



GuideMyGrades

— YOUR GOALS. OUR EXPERTISE. —

EDEXCEL INTERNATIONAL A LEVEL MATHS: QUESTIONS BY TOPIC

Vectors in Mechanics (M1.6)

International A Level Mathematics · M1: Mechanics 1 (WME01)

27 questions · 283 marks · Mark schemes included

Past papers January 2020 - June 2025 · 1 sub-topic

 guidemygrades.com

 [@Guidemygrades](https://www.instagram.com/Guidemygrades)

 [@Guidemygrades](https://twitter.com/Guidemygrades)

 [@Guidemygrades](https://www.youtube.com/Guidemygrades)

 info@guidemygrades.com

 Piccadilly Business Centre, Unit C, Aldow Enterprise Park
Blackett Street, Manchester, M12 6AE

HOW TO USE THIS BOOKLET

Questions are grouped by sub-topic and run from the lowest to the highest mark tariff, then oldest paper first.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme; < QUESTION brings you back.

A gold bar in the left margin marks exactly where the question sits on the original page.

Diagrams, graphs, grids and tables are printed exactly as they appear in the original papers.

Each question is filed under its main topic; longer questions may also test skills from other topics.

QUESTION	SOURCE	MARKS	PAGE
M1.6a VECTORS: VELOCITY, DISPLACEMENT & FORCES		27 Qs · 283 marks	2
1. Q2	IAL M1 (WME01) June 2024	4	3
2. Q6	IAL M1 (WME01) June 2022	6	5
3. Q5	IAL M1 (WME01) January 2021	7	7
4. Q5	IAL M1 (WME01) January 2025	7	9
5. Q2	IAL M1 (WME01) June 2025	7	11
6. Q4	IAL M1 (WME01) October 2021	8	15
7. Q1	IAL M1 (WME01) January 2025	8	19
8. Q3	IAL M1 (WME01) June 2021	9	21
9. Q5	IAL M1 (WME01) June 2021	9	25
10. Q6	IAL M1 (WME01) October 2022	9	29
11. Q8	IAL M1 (WME01) June 2023	9	33
12. Q3	IAL M1 (WME01) January 2023	10	40
13. Q2	IAL M1 (WME01) June 2023	10	44
14. Q4	IAL M1 (WME01) October 2023	10	46
15. Q6	IAL M1 (WME01) January 2020	11	50
16. Q7	IAL M1 (WME01) January 2024	11	52
17. Q3	IAL M1 (WME01) October 2024	11	56
18. Q6	IAL M1 (WME01) January 2021	12	58
19. Q8	IAL M1 (WME01) October 2021	12	62
20. Q6	IAL M1 (WME01) January 2022	12	67
21. Q5	IAL M1 (WME01) October 2020	13	71
22. Q7	IAL M1 (WME01) June 2024	13	75
23. Q7	IAL M1 (WME01) June 2025	13	79
24. Q8	IAL M1 (WME01) January 2022	14	83
25. Q6	IAL M1 (WME01) October 2023	15	86
26. Q8	IAL M1 (WME01) October 2022	16	90
27. Q8	IAL M1 (WME01) June 2022	17	95



QUESTIONS

27 questions · 283 marks · 1 sub-topic

SUB-TOPIC M1.6a

VECTORS: VELOCITY, DISPLACEMENT & FORCES

Sub-topic M1.6a · 27 questions · 283 marks · lowest tariff first



2. Two forces, **P** and **Q**, act on a particle.

- **P** has magnitude 10 N and acts due west
- **Q** has magnitude 8 N and acts on a bearing of 330°

Given that $\mathbf{F} = \mathbf{P} + \mathbf{Q}$, find the magnitude of $\mathbf{F}$.

(4)

Question 2 continued

Lined area for writing the answer to Question 2.

(Total for Question 2 is 4 marks)

Leave
blank

6. A particle P is moving with constant acceleration.

At time $t = 1$ second, P has velocity $(-\mathbf{i} + 4\mathbf{j}) \text{ m s}^{-1}$

At time $t = 4$ seconds, P has velocity $(5\mathbf{i} - 8\mathbf{j})\text{ m s}^{-1}$

Find the speed of P at time $t = 3.5$ seconds.

(6)

Question 6 continued

Leave
blank

Handwriting practice area with 25 horizontal lines.

(Total 6 marks)

Q6

Mark box for Q6



Leave
blank

5. A particle is acted upon by two forces **F** and **G**. The force **F** has magnitude 8 N and acts in a direction with a bearing of 240° . The force **G** has magnitude 10 N and acts due South.

Given that $\mathbf{R} = \mathbf{F} + \mathbf{G}$, find

- the magnitude of $\mathbf{R}$,
- the direction of $\mathbf{R}$, giving your answer as a bearing to the nearest degree.

(7)

Question 5 continued

Leave
blank

Handwriting practice area with 25 horizontal lines.

(Total 7 marks)

Q5

(Total for Question 5 is / marks)



Question 2 continued

Lined area for writing the answer to Question 2.



Question 2 continued

Lined area for writing the answer to Question 2.



Question 2 continued

Lined area for writing the answer to Question 2.

(Total for Question 2 is 7 marks)



Leave
blank

4. The position vector, $\mathbf{r}$ metres, of a particle P at time t seconds, relative to a fixed origin O , is given by

$$\mathbf{r} = (t - 3)\mathbf{i} + (1 - 2t)\mathbf{j}$$

- (a) Find, to the nearest degree, the size of the angle between $\mathbf{r}$ and the vector $\mathbf{j}$, when $t = 2$
- (3)**

- (b) Find the values of t for which the distance of P from O is 2.5 m. (5)

Question 4 continued

Leave
blank



Question 4 continued

Leave
blank

Lined area for writing the answer to Question 4 continued.



Question 4 continued

Leave
blank

Lined area for writing the answer to Question 4.

(Total 8 marks)

Q4



Question 1 continued

Lined area for writing the answer to Question 1.

(Total for Question 1 is 8 marks)



Question 3 continued

Leave
blank



Question 3 continued

Leave
blank

Lined area for writing the answer to Question 3 continued.



Question 3 continued

Leave
blank

(Total 9 marks)

Q3



Question 5 continued

Leave
blank



Question 5 continued

Leave
blank

Lined area for writing the answer to Question 5 continued.



Question 5 continued

Leave
blank

Lined area for writing the answer to Question 5.

(Total 9 marks)

Q5

Question 6 continued

Leave
blank

Lined area for writing the answer to Question 6 continued.



Question 6 continued

Leave
blank



Question 6 continued

Leave
blank

Q6

(Total 9 marks)



8.

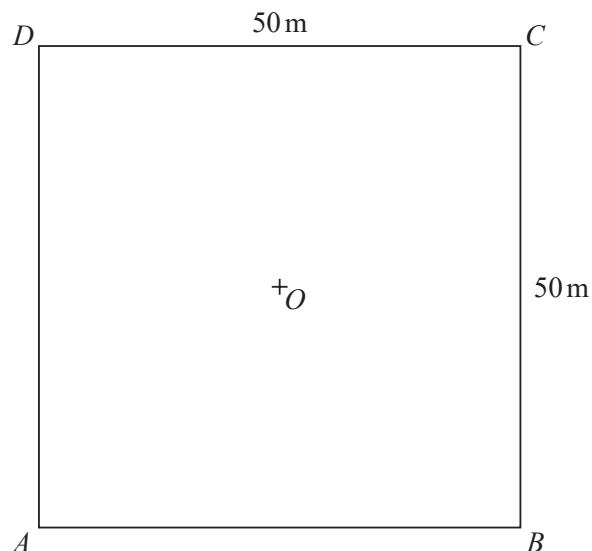


Figure 5

A square floor space $ABCD$, with centre O , is modelled as a flat horizontal surface measuring 50 m by 50 m, as shown in Figure 5.

The horizontal unit vectors $\mathbf{i}$ and $\mathbf{j}$ are in the direction of $\overrightarrow{AB}$ and $\overrightarrow{AD}$ respectively.

