Question	Scheme	Marks	AOs
	Allow column vectors throughout this question		
1(a)	Differentiate **v** wrt *t*	M1	3.1a
	$\frac{3}{2}t^{-\frac{1}{2}}\mathbf{i}-2\mathbf{j}$ isw	A1	1.1b
		(2)	
1(b)	$3t^{\frac{1}{2}}=2t$	M1	2.1
	Solve for *t*	DM1	1.1b
	$t=\frac{9}{4}$	A1	1.1b
		(3)	
1(c)	Integrate **v** wrt *t*	M1	3.1a
	$\mathbf{r}=2t^{\frac{3}{2}}\mathbf{i}-t^2\mathbf{j}(+\mathbf{C})$	A1	1.1b
	$t=1$, $\mathbf{r}=-\mathbf{j}$ => $\mathbf{C}=-2\mathbf{i}$ so $\mathbf{r}=2t^{\frac{3}{2}}\mathbf{i}-t^2\mathbf{j}-2\mathbf{i}$	A1	2.2a
		(3)	
1(d)	$\sqrt{(3t^{\frac{1}{2}})^2+(2t)^2}=10$ or $(3t^{\frac{1}{2}})^2+(2t)^2=10^2$	M1	2.1
	$9t+4t^2=100$	M(A)1	1.1b
	$t=4$	A1	1.1b
	$\mathbf{r}=14\mathbf{i}-16\mathbf{j}$	M1	1.1b
	$\sqrt{14^2+(-16)^2}$	M1	3.1a
	$\sqrt{452}$ $(2\sqrt{113})$ (m)	A1	1.1b
		(6)	
			(14 marks)

Notes:

1a	M1	Both powers decreasing by 1 (M0 if vector(s) disappear but allow recovery)
	A1	cao
1b	M1	Complete method, using **v**, to obtain an equation in *t* only, allow a sign error
	DM1	Dependent on M1,solve for *t*

	A1	cao
1c	M1	Both powers increasing by 1 (M0 if vectors disappear but allow recovery)
	A1	Correct expression without **C**
	A1	cao
1d	M1	Use of Pythagoras on **v** and 10 to set up equation in *t*
	M(A)1	Correct 3 term quadratic in *t*
	A1	cao
	M1	Substitute their numerical *t* value into their **r**
	M1	Use of Pythagoras to find the magnitude of their **r**
	A1	cso

Question	Scheme	Marks	AOs
2(a)	Put $t = 2$ in **v** and use Pythagoras: $\sqrt{12^2 + (-6\sqrt{2})^2}$	M1	3.1a
	$\sqrt{216}, 6\sqrt{6}$ or 15 or better (m s^{-1})	A1	1.1b
		(2)	
2(b)	Differentiate **v** wrt t to obtain **a**	M1	3.4
	$6t\mathbf{i} - 3t^{-\frac{1}{2}}\mathbf{j}$ oe (m s^{-2}) isw	A1	1.1b
		(2)	
2(c)	Integrate **v** wrt t to obtain **r**	M1	3.4
	$\mathbf{r} = t^3\mathbf{i} - 4t^{\frac{3}{2}}\mathbf{j}\ (+\mathbf{C})$	A1	1.1b
	$(\mathbf{i} - 4\mathbf{j}) = 4^3\mathbf{i} - 4 \times 4^{\frac{3}{2}}\mathbf{j} + \mathbf{C}$	M1	3.1a
	$(-62\mathbf{i} + 24\mathbf{j})$ (m) isw e.g. if they go on to find the distance.	A1	1.1b
		(4)	
			(8 marks)

Notes: Accept column vectors throughout apart from the answer to (b).

