Question			Answer	Marks	Guidance	
1	(i)		$v = 0$ when it arrives $150\ 000(t - \frac{1}{4}t^2) = 0$ $\Rightarrow\ t = 4$ (on arrival)	 B1 **[1]**	 Award this mark for substituting $t = 4$ to obtain $v = 0$ Condone omission of $t = 0$	
	(ii)		Distance travelled $s = \int v\mathrm{d}t$ $s = 150\ 000\left[\frac{1}{2}t^2 - \frac{1}{12}t^3\right]\ (+c)$ When $t = 4,\ s = 400\ 000$ The journey is 400 000 km	M1 A1 M1 A1 **[4]**	Do not accept multiplication by t. Substituting their $t = 4$. This mark is dependent on the previous M mark. If 400 000 seen award the previous mark	
	(iii)		For maximum speed $a = \frac{\mathrm{d}v}{\mathrm{d}t} = 0$ $\frac{\mathrm{d}v}{\mathrm{d}t} = 150\ 000(1 - \frac{1}{2}t)$ $\Rightarrow t = 2$ $v = 150\ 000(2 - \frac{1}{4} \times 2^2) = 150\ 000$ Maximum speed is 150 000 $\mathrm{km\,h^{-1}}$	 B1 B1 **[2]**	 $t = 2$ seen Accept a trial and error method CAO	

Question			Answer	Marks	Guidance
2	(i)		**p** $\sqrt{(-1)^2+(-1)^2+5^2}=\sqrt{27}$ **q** $\sqrt{(-1)^2+(-4)^2+2^2}=\sqrt{21}$ **r** $\sqrt{2^2+5^2+0^2}=\sqrt{29}$ Greatest magnitude: **r**	M1 A1 **[2]**	Use of Pythagoras Note Magnitudes are 5.196, 4.583 and 5.385 respectively
	(ii)		Weight $=\begin{pmatrix}0\\0\\-4\end{pmatrix}$ $\mathbf{p}+\mathbf{q}+\mathbf{r}+\mathbf{weight}=\begin{pmatrix}0\\0\\3\end{pmatrix}$ $0.4\mathbf{a}=\begin{pmatrix}0\\0\\3\end{pmatrix}$ Magnitude of acceleration is 7.5 m s^{-2} Direction is vertically upwards	B1 B1 B1 B1 **[4]**	Condone $g=9.8$ giving weight is $\begin{pmatrix}0\\0\\-3.92\end{pmatrix}$ N. Accept 4↓. $g=9.8$ gives $\begin{pmatrix}0\\0\\3.08\end{pmatrix}$ Relevant attempt at Newton's 2nd Law. The total force must be expressed as a vector in some form. For this mark allow the weight to be missing, in the wrong component or to have the wrong sign. Condone *mg* in place of *m* for this mark only. CAO apart from using $g=9.8 \Rightarrow a=7.7$

Question			Answer	Marks	Guidance
3			Equate **i** and **j** components of **v**	M1	The candidate recognises that the **i** and **j** components must be equal.
			$16-t^2=31-8t$	A1	An equation is formed.
			$t^2-8t+15=0$		
			$(t-3)(t-5)=0$		
			$t=3$ or 5	A1	May be implied by later working.
			When $t=3$, $\mathbf{v}=7\mathbf{i}+7\mathbf{j}$	B1	
			Speed when $t=3$ is $7\sqrt{2}=9.9$ m s^{-1}	B1	
			The values of the **i** and **j** components must both be positive for the bearing to be 045^{o} .	B1	This mark is dependent on obtaining A1 for the result $t=3$ or 5 . It is awarded if the speed for the case when $t=5$ is not included (since $t=5 \Rightarrow \mathbf{v}=-9\mathbf{i}-9\mathbf{j}$ and the bearing is 225^{o}).
					Note Candidates who obtain **r** and equate the east and north components should be awarded SC1 for the whole question.
				[6]	

Question			Answer	Marks	Guidance
3			**Alternative Trial and error**		
			The i and j components of v must be equal	M1	The candidate recognises that the **i** and **j** components must be equal.
			The **i** and **j** components of **v** must both be positive for the bearing to be 045^{o}.	B1	This can be demonstrated during the question either by a suitable convincing diagram including 45^{o}, or by a suitable convincing argument
			At least one value of t is substituted	A1	Trial and error is used
			$t = 3$	A1	$t = 3$ is found by trial and error
			When $t = 3$, $\mathbf{v} = 7\mathbf{i} + 7\mathbf{j}$	B1	
			Speed when $t = 3$ is $7\sqrt{2} = 9.9 \text{ m s}^{-1}$	B1	
					Note Candidates who obtain **r** and equate the east and north components should be awarded SC1 for the whole question.
				[6]	