All position vectors are given relative to O .

A small robot R is programmed to travel across the floor at a constant velocity.

- At time $t = 0$, R is at the point with position vector $(-2\mathbf{i} + \mathbf{j})\text{ m}$
- At time $t = 11\text{ s}$, R is at the point with position vector $(9\mathbf{i} + 23\mathbf{j})\text{ m}$
- At time t seconds, the position vector of R is $\mathbf{r}$ metres

(a) Find, in terms of t , $\mathbf{i}$ and $\mathbf{j}$, an expression for $\mathbf{r}$

(3)

A second robot S is at the point C .

- At time $t = 0$, S leaves C and moves with constant velocity $(-\mathbf{i} - \mathbf{j})\text{ m s}^{-1}$
- At time t seconds, the position vector of S is $\mathbf{s}$ metres

(b) Write down, in terms of t , $\mathbf{i}$ and $\mathbf{j}$, an expression for $\mathbf{s}$

(1)

(c) Show that

$$\overrightarrow{SR} = [(2t - 27)\mathbf{i} + (3t - 24)\mathbf{j}] \text{ m}$$

(2)

(d) Find the time when the distance between R and S is a minimum.

(3)



Question 8 continued

Lined area for writing the answer to Question 8 continued.



Question 8 continued

Lined area for writing the answer to Question 8 continued.



Question 8 continued

Lined area for writing the answer to Question 8 continued.



Question 8 continued

Lined area for writing the answer to Question 8 continued.



Question 8 continued

Lined area for writing the answer to Question 8 continued.



Question 8 continued

Lined area for writing the answer to Question 8.

(Total for Question 8 is 9 marks)

TOTAL FOR PAPER IS 75 MARKS



3. A particle P is moving with constant acceleration $(-4\mathbf{i} + \mathbf{j})\text{ms}^{-2}$

At time $t = 0$, P has velocity $(14\mathbf{i} - 5\mathbf{j}) \text{ m s}^{-1}$

- (a) Find the speed of P at time $t = 2$ seconds.

(3)

- (b) Find the size of the angle between the direction of $\mathbf{i}$ and the direction of motion of P at time $t = 2$ seconds.

(3)

At time $t = T$ seconds, P is moving in the direction of vector $(2\mathbf{i} - 3\mathbf{j})$

- (c) Find the value of T

(4)



Question 3 continued

Lined area for writing the answer to Question 3 continued.



Question 3 continued

Question 3 continued

(Total for Question 3 is 10 marks)



Question 2 continued

Lined area for writing the answer to Question 2.

(Total for Question 2 is 10 marks)



Question 4 continued

Lined area for writing the answer to Question 4 continued.



Question 4 continued

Lined area for writing the answer to Question 4 continued.



Question 4 continued

Lined area for writing the answer to Question 4.

(Total for Question 4 is 10 marks)



Question 6 continued

Leave
blank

(Total 11 marks)

Q6





Question 7 continued

Lined area for writing the answer to Question 7 continued.



Question 3 continued

Lined area for writing the answer to Question 3.

(Total for Question 3 is 11 marks)



Question 6 continued

Leave
blank

Handwriting practice area with 30 horizontal lines.



Question 6 continued

Leave
blank



Question 6 continued

Leave
blank

(Total 12 marks)

Q6



Question 8 continued

Leave
blank

Handwriting practice area with horizontal lines.



Question 8 continued

Leave
blank

Lined area for writing the answer to Question 8 continued.



Question 8 continued

Leave
blank

Lined area for writing the answer to Question 8 continued.



Question 8 continued

Leave
blank

Lined area for writing the answer to Question 8.

Q8

(Total 12 marks)

END

TOTAL FOR PAPER: 75 MARKS



Question 6 continued

Leave
blank

Lined area for writing the answer to Question 6 continued.



Question 6 continued

Leave
blank

Lined area for writing the answer to Question 6 continued.



Question 6 continued

Leave
blank

Lined area for writing the answer to Question 6.

(Total 12 marks)

Q6

--	--



Question 5 continued

Leave
blank



Question 5 continued

Leave
blank



Question 5 continued

Leave
blank

(Total 13 marks)

Q5



Question 7 continued

Lined area for writing the answer to Question 7 continued.



Question 7 continued

Lined area for writing the answer to Question 7 continued.



Question 7 continued

Lined area for writing the answer to Question 7.

(Total for Question 7 is 13 marks)



Question 7 continued

Lined area for writing the answer to Question 7 continued.



Question 7 continued

Lined area for writing the answer to Question 7 continued.



Question 7 continued

Lined area for writing the answer to Question 7.

(Total for Question 7 is 13 marks)



Question 8 continued

Leave
blank

Lined area for writing the answer to Question 8 continued.



Question 8 continued

Leave
blank

Lined area for writing the answer to Question 8.

Q8

--	--

(Total 14 marks)

TOTAL FOR PAPER: 75 MARKS

END



Question 6 continued

Lined area for writing the answer to Question 6 continued.



Question 6 continued

Question 6 continued

Lined area for writing the answer to Question 6.

(Total for Question 6 is 15 marks)



Question 8 continued

Leave
blank

Lined area for writing the answer to Question 8 continued.



Question 8 continued

Leave
blank

Lined area for writing the answer to Question 8 continued.



Question 8 continued

Leave
blank

Lined area for writing the answer to Question 8 continued.



Question 8 continued

Leave
blank

Handwriting practice area with horizontal lines.

Q8

(Total 16 marks)

TOTAL FOR PAPER: 75 MARKS

END



Question 8 continued

Leave
blank

Lined area for writing the answer to Question 8 continued.



Question 8 continued

Leave
blank

Lined area for writing the answer to Question 8 continued.



Question 8 continued

Leave
blank

Lined area for writing the answer to Question 8 continued.



Question 8 continued

Leave
blank

Lined area for writing the answer to Question 8.

Q8

(Total 17 marks)

END

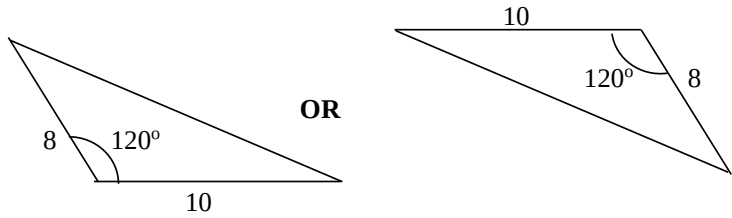
TOTAL FOR PAPER: 75 MARKS



MARK SCHEMES

official mark schemes, in the same order as the questions



Question Number	Scheme	Marks
2.	 OR Correct triangle	M1
	$(F^2) = 8^2 + 10^2 - 2 \times 8 \times 10 \cos \theta$ where $\theta < 180^\circ$	M1
	$(F^2) = 8^2 + 10^2 - 2 \times 8 \times 10 \cos 120^\circ$	A1
	$F = \sqrt{244} = 2\sqrt{61}$ or 16 (N) or better (15.620499..)	A1 (4)
	OR:	
	$\pm(10 + 8\cos 60^\circ)$ and $\pm 8\sin 60^\circ$	M1
	Use of Pythagoras on their combined components	M1
	$F^2 = (10 + 8\cos 60^\circ)^2 + (8\sin 60^\circ)^2$	A1
	$F = \sqrt{244} = 2\sqrt{61}$ or 16 (N) or better (15.620499..)	A1 (4)
		(4)
	Notes	
2.	M1: Correct triangle with lengths and the angle (arrows not needed), seen or implied.	
	M1: Use of cosine rule with correct structure but any angle $< 180^\circ$	
	A1: Correct expression with or without root	
	A1: cao	
	OR:	
	M1: Two correct components (allow inclusion of i and j)	
	M1: Use of Pythagoras using their combined i cpts and j cpts	
	A1: Correct expression with or without root	
	A1: cao	
	N.B. A scale drawing can score Max M1M0A0A0	



