adamjee maths

A-LEVEL MATHS / EDEXCEL / FREE RESOURCES

Constant acceleration

Mark scheme

6 questions

Exam questions and marking instructions remain credited to their board.

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1(a)	$v = 15 + (2 \times 4)$	M1	3.1b
	$= 23\ (\text{m s}^{-1})$	A1	1.1b
		(2)	
1(b)	$D - 400 = 800 \times 2$	M1	3.1b
	$(D =)\ 2000$	A1	1.1b
		(2)	
			(4 marks)

Notes:

1(a)	M1	Use of $v = u + at$ or any other **complete** method to form an equation in v only. Condone sign errors. e.g. May find s first: $s = (15 \times 4) + \frac{1}{2} \times 2 \times 4^2 = 76$ then either: $76 = 4v - \frac{1}{2} \times 2 \times 4^2$ or: $76 = \frac{(15 + v)}{2} \times 4$ or: $v^2 = 15^2 + 2 \times 2 \times 76$ **N.B.** If they use $v = u + at$ and have $15 = u + (2 \times 4)$, M1A0 M0 if they clearly use an incorrect *suvat* formula or $u = 0$
	A1	cao. Must be positive. A0 if they get 23 but go on and do something with it. i.e. not ISW **N.B.** 23 with no working can score both marks.
1(b)	M1	Use of $F = ma$ to form an equation in D or a complete expression for D, with correct number of terms, condone sign errors and g in the ma term.
	A1	cao **N.B.** 2000 with no working can score both marks.

Question	Scheme	Marks	AOs
N.B. Penalise the use of $g = 9.81$ ONCE (the first time it is used) for the whole question.			

3(a)	$(\mathbf{F} =)\ (\mathbf{i} - 1.2\mathbf{j})$	B1	3.4
		(1)	
3(b)	$\mathbf{v} = (-7\mathbf{i} + 7.8\mathbf{j}) + 2(2\mathbf{i} - 2.4\mathbf{j})$	M1	2.1
	$= (-3\mathbf{i} + 3\mathbf{j})\ (\text{m s}^{-1})$	A1	1.1b
		(2)	
3(c)	Use trig to find an equation in a relevant angle	M1	2.1
	e.g. $\tan\alpha = 1$ or -1 or $\sin\alpha = \frac{3}{\sqrt{3^2+3^2}}$ or $\frac{-3}{\sqrt{3^2+3^2}}$ or $\cos\alpha = \frac{3}{\sqrt{3^2+3^2}}$ or $\frac{-3}{\sqrt{3^2+3^2}}$	A1	1.1b
	315^o	A1	2.2a
		(3)	
3(d)	$\overrightarrow{OA} = 5(-7\mathbf{i} + 7.8\mathbf{j}) + \frac{1}{2}(2\mathbf{i} - 2.4\mathbf{j}) \times 5^2$	M1	3.1a
	$= (-10\mathbf{i} + 9\mathbf{j})\ (\text{m})$	A1	1.1b
		(2)	
			(8 marks)

Notes:

Accept column vectors throughout apart from in the final answer for (a) and (d) which must be in terms of i and j, but only penalise ONCE for the whole question.

N.B. For final answers to (a), (b) and (d) , penalise incorrect vector notation.

3(a)	B1	Must be in terms of **i** and **j** Do not accept $0.5 \times (2\mathbf{i} - 2.4\mathbf{j})$ Do not need **F** =
3(b)	M1	Use of **v** = **u** + **a***t* or any other complete method, e.g. integration, to find an unsimplified expression for **v** at $t = 2$, condone sign errors. **N.B.** If using integration, must have used $t = 0$, $\mathbf{v} = (-7\mathbf{i} + 7.8\mathbf{j})$ to find the constant of integration and included it in their expression for **v** at $t = 2$.
	A1	cao. **N.B.** Ignore if they go on and find the speed.
3(c)	M1	Use trig to find an equation in a relevant angle for their **v**
	A1	Correct equation.
	A1	Cao (with or without the degree sign), must come from a correct **v** **N.B.** $\pm 45^o, \pm 135^o, \pm 225^o, -315^o$ with no working scores M1A1 315^o with no working scores all 3 marks.