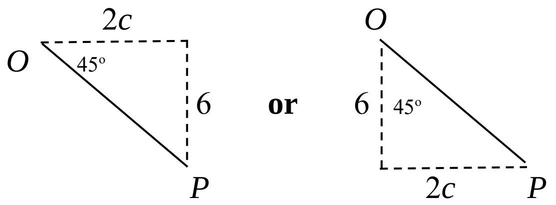
2a	M1	Need square root but -ve sign not required. Allow **i**'s and/or **j**'s to go missing from their **v** at $t = 2$, provided they have applied Pythagoras correctly.
	A1	cao **N.B**. Correct answer with no working can score 2 marks.
2b	M1	Both powers decreasing by 1. Allow a column vector. M0 if **i** or **j** is missing but allow recovery in (b).
	A1	cao. Do not accept a column vector.
2c	M1	Both powers increasing by 1 M0 if **i** or **j** is missing but allow recovery.
	A1	(**r** =) not required
	M1	Putting $\mathbf{r} = (\mathbf{i} - 4\mathbf{j})$ and $t = 4$ into their displacement **vector** expression which must have **C** (allow C) to give an equation in **C** only, seen or implied. Must have attempted to integrate **v** for this mark to be available. **N.B**. **C** does not need to be found and <u>this is a method mark, so allow slips.</u>
	A1	cao

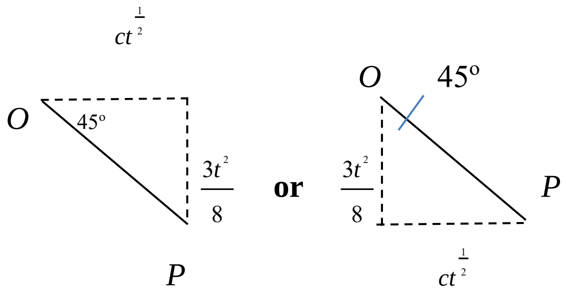
Question	Scheme	Marks	AOs
3(a)	7**i** – 3**j** seen or implied by Pythagoras	B1	1.1b
	Use Pythagoras: $\sqrt{7^2+(-3)^2}$	M1	3.1a
	$\sqrt{58}$, 7.6 or better ($\mathrm{m\ s^{-1}}$)	A1	1.1b
		(3)	
3(b)	$t^2-3t+7=2t^2-3$ **OR** $\dfrac{t^2-3t+7}{2t^2-3}=\dfrac{1}{1}=1$	M1	2.1
	t = 2 only	A1	1.1b
		(2)	
3(c)	Differentiate **v** wrt *t* to give a vector.	M1	3.1a
	$(2t-3)\mathbf{i}+4t\mathbf{j}$	A1	1.1b
		(2)	
3(d)	$2t-3=0$	M1	3.1a
	t = 1.5	A1	1.1b
		(2)	
		(9 marks)	

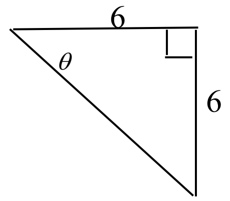
Notes: Allow column vectors throughout.

3a	B1	cao
	M1	Use of Pythagoras, including the square root, on a **velocity** vector at *t* = 0
	A1	cao. Must come from a <u>correct</u> **v**.
3b	M1	Equating **i** and **j** components of **v** or a ratio of 1:1 to obtain a quadratic in *t* only. If they use a constant, e.g. $t^2-3t+7=k$ and $2t^2-3=k$, *k* must be eliminated to earn this mark. **N.B.** M0 (since wrong working seen) if they write down $\mathbf{i}+\mathbf{j}=\left(t^2-3t+7\right)\mathbf{i}+\left(2t^2-3\right)\mathbf{j}$ **OR** $\begin{pmatrix}1\\1\end{pmatrix}=\begin{pmatrix}t^2-3t+7\\2t^2-3\end{pmatrix}$ **OR** $t^2-3t+7=1$ and $2t^2-3=1$