Question Number	Scheme	Marks
6.	$(5\mathbf{i} - 8\mathbf{j}) = (-\mathbf{i} + 4\mathbf{j}) + 3\mathbf{a}$	M1A1
	$\mathbf{v} = (-\mathbf{i} + 4\mathbf{j}) + 2.5(2\mathbf{i} - 4\mathbf{j})$	M1
	$\mathbf{v} = (4\mathbf{i} - 6\mathbf{j})$	A1
	Speed = $\sqrt{4^2 + (-6)^2} = \sqrt{52} = 7.2 \text{ (m s}^{-1}\text{) or better}$	M1A1
		(6)
	OR: $(4 - 3.5)[\mathbf{v} - (-\mathbf{i} + 4\mathbf{j})] = (3.5 - 1)[(5\mathbf{i} - 8\mathbf{j}) - \mathbf{v}]$ oe	M2A1
	$\mathbf{v} = (4\mathbf{i} - 6\mathbf{j})$	A1
	Speed = $\sqrt{4^2 + (-6)^2} = \sqrt{52} = 7.2 \text{ (m s}^{-1}\text{) or better}$	M1A1
		(6)
	Notes for question 6	
	M1 For use of $\mathbf{v} = \mathbf{u} + \mathbf{a}t$, with $t = 3$ oe, to give an <i>equation</i> in a only Allow u and v reversed	
	A1 Correct unsimplified equation in a only	
	M1 For an equation in v only using their a and $t = 2.5$ oe (e.g. they may find $\mathbf{u} (= -3\mathbf{i} + 8\mathbf{j})$, the velocity at $t = 0$, then use $t = 3.5$) M0 if they assume $\mathbf{u} = \mathbf{0}$	
	A1 $(4\mathbf{i} - 6\mathbf{j})$	
	M1 Use of Pythagoras, including square root, to find magnitude of their v	
	A1 cao	
	OR: Ratio method	
	M2 for an equation in v only, with the correct structure	
	A1 Correct unsimplified ratio equation A1 $(4\mathbf{i} - 6\mathbf{j})$	
	M1 Use of Pythagoras, including square root, to find magnitude of their v	
	A1 cao	

Question Number	Scheme	Marks
7(a)		B1 for A B1 for B B1 4 & T Allow their numerical value of T (3)
7(b)	$\frac{4}{0.8} = 5$ (s)	B1
	$100 = \frac{(t+t-5)}{2} \times 4$ OR $100 = \frac{1}{2} \times 5 \times 4 + 4(t-5)$	M1A1ft
	$t = 27.5$ (s)	A1
		(4)
7(c)	$100 = \frac{(27.5+27.5-T)}{2} \times T$ OR $100 = \frac{1}{2} \times T \times T + T(27.5-T)$	M1A1ft
	$T^2 - 55T + 200 = 0$ oe	A1
	$T = 3.915047\dots$ accept 3.9 or better	A1
		(4)
7(d)	$4 - 3.915\dots$	M1
	0.085 or better (m s^{-1})	A1ft
		(2)
		(13)
Notes for question 7		
7(a)	B1 Correct shape for A's graph.	
	B1 Correct shape for B's graph with steeper gradient initially and must cross A's graph. <u>Both graphs must end at the same time.</u> B0 once if solid vertical line at the end	
	B1 4 and T correctly marked. Allow appropriate delineators. N.B. If graphs are on separate axes can score max B1B0B1 If no labels, give BOD. If incorrect labels, max B1B0B1	
7(b)	B1 5 (s) seen – could be on graph	
	M1 Attempt at equation in <i>t</i> only, with correct structure i.e. trapezium or (rectangle + triangle) or (rectangle – triangle) oe including $\frac{1}{2}$ where appropriate, based on total area (OR distance using 2 or more <i>suvat</i> formulae) being 100 M0 for a <i>single suvat</i> equation for the <i>whole</i> motion. N.B. If they clearly use <i>T</i> (for <i>t</i>) in their equation and in their answer , it's M0 but give BOD where possible.	
	A1ft Correct equation in <i>t</i> only, ft on their 5	
	A1 cao	
7(c)	M1 Attempt at equation in <i>T</i> only, with correct structure, i.e. trapezium or (rectangle + triangle) or (rectangle – triangle) oe based on total area (OR distance using 2 or more <i>suvat</i> formulae) being 100 M0 for a <i>single suvat</i> equation for the <i>whole</i> motion.	

QUESTION NUMBER	SCHEME	MARKS
5(a)	$\frac{(10\mathbf{i} - 3\mathbf{j}) - (-2\mathbf{i} + 5\mathbf{j})}{8}$	M1 A1
	$1.5\mathbf{i} - \mathbf{j} \quad (\text{m s}^{-1})$	A1
		(3)
5(b)	$(-2\mathbf{i} + 5\mathbf{j}) + 6\mathbf{v} \quad \text{OR} \quad (10\mathbf{i} - 3\mathbf{j}) - 2\mathbf{v}$	M1
	Correct unsimplified expression $(= (7\mathbf{i} - \mathbf{j}))$	A1
	$ BT = \sqrt{(13-7)^2 + (-5-1)^2}$	M1
	$= \sqrt{52}, 2\sqrt{13} \quad \text{or } 7.2 \text{ or better (m)}$	A1
		(4)
		(7)
	Notes for Question 5	
	Accept column vectors throughout	
5(a)		
M1	Use of displacement $\div$ time. The terms in the numerator may be either way round but it must be a difference. M0 if they use 9 instead of 8	
A1	Correct unsimplified expression for $\mathbf{v}$	
A1	Correct velocity, accept column vector $\begin{pmatrix} 1.5 \\ -1 \end{pmatrix}$ Ignore (velocity) $= \sqrt{1.5^2 + (-1)^2}$ etc	
5(b)		
M1	Complete method using their velocity to find the position of B at $t = 7$. They may find the position at $t = 0 ((-3.5\mathbf{i} + 6\mathbf{j}))$ first then add $7\mathbf{v}$	
A1	Correct unsimplified expression. Note that with correct $\mathbf{v}$ this simplifies to $(7\mathbf{i} - \mathbf{j})$	
M1	Use Pythagoras to find the distance between their position of B and T , allow slips. N.B. Must have used either $(-2\mathbf{i} + 5\mathbf{j}) + k\mathbf{v}$ or $(10\mathbf{i} - 3\mathbf{j}) + k\mathbf{v}$ where k is a non-zero integer, to find the position vector of B	
A1	Correct answer. Accept 7.2 (m) or better, exact value $2\sqrt{13}, \sqrt{52}$	



Q	Scheme	Marks	Notes
	Allow column vectors throughout apart from in the answers to (a) and (b).		
2a	Use of $\frac{1}{3}(10\mathbf{i} + 4\mathbf{j} - (-5\mathbf{i} + 16\mathbf{j}))$	M1	Condone subtraction in the wrong order and missing brackets
	$= (5\mathbf{i} - 4\mathbf{j}) (\text{ms}^{-1})$	A1	Correct only
		(2)	
2b	$\{-5\mathbf{i} + 16\mathbf{j} - 2(5\mathbf{i} - 4\mathbf{j})\} + t(5\mathbf{i} - 4\mathbf{j})$ OR $\{10\mathbf{i} + 4\mathbf{j} - 5(5\mathbf{i} - 4\mathbf{j})\} + t(5\mathbf{i} - 4\mathbf{j})$	M1	Any equivalent unsimplified form using their v , with correct structure.
	$= (-15 + 5t)\mathbf{i} + (24 - 4t)\mathbf{j}$	A1	Correct simplified form
		(2)	
2c	Finding AB (or BA) at $t = 5$ (AB = $-5\mathbf{i} - 12\mathbf{j}$) Must use given r at $t = 5$.	M1	Seen or implied, allow slips.
	e.g. $\theta = \tan^{-1}(\pm \frac{5}{12})$ or $\tan^{-1}(\pm \frac{12}{5})$ or $\sin^{-1}(\pm \frac{5}{13})$ or $\sin^{-1}(\pm \frac{12}{13})$ etc etc	M1	Correct use of trig to find a relevant angle, using their AB or BA , seen or implied
	Bearing $203(^{\circ})$	A1	Correct only, to nearest degree.
		(3)	
		(7)	