3(d)	M1	Use of $\mathbf{r} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$ with $t = 5$ or any other complete method, e.g. integration of their $\mathbf{v} = f(t)$ and use of $t = 5$, to find an unsimplified expression for $\overrightarrow{OA}$ (No need to show that $\mathbf{C} = \mathbf{0}$) M0 if they use $\mathbf{u} = \mathbf{0}$
	A1	Must be in terms of **i** and **j** **N.B.** Ignore if they go on and find the length *OA*

Question	Scheme	Marks	AOs

1(a)	16 ($\mathrm{m\,s^{-1}}$) seen as the answer	B1	1.1b
		(1)	
1(b)	$s=\frac{1}{2}\times 3.2\times 5^2$ **OR** $s=\frac{(0+16)}{2}\times 5$ **OR** $s=(16\times 5)-\frac{1}{2}\times 3.2\times 5^2$ **OR** $16^2=2\times 3.2\times s$ **OR** from a *v*-*t* graph, $s=\frac{1}{2}\times 5\times 16$	M1	3.1b
	s = 40 (m)	A1	1.1b
		(2)	
			(3 marks)

Notes:

1a	B1	cao. Must be positive. Ignore any working.		
1b	M1	Complete method to find an equation in s only, possibly using their '16' Allow 'reversed motion': use of $s=vt-\frac{1}{2}at^2$ with v = 0 i.e. $s=-\frac{1}{2}\times 3.2\times 5^2$ can score M1 and s = -40 so distance is 40 (m) can score the A1		
	A1	cao. Must be positive.		
		N.B. correct answer only, in (b), can score both marks.		

Question	Scheme	Marks	AOs

4(a)	$\mathbf{v}_B = (-16\mathbf{i} - 3\mathbf{j}) + 5(2.4\mathbf{i} + \mathbf{j})$	M1	3.4
	$\mathbf{v}_B = (-4\mathbf{i} + 2\mathbf{j})$	A1	1.1b
	$\sqrt{(-4)^2 + 2^2}$	M1	3.1a
	$\sqrt{20}$ = $2\sqrt{5}$, 4.5 or better ($\mathrm{m\,s^{-1}}$)	A1	1.1b
		(4)	
4(b)	Using *A* as the initial position: $\mathbf{r}_C = \mathbf{v}_A t + \frac{1}{2}\mathbf{a}t^2 + \mathbf{r}_A$ where $t = T$ $(4\mathbf{i} + c\mathbf{j}) = (-16\mathbf{i} - 3\mathbf{j})T + \frac{1}{2}(2.4\mathbf{i} + \mathbf{j})T^2 + (44\mathbf{i} - 10\mathbf{j})$ **OR** $\begin{pmatrix}4\\c\end{pmatrix} = \begin{pmatrix}-16\\-3\end{pmatrix}T + \frac{1}{2}\begin{pmatrix}2.4\\1\end{pmatrix}T^2 + \begin{pmatrix}44\\-10\end{pmatrix}$ Equating **i**-components, to give a **quadratic** equation in *T* only. Allow *t* instead of *T*. **N.B.** Allow omission of 44 for this M mark. Also allow ± 4 but M0 if 4 is not used at all i.e. $4 = -16T + \frac{1}{2} \times 2.4T^2$ scores M1A0A0	M1	3.1a
	$4 = -16T + \frac{1}{2} \times 2.4T^2 + 44$	A1	1.1b
	(*T* =) 10	A1	1.1b
	ALTERNATIVE using *B* as the initial position: (The position vector of *B*, $\mathbf{r}_B$, should be $-6\mathbf{i} - 12.5\mathbf{j}$ but no credit for finding this) $\mathbf{r}_C = \mathbf{v}_B t + \frac{1}{2}\mathbf{a}t^2 + \mathbf{r}_B$ using **their** $\mathbf{v}_B$ from (a) and **their** $\mathbf{r}_B$ $(4\mathbf{i} + c\mathbf{j}) = (-4\mathbf{i} + 2\mathbf{j})t + \frac{1}{2}(2.4\mathbf{i} + \mathbf{j})t^2 + (-6\mathbf{i} - 12.5\mathbf{j})$ $\begin{pmatrix}4\\c\end{pmatrix} = \begin{pmatrix}-4\\2\end{pmatrix}t + \frac{1}{2}\begin{pmatrix}2.4\\1\end{pmatrix}t^2 + \begin{pmatrix}-6\\-12.5\end{pmatrix}$ Equating **i**-components, to give a **quadratic** equation in *t* only. Allow if they have *T* instead of *t*.	M1	3.1a