		and then $t^2 - 3t + 7 = 2t^2 - 3$
	A1	$t = 2$
		N.B. Allow M1A1 for a **correct** trial and error method where they obtain $\mathbf{v} = 5\mathbf{i} + 5\mathbf{j}$ when t = 2 but M0 if they don't get t = 2
3c	M1	At least one power decreasing by 1 in **each** component in their **v** (M0 if clearly dividing by t) **Both i** and **j** needed in their answer or a column vector Allow recovery if the **i** and **j** disappear and then reappear.
	A1	cao (must be a vector) isw e.g. if they find the magnitude or put t = 0 or differentiate again **i**'s and **j**'s do not need to be collected. **N.B**. Allow M1A0 for $2t - 3\mathbf{i} + 4t\mathbf{j}$
3d	M1	$2t - 3 = 0$ or (their **derivative** of the **i**-component of **v)** = 0 **N.B**. M0 if they equate the derivative of both components of **v** to zero.
	A1	cao **N.B.** Correct answer, with no working, can score both marks.

Question	Scheme	Marks	AOs
4(a)	**ALTERNATIVES** when $t = 4$ is substituted at the beginning.		
	$2c\mathbf{i} - 6\mathbf{j}$ or as a column vector, seen or implied.	B1	1.1b
	ALT 1  **AND** **either** $\tan 45^{\circ} = \frac{2c}{6}$ => $2c = 6$ **or** **states** isosceles triangle so $2c = 6$ **N.B.** In both of the above,we must see the justification for the equation. **ALT 2** $\tan 135^{\circ} = \frac{2c}{-6}$ => $2c = 6$ **N.B.** M0 if they are using the wrong bearing.	M1	3.1a
	$c = 3$ *	A1*	2.2a
	SC 1 M1A0: no right-angled triangle $2c\mathbf{i} - 6\mathbf{j} = k(\mathbf{i} - \mathbf{j})$ => $2c = 6$ **or** **i**-cpt = − **j**-cpt => $2c = 6$ **N.B.** In both of the above,we must see the justification for the equation. **SC 2 M1A0:** no right-angled triangle $\tan 45^{\circ} = \frac{2c}{6}$ or $\frac{6}{2c}$ => $2c = 6$ **N.B.** In the above,we must see the justification for the equation.		

	ALTERNATIVES when $t = 4$ is substituted at the end:		
	$ct^{\frac{1}{2}} = 2c$ **and** $(-)\frac{3t^2}{8} = (-)6$ when $t = 4$, seen or implied	B1	
	ALT 3  **AND** **either** $\tan 45^o = \frac{\frac{3t^2}{8}}{ct^{\frac{1}{2}}}$ => $2c = 6$ when $t = 4$ **or** **states** isosceles triangle, so $ct^{\frac{1}{2}} = \frac{3t^2}{8}$ => $2c = 6$ when $t = 4$ **N.B.** In both of the above,we must see the justification for the equation. **N.B.** M0 if they are using the wrong bearing.	M1	
	$c = 3$	A1*	
	SC 3 M1A0: no right-angled triangle $(ct^{\frac{1}{2}}\mathbf{i} - \frac{3t^2}{8}\mathbf{j}) = k(\mathbf{i} - \mathbf{j})$ => $2c = 6$ when $t = 4$ **or** **i**-cpt = − **j**-cpt => $ct^{\frac{1}{2}} = \frac{3t^2}{8}$ => $2c = 6$ when $t = 4$ **N.B.** In both of the above,we must see the justification for the equation. **SC 4 M1A0:** no right-angled triangle $\tan 45^o = \frac{\frac{3t^2}{8}}{ct^{\frac{1}{2}}}$ => $2c = 6$ when $t = 4$.		