Question Number	Scheme	Marks
	Allow column vectors throughout	
4(a)	$\mathbf{r} = -\mathbf{i} - 3\mathbf{j}$	B1
	$\tan \theta = \pm \frac{1}{3}$ or $\pm \frac{3}{1}$	M1
	162° or 198° nearest degree	A1
		(3)
4(b)	$\sqrt{(t-3)^2 + (1-2t)^2} = 2.5$	M1
	$4t^2 - 8t + 3 = 0$ ($5t^2 - 10t + 3.75 = 0$)	DM1A1
	$t = \frac{1}{2}$ or $\frac{3}{2}$ isw	M (A)1 A1
		(5)
		(8)
	Notes for question 4	
4(a)	B1 cao	
	M1 for any trig ratio of a relevant angle from <u>their</u> $\mathbf{r}$ (trig ratio could be implied by a relevant angle) (cosine could come from use of the scalar product of their $\mathbf{r}$ with $\mathbf{j}$)	
	A1 cao	
4(b)	M1 oe	
	DM1, dependent on first M1, for simplifying to a 3 term quadratic or to a form from use of completing the square.	
	A1 correct quadratic	
	M(A)1 for $t = 0.5$	
	A1 for $t = 1.5$	

QUESTION NUMBER	SCHEME	MARKS
1(a)	Resultant force $(6\mathbf{i} + 8\mathbf{j}) + (-16\mathbf{i} + 2\mathbf{j}) + (-2\mathbf{i} + 8\mathbf{j})$	M1
	N2L $-12\mathbf{i} + 18\mathbf{j} = 2.5a \text{ oe}$ OR $\sqrt{((-12)^2 + 18^2)} = 2.5a \text{ oe}$	M1
	Pythagoras $\sqrt{((-4.8)^2 + (7.2)^2)}$ OR $\sqrt{((-12)^2 + 18^2)}$	M1
	8.7 or better (m s^{-2})	A1
		(4)
1(b)	$-12\mathbf{i} + 18\mathbf{j} + p\mathbf{i} + p\mathbf{j} = (-12+p)\mathbf{i} + (18+p)\mathbf{j}$	M1
	$\frac{-12+p}{18+p} = \frac{7}{2}$	M1 A1
	$p = -30$	A1
		(4)
		(8)
	Notes for Question 1	
	Accept column vectors throughout	
1(a)		
M1	Find the resultant force by finding the sum of $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ $\mathbf{i}$'s and $\mathbf{j}$'s do NOT need collecting	
M1	Use of N2L, in vector or scalar form, with <u>their resultant force</u>	
M1	Use of Pythagoras to find a magnitude. This may be magnitude of acceleration or magnitude of their resultant force if carried out before N2L.	
A1	Correct answer from correct working. Exact value is $\frac{12}{5}\sqrt{13}$, accept 8.7 or better. (8.653323061..)	
1(b)		
M1	Find the resultant force AND collect $\mathbf{i}$'s and $\mathbf{j}$'s. Can be scored for a clear attempt at adding $p\mathbf{i} + p\mathbf{j}$ to their possibly incorrect resultant from (a)	
M1	Use direction $7\mathbf{i} + 2\mathbf{j}$ with their $\mathbf{i}$ and $\mathbf{j}$ components of their resultant force to form a ratio equation in p ONLY. Condone a sign error and reciprocal, but must be using 7 and 2. May use $(-12+p)\mathbf{i} + (18+p)\mathbf{j} = \lambda(7\mathbf{i} + 2\mathbf{j})$, equate components AND eliminate $\lambda (= -6)$ to form an equation in p ONLY.	
A1	Correct unsimplified equation in p ONLY.	
A1	Correct answer.	

2.	Use of $s = ut + \frac{1}{2}at^2$	M1	Form equation in u and a . N.B. Marks are available if they use two other unknowns, rather than u and a
	$20 = 3u + \frac{9a}{2}$	A1	Correct unsimplified equation
	Use of $suvat$	M1	Form second equation in u and a . N.B. Marks are available if they use the same two other unknowns, rather than u and a
	$10 = (u + 3a) + \frac{a}{2}$ or $30 = 4u + 8a$	A1	Correct unsimplified equation
	$30 = 3u + \frac{21a}{2} \Rightarrow 10 = 6a, a = \frac{5}{3}$	M1	Solve for u or a Or for one of their unknowns.
	$u = \frac{25}{6}$	A1	u and a both correct or both their unknowns correct. Accept equivalent forms. 1.7, 4.2 or better
	Use of $v = u + at$, $20 = \frac{25}{6} + \frac{5}{3}t$	M1	Complete method using $suvat$ to find t . Correct unsimplified for their u, a .
	$t = 9.5$ (s)	A1	cao
		[8]	

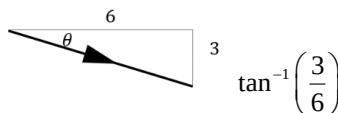
	Allow use of column vectors		
5a	$\mathbf{a} = \frac{(\mathbf{i} + 7\mathbf{j}) - (3\mathbf{i} + 5\mathbf{j})}{0.5}$ oe	M1	Use of $\mathbf{a} = \frac{\mathbf{v} - \mathbf{u}}{t}$ Allow $\mathbf{u}$ and $\mathbf{v}$ reversed
	$\mathbf{a} = -4\mathbf{i} + 4\mathbf{j}$	A1	Or equivalent
	$\Rightarrow \mathbf{v}_p = (3\mathbf{i} + 5\mathbf{j}) + (-4\mathbf{i} + 4\mathbf{j})t$	M1	For their $\mathbf{a}$
	$= (3 - 4t)\mathbf{i} + (5 + 4t)\mathbf{j}$	A1ft	Follow their $\mathbf{a}$. Must collect $\mathbf{i}$'s and $\mathbf{j}$'s This could be implied in subsequent working
	$\Rightarrow 5 + 4T = -2(3 - 4T)$	M1	Use of correct ratio to form equation in T (allow t)
	$T = \frac{11}{4}$ oe	A1	cao
		(6)	
5b	$\mathbf{v}_p = \mathbf{v}_Q \Rightarrow \begin{pmatrix} 3 - 4t \\ 5 + 4t \end{pmatrix} = \begin{pmatrix} -4 - 2t \\ \mu + 3t \end{pmatrix}$ $\Rightarrow 3 - 4t = -4 - 2t$ and $5 + 4t = \mu + 3t$	M1	Equate velocities and form two equations in t and μ i.e. must equate coefficients of $\mathbf{i}$ and $\mathbf{j}$ oe Follow their $\mathbf{v}_p$
		M1	Solve for μ . Follow their $\mathbf{v}_p$
	$\mu = 8.5$ oe	A1	cao
		(3)	
		[9]	

Question Number	Scheme	Marks
6(a)	$(-3\mathbf{i} + 2\mathbf{j}) + (p\mathbf{i} + q\mathbf{j}) = (-3 + p)\mathbf{i} + (2 + q)\mathbf{j}$	M1
	$\frac{(-3 + p)}{(2 + q)} = \frac{1}{-2}$	M1A1
	$2p + q - 4 = 0$ * Allow $0 = 2p + q - 4$ but nothing else	A1*
		(4)
6(b)	$p = 5 \Rightarrow q = -6 \Rightarrow \text{Resultant force} = (2\mathbf{i} - 4\mathbf{j})$	B1
	$(2\mathbf{i} - 4\mathbf{j}) = 0.5\mathbf{a}$	M1
	$\mathbf{v} = (4\mathbf{i} - 8\mathbf{j}) \times 4$	M1
	Speed = $\sqrt{16^2 + (-32)^2} = \sqrt{1280} = 16\sqrt{5} = 36 \text{ (m s}^{-1}\text{) or better}$	M1A1
		(5)
		(9)
	Notes for question 6	
6(a)	M1 For adding <i>and</i> collecting i 's and j 's. N.B. Could be implied by $p = 4$ and $q = -4$	
	M1 Using ratios oe to set up an equation in p and q only, allow the ratio the wrong way round. M0 if they write down: $-3 + p = 1$ and $2 + q = -2$ and NEVER use ratios, but ignore these equations if they go on to use ratios	
	A1 Correct equation	
	A1* Correct answer correctly obtained	
6(b)	B1 Correct resultant force seen	
	M1 Use of $\mathbf{F} = m\mathbf{a}$ OR $F = ma$ where F (F) is their <i>resultant</i> (must have attempted to add the two forces) (M0 if they include g)	
	M1 Use of $\mathbf{v} = \mathbf{a}t$ OR $v = at$ with $t = 4$ where a or a is their acceleration. (M0 if u or u is non-zero)	
	M1 Use of Pythagoras to find magnitude of v OR a OR F , including square root	
	N.B. The above 3 steps may appear in any order but must be entered on ePen in the order as above.	
	A1 Any equivalent surd or correct to at least 2 SF	