	N.B. Allow omission of their -6 or if they use 44 for this M mark. Also allow ± 4 but M0 if 4 is not used at all. e.g. $4 = -4t + \frac{1}{2} \times 2.4t^2$ scores M1A0A0		
	$4 = -4t + \frac{1}{2} \times 2.4t^2 - 6$	A1	1.1b
	t = 5 so (T =) 10	A1	1.1b
		(3)	
4(c)	Equating **j**-components, with <u>their value of T or t substituted</u>, to give an equation, which must have a square term, in c only. **N.B.** Allow $\pm c$ in their equation. **(N.B.** Allow omission of -10 or their -12.5 for this M mark i.e. if using A as initial position $c = (-3 \times 10) + \frac{1}{2} \times 1 \times 10^2$ scores M1M0A0 **OR** if using B as initial position $c = (2 \times 5) + \frac{1}{2} \times 1 \times 5^2$ scores M1M0A0)	M1	2.1
	if using A as initial position $c = (-3 \times 10) + \frac{1}{2} \times 1 \times 10^2 + (-10)$ **N.B.** Allow $\pm c$ and/or $\pm(-10)$ in their equation **OR** if using B as initial position $c = (2 \times 5) + \frac{1}{2} \times 1 \times 5^2 + (-12.5)$ **N.B.** Allow $\pm c$ and/or $\pm(-12.5)$ in their equation	M1	1.1b
	c = 10	A1	1.1b
		(3)	
			(10 marks)

Notes: Accept column vectors throughout		
4a	M1	Use of **v** = **u** + **a***t* with t = 5 to give an unsimplified $\mathbf{v}_B$ M0 if **u** = **0**

		N.B. If using integration, they must get to the same stage i.e. have found the constant and put $t = 5$ M0 if they omit the constant altogether
	A1	Correct $\mathbf{v}_B$ with **i**'s and **j**'s collected
	M1	Use of Pythagoras on *their* $\mathbf{v}_B$ to give a magnitude (need the root)
	A1	Must be positive
4b	M1	Equating components of **i** to give an equation in T or t only. **N.B.** (they could use integration to get to the same stage) for this M mark, they **only** need to be equating the **i**-components, and receive no credit until they do so. M0 if **u** = **0**
	A1	A correct equation in T or t only (could be in $(T - 5)$ if using B as initial position)
	A1	$T = 10$
4c	M1	Equating components of **j** to give an equation in c only but allow omission of their initial position
	M1	With their value of T or t and **must include t = 0 position** (should be -10 if using A **OR** their -12.5 if using B)
	A1	cao

Question	Scheme	Marks	AOs
	N.B. In this question, allow misread of α for a.		

1(a)	Use of $\mathbf{v} = \mathbf{u} + \mathbf{a}t$ with $t = 2$: $\mathbf{v} = 4\mathbf{i} + 2(2\mathbf{i} - 3\mathbf{j})$ **OR integration**: $\mathbf{v} = (2\mathbf{i} - 3\mathbf{j})t + 4\mathbf{i}$, with $t = 2$	M1	3.1a
	$\mathbf{v} = 8\mathbf{i} - 6\mathbf{j}$	A1	1.1b
		(2)	
1(b)	Use of $\mathbf{r} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$ at $t = 3$: $(\mathbf{i} + \mathbf{j}) + \left[3 \times 4\mathbf{i} + \frac{1}{2} \times (2\mathbf{i} - 3\mathbf{j}) \times 3^2\right]$ **OR**: find $\mathbf{v}$ at $t = 3$: $4\mathbf{i} + 3(2\mathbf{i} - 3\mathbf{j}) = (10\mathbf{i} - 9\mathbf{j})$ then use $\mathbf{r} = \frac{1}{2}(\mathbf{u} + \mathbf{v})t$ $(\mathbf{i} + \mathbf{j}) + \left[\frac{1}{2}\left[4\mathbf{i} + (10\mathbf{i} - 9\mathbf{j})\right] \times 3\right]$ or $\mathbf{r} = \mathbf{v}t - \frac{1}{2}\mathbf{a}t^2$ $(\mathbf{i} + \mathbf{j}) + \left[3 \times (10\mathbf{i} - 9\mathbf{j}) - \frac{1}{2} \times (2\mathbf{i} - 3\mathbf{j}) \times 3^2\right]$ **OR integration:** $\mathbf{r} = (\mathbf{i} + \mathbf{j}) + \left[(2\mathbf{i} - 3\mathbf{j})\frac{1}{2}t^2 + 4t\mathbf{i}\right]$, with $t = 3$	M1	3.1a
	$\mathbf{r} = 22\mathbf{i} - 12.5\mathbf{j}$	A1	2.2a
		(2)	
			(4 marks)