	N.B. Allow a **verification**: i.e. use $c = 3$ and $t = 4$ to show that P is on a bearing of 135° from O. $6\mathbf{i} - 6\mathbf{j}$	B1	
	then a diagram: 	M1	
	AND $\tan\theta = \frac{6}{6}$ or isosceles triangle => $\theta = 45°$ **N.B.** In the above,we must see the justification for the equation.		
	bearing = 45° + 90° = 135°	A1*	
		(3)	
4(b)	Differentiate **r** wrt t to obtain **v**	M1	2.1
	$\mathbf{v} = 3\times\frac{1}{2}t^{-\frac{1}{2}}\mathbf{i} - \frac{3}{8}\times 2t\mathbf{j} = \frac{3}{2}t^{-\frac{1}{2}}\mathbf{i} - \frac{3}{4}t\mathbf{j}$ oe	A1	1.1b
	Put $t = 4$ into **both** components and use Pythagoras: $\sqrt{\left(\frac{3}{4}\right)^2 + (-3)^2}$	M1	3.1a
	$\sqrt{\frac{153}{16}}$ or $\frac{\sqrt{153}}{4}$ or $\frac{3\sqrt{17}}{4}$ or $3\sqrt{\frac{17}{16}} = 3.0923..$ (m s^{-1})	A1	1.1b
		(4)	
4(c)	Differentiate their **v** wrt t to obtain **a**	M1	3.4
	$\mathbf{a} = -\frac{3}{4}t^{-\frac{3}{2}}\mathbf{i} - \frac{3}{4}\mathbf{j}$	A1	1.1b
	$\frac{-\frac{3}{4}T^{-\frac{3}{2}}}{-\frac{3}{4}} = \frac{-1}{-27}$ oe	M1	2.1
	$(T =)\ 9$	A1	1.1b
		(4)	

		(11 marks)
Notes: Accept column vectors throughout		
4a	B1	$2c\mathbf{i}-6\mathbf{j}$ seen or implied. B0 for r = $2c$ – 6 if no evidence of components.
	M1	**ALT 1:** Use the bearing to obtain a CORRECT diagram showing a right-angled triangle with at least one 45° angle marked or clearly explained (i.e. 135° marked on the diagram and either $135^o - 90^o = 45^o$ or $180^o - 135^o = 45^o$), and $2c$ and ± 6 marked **AND** use of isosceles triangle or tan or (sin/cos and Pythag) to obtain $2c = 6$ **ALT 2: No diagram required** Use $\tan 135^o = \frac{2c}{-6}$ => $2c = 6$
	A1*	Given answer correctly obtained
		ALTERNATIVE when $t = 4$ is substituted at the end:
	B1	$ct^{\frac{1}{2}} = 2c$ **and** $(-)\frac{3t^2}{8} = (-)6$ when $t = 4$, seen or implied
	M1	**ALT 3:** Use the bearing to obtain a CORRECT diagram showing a right-angled triangle with at least one 45° angle marked or clearly explained (i.e. 135° marked on the diagram and either $135^o - 90^o = 45^o$ or $180^o - 135^o = 45^o$), and $ct^{\frac{1}{2}}$ and $\pm \frac{3t^2}{8}$ marked **AND** use of isosceles triangle or tan or (sin/cos and Pythag) to obtain $2c = 6$ when $t = 4$
	A1*	Given answer correctly obtained
4b	M1	Both powers of t decreasing by 1 (M0 if **i** or **j** is missing but allow recovery or working with components only) **N.B.** This mark is available if c has not been substituted for.
	A1	Correct unsimplified derivative or two correct components
	M1	Put $t = 4$ in their **v** (must be using an attempted derivative of **r**) and then use Pythagoras with the root, allow a missing – sign **N.B.** If they **state** $t = 4$, allow a slip when they substitute in, for this M mark. This mark is available if c has not been substituted for.
	A1	Accept 3.1 or better
4c	M1	Both powers of t decreasing by 1 **N.B.** This mark is available if c has not been substituted for (M0 if **i** or **j** is missing but allow recovery or working with components only).
	A1	Correct unsimplified derivative
	M1	Use of an appropriate **ratio** (must be using an attempted derivative of **their v)**, condone sign error and the **reciprocal,** to obtain an equation in t or ***T* only**. **N.B.** If they state that $-\frac{3}{4}T^{-\frac{3}{2}}\mathbf{i} - \frac{3}{4}\mathbf{j} = k(-\mathbf{i} - 27\mathbf{j})$ and then equate coefficients to give two simultaneous equations in k and T, these need to be used to produce an equation in ***T* only**, before the M mark is earned.
	A1	cao (allow t instead of T)