Question Number	Scheme	Marks
	Allow working in column vectors and penalise answers to (a) and (b) in column vector form ONCE at the first time it occurs.	
8(a)	$\mathbf{v} = \frac{(9\mathbf{i} + 23\mathbf{j}) - (-2\mathbf{i} + \mathbf{j})}{11}$	M1
	Expression for $\mathbf{r}$ with correct structure	M1
	$\mathbf{r} = (-2\mathbf{i} + \mathbf{j}) + t(\mathbf{i} + 2\mathbf{j})$ or $\mathbf{r} = (t-2)\mathbf{i} + (2t+1)\mathbf{j}$	A1 cao
		(3)
8(b)	Or $\mathbf{s} = (25\mathbf{i} + 25\mathbf{j}) + t(-\mathbf{i} - \mathbf{j})$	B1
	$\mathbf{s} = (25-t)\mathbf{i} + (25-t)\mathbf{j}$	
		(1)
8(c)	Either $\mathbf{r} - \mathbf{s}$ Or $\mathbf{s} - \mathbf{r}$ with their $\mathbf{r}$ and $\mathbf{s}$ substituted	M1
	$\overrightarrow{SR} = [(2t-27)\mathbf{i} + (3t-24)\mathbf{j}] \text{ m}^*$	A1*
		(2)
8(d)	Distance $(d) = \sqrt{(2t-27)^2 + (3t-24)^2}$ $(d^2) = (2t-27)^2 + (3t-24)^2$	M1
	$(d^2) = 13t^2 - 252t + 1305$	A1
	$t = \frac{126}{13} = 9.7 \text{ (s)}$ or better	A1
		(3)
		(9)
Notes for Question 8		
(a)		
M1	Use of displacement/time to find velocity. Allow the difference either way round.	
M1	Expression for $\mathbf{r}$ with correct structure using <i>their</i> $\mathbf{v}$ and the correct initial position vector.	
A1	Correct expression in terms of t , $\mathbf{i}$ and $\mathbf{j}$	
(b)		
B1	Any correct expression for $\mathbf{s}$ in terms of t , $\mathbf{i}$ and $\mathbf{j}$	
(c)		
M1	(Their $\mathbf{r} - \text{their } \mathbf{s}$) or vice versa, unsimplified	
A1*	Correct answer correctly obtained. Allow missing square brackets and m, but rest must be identical to given answer.	
(d)		
M1	Use of Pythagoras to find an expression for distance (or distance squared)	
A1	Correct 3 term quadratic expression N.B. If no 3 term quadratic expression is seen but a correct derivative is, award this mark.	
A1	9.7 or better. N.B. If a fraction is given as the answer, it must be the ratio of two positive integers or a mixed fraction.	

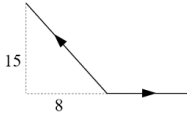


Question Number	Scheme	Marks
2(a)	Correct relationship between the speeds after the collision. v and $v+1$ OR $w-1$ and w	B1
	$(3m \times 1.5) + (m \times -1.5) = 3mv + m(v+1)$ [Or $(3m \times 1.5) + (m \times -1.5) = 3m(w-1) + mw$]	M1 A1
	Speed of A = $\frac{1}{2}$ (m s ⁻¹) Speed of B = $\frac{3}{2}$ (m s ⁻¹)	A1 A1
		(5)
2(b)	For B: $\pm m(1.5 - -1.5)$ OR For A: $\pm 3m(0.5 - 1.5)$	M1 A1ft
	$3m$ (Ns)	A1
		(3)
		(8)
	NOTES	
(a) B1	<i>speed</i> of B = 1 + <i>speed</i> of A . Must be seen before the CLM equation is used i.e. algebraic not numerical quantities	
M1	Dimensionally correct CLM equation with correct number of terms. Allow consistent extra <i>g</i> 's or cancelled <i>m</i> 's. Ignore sign errors. Allow the use of 2 unknowns for speeds after. (M0 if same speeds)	
A1	Correct equation in 1 unknown	
A1	Correct speed of A	
A1	Correct speed of B	
(b) M1	Dimensionally correct impulse-momentum equation using A or B with correct number of appropriate terms. Condone sign errors but must be difference of momenta. M0 if <i>g</i> is included.	
A1ft	Correct unsimplified equation. Follow through their answer in (a),but if using B, terms must have same signs, if using A, terms must have opposite signs.	
A1	Cao (must be positive)	

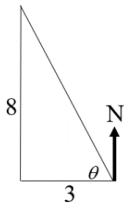
Question Number	Scheme	Marks
3(a)	Velocity = $(14\mathbf{i} - 5\mathbf{j}) + 2(-4\mathbf{i} + \mathbf{j})$	M1
	Speed = $\sqrt{6^2 + (-3)^2}$	M1
	Speed = $\sqrt{45} = 3\sqrt{5} = 6.7(\text{ms}^{-1})$ or better	A1 cso
		(3)
3(b)		M1 A1ft
	27° or better OR 333° or better 0.46 rads or better OR 5.8 rads or better	A1
		(3)
3(c)	$\mathbf{v} = (14\mathbf{i} - 5\mathbf{j}) + (-4\mathbf{i} + \mathbf{j})T$ (allow t) OR $\mathbf{v} = (6\mathbf{i} - 3\mathbf{j}) + (-4\mathbf{i} + \mathbf{j})t$ ($t = T - 2$)	M1
	$\frac{14 - 4T}{-5 + T} = \frac{2}{-3}$	M1 A1
	$T = 3.2$	A1
		(4)
(10)		
	NOTES	
	Accept the use of column vectors throughout	
(a)		
M1	Correct use of $t = 2$ to find the velocity (unsimplified).	
M1	Use of Pythagoras to find the speed when $t = 2$ with <u>their</u> velocity.	
A1	$\sqrt{45} = 3\sqrt{5} = 6.7(\text{ms}^{-1})$ or better (6.70820...). Must come from correct velocity.	
(b)		
M1	Use trig to find an equation in a relevant angle e.g. $(90^\circ - \theta)$ for their <i>velocity</i> .	
A1ft	Correct equation for a relevant angle, ft on their $\mathbf{v}$	
A1	Cao. No isw (A0 for a negative answer)	

(c)		
M1	Use of $\mathbf{v} = \mathbf{u} + \mathbf{a}T$ to obtain a velocity vector in T (allow t)	
M1	Use ratios, using <i>their velocity</i> , to produce an equation in T only (Allow reciprocal and incorrect sign)	
A1	Correct equation in T only	
A1	Cao N.B. If they use their answer to (a) instead of $\mathbf{u} = (14\mathbf{i} - 5\mathbf{j})$ but never correct their value of t , can score M1M1A0A0 N.B. If they use $\mathbf{v} = k(2\mathbf{i} - 3\mathbf{j})$ to produce 2 simultaneous equations in k and T , and then they use a calculator to solve and get $T = 3.2$, award all the marks, but if they get the wrong answer, they lose the last 3 marks.	