Notes: Accept column vectors throughout

1a	M1	Complete method to find **v**, using **ruva***t* or integration (M0 if **i** and/or **j** is missing)
	A1	Apply isw if they also find the speed
1b	M1	Complete method to find the p.v. but this mark can be scored if they omit **(i + j)** i.e. the M1 is for the expression in the square bracket If they integrate, the M1 is earned once the expression in the square bracket is seen with $t = 3$ (M0 if **i** and/or **j** is missing)
	A1	cao

Question	Scheme	Marks	AOs
	Mark parts (a) and (b) together		

8(a)	Use of $\mathbf{r} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$: $(7\mathbf{i} - 10\mathbf{j}) = 2(2\mathbf{i} - 3\mathbf{j}) + \frac{1}{2}\mathbf{a}2^2$	M1	3.1b
	$\mathbf{a} = (1.5\mathbf{i} - 2\mathbf{j})$	A1	1.1b
	$\lvert\mathbf{a}\rvert = \sqrt{1.5^2 + (-2)^2}$	M1	1.1b
	= 2.5 m s^{-2} * GIVEN ANSWER	A1*	2.1
		(4)	
(b)	Use of $\mathbf{v} = \mathbf{u} + \mathbf{a}t = (2\mathbf{i} - 3\mathbf{j}) + 2(1.5\mathbf{i} - 2\mathbf{j})$	M1	3.1b
	$= (5\mathbf{i} - 7\mathbf{j})$	A1	1.1b
	$\mathbf{v} = (5\mathbf{i} - 7\mathbf{j}) + t(4\mathbf{i} + 8.8\mathbf{j}) = (5 + 4t)\mathbf{i} + (8.8t - 7)\mathbf{j}$ and $(5 + 4t) = (8.8t - 7)$	M1	3.1b
	t = 2.5 (s)	A1	1.1b
		(4)	
			(8 marks)

Notes: Allow column vectors throughout

(a)

No credit for individual component calculations

M1: Using a complete method to obtain the acceleration. **N.B.** Equation, in **a** only, could be obtained by two integrations

ALTERNATIVE

M1: Use velocity at half-time (t = 1) = Average velocity over time period

So at $t = 1$, $\mathbf{v} = \frac{1}{2}(7\mathbf{i} - 10\mathbf{j})$ so $\mathbf{a} = \frac{1}{2}(7\mathbf{i} - 10\mathbf{j}) - (2\mathbf{i} - 3\mathbf{j})$

N.B. could see $(7\mathbf{i} - 10\mathbf{j}) = (4\mathbf{i} - 6\mathbf{j}) + 2\mathbf{a}$ as first line of working

A1: Correct **a** vector

M1: Attempt to find magnitude of their **a** using form $\sqrt{a^2 + b^2}$

A1*: Correct GIVEN ANSWER obtained correctly

(b)

M1: Using a complete method to obtain the velocity at A e.g.by use of $\mathbf{v} = \mathbf{u} + \mathbf{a}t$ with t = 2 and **u** = 2**i** – 3**j** and their **a**

OR: by use of $\mathbf{s} = \mathbf{v}t - \frac{1}{2}\mathbf{a}t^2$

OR: by integrating their **a,** with addition of **C** = 2**i** – 3**j,** and putting t = 2

A1: correct vector

M1: Complete method to find equation in t only

e.g. by using $\mathbf{v} = \mathbf{u} + \mathbf{a}t$, with their **u** and equating **i** and **j** components

OR: by integrating $(4\mathbf{i} + 8.8\mathbf{j})$, with addition of a constant, and equating **i** and **j** components.

N.B. Must be equating **i** and **j** components of a velocity vector and must be their velocity at *A*, to give an equation in *t* only for this M mark

A1: 2.5 (s)

Question	Scheme	Marks	AOs