constant resultant force. At time $t = 0$ it is at the point with position vector $(2\mathbf{i} + 3\mathbf{j})$ m and has velocity $(3\mathbf{i} - 5\mathbf{j})$ m s$^{-1}$. At time $t = 2$ seconds its velocity is $(5\mathbf{i} + \mathbf{j})$ m s$^{-1}$. Find the magnitude of the resultant force. Show that, for $t \geq 0$, the particle never moves parallel to $\mathbf{j}$. Find the position vector of the particle at the instant it moves in the direction of $\mathbf{i} + \mathbf{j}$. [10 marks]

Answer $|\mathbf{F}| = \ldots$ N, $\mathbf{r} = \ldots$ m


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**X7** A drone flies in a straight line at constant velocity. Its position vector, in metres, $t$ seconds after it is first seen is $\mathbf{r} = (-30 + 6t)\mathbf{i} + (40 - 2t)\mathbf{j} + (5 + 3t)\mathbf{k}$, relative to a point $O$ on horizontal ground. The vectors $\mathbf{i}$ and $\mathbf{j}$ point east and north and $\mathbf{k}$ points vertically upwards.

**(a)** Show that the speed of the drone is $7$ m s$^{-1}$, and find the angle its path makes with the horizontal. [4 marks]

Answer angle $= \ldots^\circ$

**(b)** Find the height of the drone when it is directly north of $O$. [2 marks]

Answer ... m


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**(c)** A vertical mast of height $18$ m stands on the ground at the point with position vector $(6\mathbf{i} + 28\mathbf{j})$ m. Show that the drone passes directly over the mast, and find by how much it clears the top of the mast. [3 marks]

Answer clears it by ... m

**(d)** Give two reasons why this model may not be realistic, and suggest one way to improve it. [3 marks]

**Total for X7: 12 marks**


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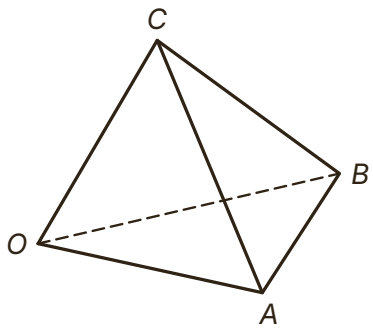
**X8** $OABC$ is a tetrahedron with $\overrightarrow{OA} = \mathbf{a}$, $\overrightarrow{OB} = \mathbf{b}$ and $\overrightarrow{OC} = \mathbf{c}$. Three lines are drawn, each joining the midpoints of a pair of opposite edges: $OA$ with $BC$, $OB$ with $AC$, and $OC$ with $AB$. Prove that the three lines meet at one point, and that this point is the midpoint of each line. [8 marks]





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## F How did it go?

Colour one circle on each line.

| | Not yet | Nearly | Yes |
|---|---|---|---|
| I can find lengths, angles and areas from vectors in three dimensions. | ○ | ○ | ○ |
| I can find a ratio by writing a vector two ways and comparing coefficients. | ○ | ○ | ○ |
| I can solve problems with a parameter, including collinearity and given distances. | ○ | ○ | ○ |
| I can use vectors for forces, acceleration and motion, and criticise a model. | ○ | ○ | ○ |


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# Hints

Use one hint at a time. Cover the ones below it with a sheet of paper.

**X1**

**Hint 1** Find the three squared lengths of the sides of triangle $OMB$. No angle formula is needed.

**Hint 2** Every point on the line through $O$ and $M$ is $\lambda(6\mathbf{i} + 4\mathbf{j} + 4\mathbf{k})$ for some $\lambda$.

**Hint 3** If $BO = BP$, the triangle $OBP$ is isosceles. Where does the perpendicular from $B$ meet $OP$?

**X2**

**Hint 1** Write $\overrightarrow{ON}$ by going from $O$ to $A$, then $\frac{3}{4}$ of the way along $\overrightarrow{AB}$.

**Hint 2** Write $\overrightarrow{OP}$ in two ways: as $\lambda\overrightarrow{ON}$, and as $\overrightarrow{OB} + \mu\overrightarrow{BM}$.

**Hint 3** Because $\mathbf{a}$ and $\mathbf{b}$ are not parallel, the two coefficients of $\mathbf{a}$ must be equal, and so must the two coefficients of $\mathbf{b}$.

**X3**

**Hint 1** Collinear means $\overrightarrow{AC}$ is a multiple of $\overrightarrow{AB}$. Use two components to find $p$, then check the third.

**Hint 2** Write $\overrightarrow{BC}$ in terms of $p$ and set the sum of the squares of its components equal to $54$.

**Hint 3** Find all three side lengths, use the cosine rule, then $\sin^2\theta + \cos^2\theta = 1$ for the area.

**X4**

**Hint 1** In equilibrium the four forces add to zero. The weight is $-2g\mathbf{k}$.

**Hint 2** Once $\mathbf{F}_2$ is removed, the other three forces add to $-\mathbf{F}_2$. Divide by the mass.

**Hint 3** From rest, $\mathbf{s} = \frac{1}{2}\mathbf{a}t^2$. The downward vertical is $-\mathbf{k}$, so use the $\mathbf{k}$ component of $\mathbf{a}$ over $|\mathbf{a}|$.

**X5**

**Hint 1** A bearing is measured clockwise from north, so use the $\mathbf{i}$ component over the $\mathbf{j}$ component.

**Hint 2** The displacement from $S$ to $T$ is $\mathbf{r}_T - \mathbf{r}_S$.

**Hint 3** Solve $d^2 \leq 169$. Check whether the ships are already within range at noon.


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| | | |
|---|---|---|
| **X6** | **Hint 1** | The acceleration is constant, so it is the change in velocity divided by the time. |
| | **Hint 2** | Moving parallel to $\mathbf{j}$ means the $\mathbf{i}$ component of $\mathbf{v}$ is zero. |
| | **Hint 3** | Moving in the direction of $\mathbf{i} + \mathbf{j}$ means the two components of $\mathbf{v}$ are equal and positive. Then use $\mathbf{r} = \mathbf{r}_0 + \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$. |
| **X7** | **Hint 1** | The velocity is the vector of the coefficients of $t$. The vertical part of the speed is the $\mathbf{k}$ component. |
| | **Hint 2** | Directly north of $O$ means the $\mathbf{i}$ component is zero. |
| | **Hint 3** | Find $t$ from one horizontal component. The drone is over the mast only if the other component matches at the same $t$. |
| **X8** | **Hint 1** | The midpoint of the line joining points with position vectors $\mathbf{p}$ and $\mathbf{q}$ is $\frac{1}{2}(\mathbf{p} + \mathbf{q})$. |
| | **Hint 2** | Find the midpoint of the line joining the midpoints of $OA$ and $BC$ in terms of $\mathbf{a}$, $\mathbf{b}$ and $\mathbf{c}$. |
| | **Hint 3** | Do the same for the other two lines. If all three give the same vector, that point is on all three lines, halfway along each. |


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