Question Number	Scheme	Marks
1(a)	$\xrightarrow{\quad} 2u$ $3u \xleftarrow{\quad}$ $A (4 \text{ kg})$ $B (2 \text{ kg})$ $\xrightarrow{\quad} v$ $\xrightarrow{\quad} 2u$ CLM: $(4 \times 2u) + (-3u \times 2) = 4v + (2 \times 2u)$ OR Equating impulses: $2(2u - 3u) = 4(-v - 2u)$	M1 A1
	$\frac{1}{2}u \text{ (m s}^{-1}\text{)}$	A1
		(3)
1(b)	The direction of motion is reversed.	B1
		(1)
1(c)	OR For B: $I = \pm 2(2u - 3u)$ For A: $I = \pm 4\left(\frac{u}{2} - 2u\right)$	M1 A1
	$I = 10u \text{ N s or } 10u \text{ kgms}^{-1}$	A1
		(3)
		(7)
Notes		
(a)		
M1	Dimensionally correct CLM equation or equating of impulses equation. Allow consistent extra g's. Ignore sign errors. May be +v or -v	
A1	Correct unsimplified equation	
A1	Cao. Must be positive .	
(b)		
B1	Accept <i>opposite direction</i> . Do not accept <i>changed</i> or <i>to the left</i> or <i>backwards</i> , away from B	
	N.B. This mark is dependent on correctly obtaining $\frac{1}{2}u$ or $-\frac{1}{2}u$ in (a)	
(c)		
M1	Dimensionally correct impulse-momentum equation using A or B. Condone sign errors with appropriate velocities. M0 if g is included	
A1	Correct unsimplified equation	
A1	Cao with units. Accept kg m/s	

Question Number	Scheme	Marks
2(a)	$\mathbf{F}_3 + (3\mathbf{i} + 4\mathbf{j}) + (-14\mathbf{i} + 7\mathbf{j}) = \mathbf{0}$ oe	M1
	$\mathbf{F}_3 = (14 - 3c)\mathbf{i} + (-7 - 4c)\mathbf{j}$	A1
		(2)
2(b)	Resultant force $\mathbf{F}_1 + \mathbf{F}_2 = (6 - 14)\mathbf{i} + (8 + 7)\mathbf{j}$ $(= -8\mathbf{i} + 15\mathbf{j})$	M1
	 Find any relevant angle for their (even if they've subtracted) resultant (need not be acute nor positive)	M1
	any of $\tan^{-1}\left(\pm \frac{8}{15}\right), \tan^{-1}\left(\pm \frac{15}{8}\right), \sin^{-1}\left(\pm \frac{8}{17}\right), \cos^{-1}\left(\pm \frac{8}{17}\right), \dots$	A1ft
	120° or better (118.0724...) OR 240° or better (241.9276..) In radians 2.1 or better (2.0607..) OR 4.2 or better (4.2224...)	A1
		(4)
2(c)	Use of Pythagoras on their resultant : $\sqrt{(-8)^2 + 15^2}$ or their acceleration: $\sqrt{\left(\frac{-8}{m}\right)^2 + \left(\frac{15}{m}\right)^2}$	M1
	Use of $ \text{their } \mathbf{R} = 8.5m$ or their Resultant = ma	M1
	A correct equation in m only eg $17 = m \times 8.5$	A1ft
	$m = 2$	A1
	N. B. $\sqrt{\left(\frac{-8}{8.5}\right)^2 + \left(\frac{15}{8.5}\right)^2}$ M1 $-8\mathbf{i} + 15\mathbf{j} = 8.5m$ M1 $\sqrt{\left(\frac{-8}{8.5}\right)^2 + \left(\frac{15}{8.5}\right)^2} = m$ A1ft $2 = m$ A1	
		(4)
		(10)

Notes	
Accept column vectors throughout apart from answer for (a)	
(a)	
M1	Uses the vector sum of all 3 forces being equal to zero oe N.B. $\mathbf{F}_3 = \mathbf{F}_1 + \mathbf{F}_2$ is M0
A1	cao Must be in terms of c , $\mathbf{i}$ and $\mathbf{j}$ but allow uncollected $\mathbf{i}$'s and $\mathbf{j}$'s and apply isw if necessary.
(b)	
M1	Finds the resultant using $\mathbf{F}_1 + \mathbf{F}_2$ or $-\mathbf{F}_3$
M1	Uses trig to find a relevant angle for their resultant
A1ft	Any correct relevant angle (does not need to be acute), ft on their resultant
A1	Cso.
(c)	
M1	Use of Pythagoras to find the magnitude of their resultant force or their acceleration
M1	Allow their $\mathbf{R} = 8.5\ m$
A1ft	A correct scalar equation in m only eg $17 = m \times 8.5$, ft on their resultant
A1	cso

QUESTION NUMBER	SCHEME	MARKS
4(a)	$(5\mathbf{i} - 8\mathbf{j}) + 5(-\lambda\mathbf{i} + 2\lambda\mathbf{j})$ (m s ⁻¹) isw	M1 A1
		(2)
4(b)	$13 = \sqrt{(5 - 5\lambda)^2 + (-8 + 10\lambda)^2}$	M1 A1
	$169 = 25 - 50\lambda + 25\lambda^2 + 64 - 160\lambda + 100\lambda^2$	
	$25\lambda^2 - 42\lambda - 16 = 0^*$	A1* cso
		(3)
4(c)	$(-2\mathbf{i} + 4\mathbf{j})$ seen or implied	B1
	$(5\mathbf{i} - 8\mathbf{j}) + (-2\mathbf{i} + 4\mathbf{j})4$	M1A1
	 e.g. $\tan^{-1}\left(\pm \frac{8}{3}\right), \tan^{-1}\left(\pm \frac{3}{8}\right), \sin^{-1}\left(\pm \frac{8}{\sqrt{73}}\right), \dots$	M1
	339°	A1
		(5)
		(10)
	Notes for question 4	
(a) M1 A1	Use of $\mathbf{v} = \mathbf{u} + \mathbf{at}$ to form a vector expression in λ and t Correct unsimplified expression with $t = 5$ N.B. Allow use of column vectors for the M mark but not for the A mark.	
(b) M1 A1 A1*	Collect $\mathbf{i}$'s and $\mathbf{j}$'s and correct use of Pythagoras to form an equation in λ Correct equation cso. Expand brackets and correctly reach the GIVEN answer. N.B. Allow $0 = 25\lambda^2 - 42\lambda - 16$	
(c) B1 M1 A1 M1 A1	Or column vector Complete method to find the velocity when $t = 4$. Correct unsimplified expression. Note the correct velocity is $\mathbf{v} = -3\mathbf{i} + 8\mathbf{j}$ Use their velocity vector at $t = 4$ with trig to find a relevant angle. Cao. Degrees sign not required. N.B. if they work with both values of λ , can score max all the marks except the last one.	