4		mark	notes
			Column vectors may be used throughout; lose 1 mark once if **j** components put at top or if fraction line included. . Notation used must be clear.
(i)	**Either** using *suvat*: Use of $\mathbf{v} = \mathbf{u} + t\mathbf{a}$ $\mathbf{v} = 4\mathbf{i} - 2t\mathbf{j}$ Use of $\mathbf{r} = (\mathbf{r}_0 +) t\mathbf{u} + \frac{1}{2} t^2\mathbf{a}$ $+ 3\mathbf{j}$ $\mathbf{r} = 4t\mathbf{i} + (3 - t^2)\mathbf{j}$	 M1 A1 M1 B1 A1 5	 substitution required. Must be vectors. substitution required. $\mathbf{r}_0$ not required. Must be vectors. May be seen on either side of a meaningful equation for **r** Accept $\mathbf{r} = 3\mathbf{j} + 4t\mathbf{i} - \frac{1}{2} \times 2 \times t^2\,\mathbf{j}$ oe written in a correct notation. Isw, providing not reduced to scalar: (see 12c in marking instructions)
	Or using integration: $\mathbf{v} = \int \mathbf{a}dt$ $\mathbf{v} = 4\mathbf{i} - 2t\mathbf{j}$ $\mathbf{r} = \int \mathbf{v}dt$ $+ 3\mathbf{j}$ $\mathbf{r} = 4t\mathbf{i} + (3 - t^2)\mathbf{j}$	 M1 A1 M1 B1 A1 5	 Attempt at integration. Condone no '+**c**'. Must be vectors. cao Integrate their **v** but must contain 2 components. Must be vectors. May be seen on either side of a meaningful equation for **r** Accept $\mathbf{r} = 3\mathbf{j} + 4t\mathbf{i} - \frac{1}{2} \times 2 \times t^2\,\mathbf{j}$ oe written in a correct notation. Isw, providing not reduced to scalar: (see 12e in marking instructions)
		5	
(ii)	$\mathbf{v}(2.5) = 4\mathbf{i} - 5\mathbf{j}$ Angle is $(90+)\arctan\frac{5}{4}$ = 141.34019… so 141° (3 s. f.)	B1 M1 A1 3	FT **their v** Award for arctan attempted oe. FT **their** values. Allow argument to be ± (**their i** cpt)/(**their j** cpt) or ± (**their j** cpt)/(**their i** cpt). Allow this mark if bearing of position vector attempted. cao
		8	

5		mark	notes
(i)	$\begin{pmatrix}-1\\14\\-8\end{pmatrix}+\begin{pmatrix}3\\-9\\10\end{pmatrix}+\mathbf{F}=4\begin{pmatrix}-1\\2\\4\end{pmatrix}$	M1	N2L. Allow sign errors in applying N2L. Do not condone $\mathbf{F} = m\mathbf{a}$. Allow one given force omitted.
		M1	Attempt to add $\begin{pmatrix}-1\\14\\-8\end{pmatrix}$ and $\begin{pmatrix}3\\-9\\10\end{pmatrix}$
	$\mathbf{F}=\begin{pmatrix}-6\\3\\14\end{pmatrix}$	A1 A1 4	Two components correct cao
(ii)	$\mathbf{v}=\begin{pmatrix}-3\\3\\6\end{pmatrix}+3\begin{pmatrix}-1\\2\\4\end{pmatrix}=\begin{pmatrix}-6\\9\\18\end{pmatrix}$ so $\begin{pmatrix}-6\\9\\18\end{pmatrix}$ m s^{-1}.	M1	$\mathbf{v} = \mathbf{u} + t\mathbf{a}$ with given $\mathbf{u}$ and $\mathbf{a}$. Could go via $\mathbf{s}$. If integration used, require arbitrary constant (need not be evaluated)
		A1	cao isw
	speed is $\sqrt{(-6)^2+9^2+18^2}$ = 21 m s^{-1}.	M1	Allow -6^2 even if interpreted as – 36. Only FT **their v**.
		F1 4	FT their **v** only. [Award M1 F1 for 21 seen WWW]
		8	

		mark	comment	sub
6(i)				
	$\mathbf{v} = \mathbf{i} + (3-2t)\mathbf{j}$	M1	Differentiating **r.** Allow 1 error. Could use const accn.	
		A1		
	v(4) = **i** – 5**j**	F1	Do not award if $\sqrt{26}$ is given as vel (accept if **v** given and *v* given as well called speed or magnitude).	
				3
(ii)				
	a = – 2**j**	B1	Diff **v.** FT **their v.** Award if – 2**j** seen & isw.	
	Using N2L **F** = $1.5\times$ (– 2**j**)	M1	Award for $1.5\times(\pm$ **their a** or $a)$ seen.	
	so – 3**j** N	A1	cao Do not award if final answer is not correct. [Award M1 A1 for – 3**j** WW]	
				3
(iii)				
	$x = 2 + t$ and $y = 3t - t^2$	B1	Must have both but may be implied.	
	Substitute $t = x - 2$			
	so $y = 3(x-2) - (x-2)^2$	B1	cao. isw. Must see the form *y* = ….	
	$[= (x-2)(5-x)]$			
				2
		8		

7		mark	comment	sub
(i)	**F** = $5\begin{pmatrix}-1\\2\end{pmatrix}=\begin{pmatrix}-5\\10\end{pmatrix}$ so $\begin{pmatrix}-5\\10\end{pmatrix}$ N	 M1 A1	Penalise spurious notation by 1 mark at most once in paper Use of N2L in vector form Ignore units. [Award 2 for answer seen] [SC1 for $\sqrt{125}$ or equiv seen]	 2
(ii)	**s** = $\begin{pmatrix}-2\\3\end{pmatrix}+4\begin{pmatrix}4\\5\end{pmatrix}+\frac{1}{2}\times4^2\times\begin{pmatrix}-1\\2\end{pmatrix}$ $\mathbf{s}=\begin{pmatrix}6\\39\end{pmatrix}$ so $\begin{pmatrix}6\\39\end{pmatrix}$ m	M1 A1 B1	Use of $\mathbf{s}=t\mathbf{u}+0.5t^2\mathbf{a}$ or integration of **a**. Allow $\mathbf{s}_0$ omitted. If integrated need to consider **v** when $t = 0$ Correctly evaluated; accept $\mathbf{s}_0$ omitted. Correctly adding $\mathbf{s}_0$ to a vector (FT). Ignore units. [NB $\begin{pmatrix}8\\36\end{pmatrix}$ seen scores M1 A1]	 3
		5		