Question Number	Scheme	Marks
6(a)	Magnitude = $\sqrt{10^2 + 1^2} = \sqrt{101}$ (N)	M1A1
		(2)
6(b)	$\tan \alpha = \frac{1}{10}$	M1
	45°	B1
	Angle = $45^\circ - \alpha = 39.289\dots$ Accept 39° or better	M1 A1 (4)
	ALTERNATIVE 1 Scalar Product	
	$(10\mathbf{i} + \mathbf{j}) \cdot (\mathbf{i} + \mathbf{j}) = \sqrt{10^2 + 1^2} \cdot \sqrt{1^2 + 1^2} \cos \theta$	M1
	$(10\mathbf{i} + \mathbf{j}) \cdot (\mathbf{i} + \mathbf{j}) = 11$	B1
	$11 = \sqrt{10^2 + 1^2} \cdot \sqrt{1^2 + 1^2} \cos \theta$	M1
	$\theta = 39^\circ$ or better	A1 (4)
	ALTERNATIVE 2 Cosine Rule	
	$(10^2 + 1^2) + (1^2 + 1^2) - 2\sqrt{10^2 + 1^2} \cdot \sqrt{1^2 + 1^2} \cos \theta$	M1
	$(10\mathbf{i} + \mathbf{j}) \cdot (\mathbf{i} + \mathbf{j}) = 9\mathbf{i}$ or $(\mathbf{i} + \mathbf{j}) \cdot (10\mathbf{i} + \mathbf{j}) = -9\mathbf{i}$	B1
	$9^2 = (10^2 + 1^2) + (1^2 + 1^2) - 2\sqrt{10^2 + 1^2} \cdot \sqrt{1^2 + 1^2} \cos \theta$	M1
	$\theta = 39^\circ$ or better	A1 (4)
6(c)	$(10\mathbf{i} + \mathbf{j}) + (-15\mathbf{i} + a\mathbf{j}) = -5\mathbf{i} + (a+1)\mathbf{j}$	B1
	$\frac{a+1}{-5} = \frac{-3}{2}$	M1A1
	Solve for a	M1
	$a = 6.5$	A1
		(5)
		(11)
	Notes for question 6	
6(a)	M1 Use of Pythagoras	
	A0 if they <i>only</i> give a decimal	
6(b)	M1 For any relevant trig ratio for α or $(90^\circ - \alpha)$	
	B1 45° seen	
	M1 Finding the difference between 45° and α or $(90^\circ - \alpha)$ and 45°	
	A1 Accept 39° or better	
6(c)	B1 Adding the two forces and collecting i 's and j 's. Seen or implied.	
	M1 For producing an equation in a <i>only</i> e.g. using ratios from their resultant (M0 if no resultant attempted and M0 if equation comes from <i>equating</i> their resultant to $(2\mathbf{i} - 3\mathbf{j})$. Condone sign error but M0 if ratio is upside down.	
	A1 Correct equation in a only	
	M1 Solve for a . This is an independent M mark but their equation must have come from a ratio equation obtained from using their resultant	
	A1 $a = 6.5$	



QUESTION NUMBER	SCHEME	MARKS
N.B. Column vectors acceptable throughout apart from the answer to (b).		
7(a)	$\sqrt{12^2 + 16^2} = 20 \text{ (km h}^{-1}\text{)}$	M1 A1
		(2)
7(b)	$(19\mathbf{i} + 22\mathbf{j}) + t(12\mathbf{i} - 16\mathbf{j})$	M1 A1
		(2)
7(c) (i)	Displacement vector $\overrightarrow{LS} = (19 + 12t - 26)\mathbf{i} + (22 - 16t - 15)\mathbf{j}$ or $\overrightarrow{SL} = (26 - 19 - 12t)\mathbf{i} + (15 - 22 + 16t)\mathbf{j}$	M1
	Correct with i and j collected $\overrightarrow{LS} = (12t - 7)\mathbf{i} + (7 - 16t)\mathbf{j}$ or $\overrightarrow{SL} = (7 - 12t)\mathbf{i} + (16t - 7)\mathbf{j}$	A1
	Use of Pythagoras to find the distance $ \overrightarrow{LS} = \sqrt{(12t - 7)^2 + (7 - 16t)^2}$	M1
	Correct 3TQ $400t^2 - 392t + 98$	A1
	Min occurs when $t = 0.49$	A1
	Alternative for last 3 marks: Closest when relative pv is perpendicular to relative velocity i.e $[(12t - 7)\mathbf{i} + (7 - 16t)\mathbf{j}] \cdot (12\mathbf{i} - 16\mathbf{j}) = 0$ $400t - 196 = 0$ Min occurs when $t = 0.49$	M1 A1 A1
(ii)	$\sqrt{1.96} = 1.4 \text{ (km)}$	M1
	$1.4 > 1.3$ so it is safe for S to continue its course.	A1 cs
		(7)
	Alternative for (c)(i) and (ii):	
7(c) (i)	Path of S: $y - 22 = \frac{-16}{12}(x - 19)$	M1
	Normal through L: $y - 15 = \frac{12}{16}(x - 26)$	A1
	Solve for either x OR y	M1
	$x = 24.88$ OR $y = 14.16$	A1
	$24.88 = 12t + 19$ OR $14.16 = 22 - 16t \Rightarrow t = 0.49$	A1
(ii)	$\sqrt{(26 - 24.88)^2 + (15 - 14.16)^2} = 1.4$	M1
	$1.4 > 1.3$ so it is safe for S to continue its course.	A1 cs
		(7)
	Alternative for (c)(i):	
	Path of S: $(19\mathbf{i} + 22\mathbf{j}) + t(12\mathbf{i} - 16\mathbf{j})$	
	Normal through L: $(26\mathbf{i} + 15\mathbf{j}) + k(16\mathbf{i} + 12\mathbf{j})$ oe	M1 A1
	Solve for t	M1
	$t = 0.49$	A2
		(5)
		(11)

	Notes for question 7	
(a) M1 A1	Use of Pythagoras to find the speed. Since this is a 3,4,5 triangle the correct answer may appear without working. cao	
(b) M1 A1	Correct structure Correct answer o.e. with i 's and j 's	
(c) (i) M1 A1 M1 A1 A1	Subtraction used to find the displacement vector $\overrightarrow{LS}$ or $\overrightarrow{SL}$ Correct components for $\overrightarrow{LS}$ or $\overrightarrow{SL}$ with i 's and j 's collected, seen or implied. Use of Pythagoras with their components, which must have come from attempt at subtracting or adding s and l , to form a 3TQ for distance or distance squared. Correct 3TQ, seen or implied, e.g allow $400t^2 - 392t + 96.31$ cao Note: The correct value $t = 0.49$ may appear without working as a result of the quadratic solver on a calculator. Other methods may include completing the square or differentiation. N.B. Correct 3TQ = 1.3^2 oe can score max M1A1M1A1	
(ii) M1 A1cso	Use of their t value, which must have come from an attempt to minimise the distance LS , to find the shortest distance between S and L . Note: The correct value 1.4 may appear without working since the quadratic solver on a calculator will give a min value for d^2 as 1.96. Correct conclusion by comparing 1.4 and 1.3. N.B. Accept e.g. '1.4 therefore it is safe'.	

Q	Scheme	Marks	Notes
1			
(a)	Use of CLM Or equating impulses	M1	Dimensionally correct. Condone sign errors and allow missing m 's and extra g 's.
	$(4m \times 2x) - 3mx = (3m \times 5y) - 4my$ Or: $3m(5y - x) = 4m(y - 2x)$	A1	Correct unsimplified equation and must see all 4 terms but allow missing m 's.
	$y = \frac{5}{11}x$ *	A1*	Obtain given answer from correct working with m 's seen. Allow $y = \frac{5x}{11}$ but A0 if x is <i>clearly</i> in the denominator of the fraction.
		[3]	
(b)	Use of $I = mv - mu$	M1	Dimensionally correct. Condone sign errors and y not substituted but mass and velocities must match. M0 if m is used for mass or g is included or m is missing.
	$\pm 3m \left(\frac{25}{11}x + x \right)$ or $\left(\pm 4m \left(\frac{5}{11}x + 2x \right) \right)$	A1	Correct unsimplified expression
	$\frac{108}{11}mx$ oe	A1	$9.8mx$ or better ($9.8181..mx$), must be positive.
		[3]	
		(6)	

Question Number	Scheme	Marks
6(a)	$(11\mathbf{i} + 11\mathbf{j}) + t(3\mathbf{i} - \mathbf{j})$	M1A1 (2)
6(b)	When $t = 6$, $\mathbf{r}_A = (29\mathbf{i} + 5\mathbf{j})$	M1
	$\mathbf{r}_B = (7\mathbf{i} + 16\mathbf{j}) + t(4\mathbf{i} - 2\mathbf{j}) = (29\mathbf{i} + 5\mathbf{j})$	M1
	Solve both $4t + 7 = 29$ and $16 - 2t = 5$ explicitly to give $t = 5.5$ for both equations (Division by vectors is DM0)	DM1 A1* (4)
6(c)	$\overrightarrow{AB} = (7\mathbf{i} + 16\mathbf{j}) + t(4\mathbf{i} - 2\mathbf{j}) - \{(11\mathbf{i} + 11\mathbf{j}) + t(3\mathbf{i} - \mathbf{j})\}$	M1
	$\overrightarrow{AB} = [(t - 4)\mathbf{i} + (5 - t)\mathbf{j}]$ m GIVEN ANSWER	A1* (2)
6(d)	$AB^2 = (t - 4)^2 + (5 - t)^2$ oe seen or implied by a numerical calculation	M1
	$= 2(t - 4.5)^2 + 0.5$	A1
	Complete method using the above to find the minimum	M1
	Minimum $AB = \sqrt{0.5} = 0.71$ m (or better)	A1
	OR $AB^2 = (t - 4)^2 + (5 - t)^2$ oe seen or implied by a numerical calculation	M1
	$4t - 18$ or $2(t - 4) - 2(5 - t)$	A1
	N.B. Either of these could be implied by seeing $t = 4.5$	
	Complete method using the above to find the minimum	M1
	Minimum $AB = \sqrt{0.5} = 0.71$ m (or better)	A1 (4)
	OR $AB^2 = (t - 4)^2 + (5 - t)^2$ oe seen or implied by a numerical calculation	M1
	$2t^2 - 18t + (41 - d^2) = 0$ ($d = AB$)	A1
	Complete method using $b^2 - 4ac = 0$: $(-18)^2 - 4 \times 2(41 - d^2) = 0$ to find minimum	M1
	Minimum $AB = \sqrt{0.5} = 0.71$ m (or better)	A1
Accept column vectors throughout except in (c)		(12)
Notes for question 6		
6(a)	M1 for an attempt at $\mathbf{r}_A$ with a correct structure	
	A1 cao	
6(b)	M1 for putting $t = 6$ into their $\mathbf{r}_A$ to find $\mathbf{r}_P$	
	M1 for equating their $\mathbf{r}_B$ at time t (with correct structure) to their $\mathbf{r}_P$	
	DM1 Solve their vector equation for both components, dependent on both previous M marks. Need to see 5.5 occurring twice . N.B. One ratio equation is not sufficient for this mark	

Question Number	Scheme	Marks
6(a)	$(p\mathbf{i} + q\mathbf{j}) + (2q\mathbf{i} + p\mathbf{j}) = 2(\mathbf{i} - \mathbf{j})$ (allow 2g)	M1
	Equating coefficients of $\mathbf{i}$ or $\mathbf{j}$	M1
	$p + 2q = 2$	A1
	$q + p = -2$	A1
	$p = -6; q = 4$	A1
		(5)
6(b)	$\tan \alpha = \pm 1$; e.g. 45° or $\frac{\pi}{4}$	M1
	Angle is 135° or 225° or $\frac{3\pi}{4}$ or $\frac{5\pi}{4}$	A1
		(2)
6(c)	$\mathbf{v} = (3\mathbf{i} - 4\mathbf{j}) + T(\mathbf{i} - \mathbf{j})$	M1
	$\frac{3+T}{-4-T} = \frac{11}{-13}$	M1A1
	Solve for T	DM1
	$T = 2.5$	A1
		(5)
		(12)
	Notes for question 6	
6(a)	M1 Use of $\mathbf{F} = m\mathbf{a}$ with $m = 2$. Correct no. of terms and must be attempting to add the two forces.	
	M1 Must have an equation in p and q only (no vectors) This mark is available if m has been omitted.	
	M0 if they use a ratio i.e. $\frac{p+2q}{2} = \frac{q+p}{-2}$ but never equate coefficients.	
	A1 A correct equation in any form	
	A1 Two correct equations in any form	
	A1 cao	
6(b)	M1 (Use of trig.) to find a relevant angle	
	A1 cao accept radians or degrees	
6(c)	M1 Use of $\mathbf{v} = \mathbf{u} + \mathbf{a}T$ to obtain a velocity vector.	
	M1 Use of ratios using <i>their</i> $\mathbf{v}$ (must be a velocity) to produce an equation in T (allow t) only Condone sign error but must be the correct way up.	
	A1 Correct equation	
	DM1 Dependent on previous M mark for solving for T	
	A1 cao	

Question Number	Scheme	Marks
5(a)	Put $t = 2$ to give $-3\mathbf{i} + 4\mathbf{j}$	M1
	$\sqrt{(-3)^2 + 4^2}$ The – sign is not required	M1
	5 (m s^{-1})	A1
		(3)
(b)	e.g. $\tan \theta = \frac{3}{4}$	M1
	A correct equation	A1ft
	37° or 323° nearest degree	A1
		(3)
(c)	$\mathbf{v} = (7 - 5t)\mathbf{i} + (12t - 20)\mathbf{j}$	
	$= (7\mathbf{i} - 20\mathbf{j}) + t(-5\mathbf{i} + 12\mathbf{j})$	M1
	$\frac{\mathbf{v} - (7\mathbf{i} - 20\mathbf{j})}{t} = (-5\mathbf{i} + 12\mathbf{j})$	M1 A1
	OR: $t = 0$, $\mathbf{v} = 7\mathbf{i} - 20\mathbf{j}$	M1
	$\frac{(-3\mathbf{i} + 4\mathbf{j}) - (7\mathbf{i} - 20\mathbf{j})}{2} = (-5\mathbf{i} + 12\mathbf{j})$	M1A1
	OR: Differentiate wrt t	M2
	$\frac{d\mathbf{v}}{dt} = \mathbf{a} = (-5\mathbf{i} + 12\mathbf{j})$	A1
		(3)
(d)	$\frac{(7 - 5t)}{(12t - 20)} = \frac{-5}{8}$	M1 A1
	Solve for t	M1
	$t = 2.2$	A1
		(4)
		(13)

Notes for Question 5		
5(a)	M1 Allow column vectors	
	M1 Finding the magnitude of their $\mathbf{v}$	
	A1 Correct answer	
5(b)	M1 For a relevant trig equation	
	A1ft A correct equation follow through on their $\mathbf{v}$	
	A1 Correct answer (must be in degrees to nearest degree)	
5(c)	M1 Collecting terms in t and constant terms (may be implied)	
	M1 Rearranging to required form	
	A1 Correct answer (isw if they find the magnitude)	
OR:	M1 Finding the initial velocity or some other specific velocity	
	M1 Use of $\mathbf{a} = \frac{\mathbf{v} - \mathbf{u}}{t}$ with $t = 2$ (or possibly another appropriate value)	
	A1 Correct answer (isw if they find the magnitude)	
5(d)	M1 Attempt at equation in t only, using ratio of components, allow reciprocal and a sign error	
	A1 Correct equation	

	M1 Solve for t (equation must have come from considering ratios)	
	A1 Correct answer	



Question Number	Scheme	Marks
	N.B. Answers to (a) and (b) should be in terms of i and j , but only penalise once. Column vectors can be used in working.	
7(a)	$\mathbf{v}_B = (20\sin\alpha)\mathbf{i} + (20\cos\alpha)\mathbf{j}$ oe e.g. use of Pythagoras but must get to an answer	M1
	$= 16\mathbf{i} + 12\mathbf{j}$ (km h ⁻¹)	A1 (2)
7(b)	$(s =) (10\mathbf{i} + 5\mathbf{j}) + t(16\mathbf{i} + 12\mathbf{j})$ or $(10 + 16t)\mathbf{i} + (5 + 12t)\mathbf{j}$	M1 A1 ft (2)
7(c)	$\overrightarrow{AB} = \mathbf{s} - \mathbf{r} = (10\mathbf{i} + 5\mathbf{j}) + t(16\mathbf{i} + 12\mathbf{j}) - [20\mathbf{j} + 40t\mathbf{i}]$	M1
	$\overrightarrow{AB} = [(10 - 24t)\mathbf{i} + (12t - 15)\mathbf{j}]$ km *	A1* (2)
7(d)	$10 - 24t = 0$ and $12t - 15 = 0$ OR $40t = 10 + 16t$ and $20 = 5 + 12t$	M1
	$t = \frac{5}{12}$ and $\frac{5}{4}$ or one correct t value which is then used in the other equation correctly to show that the equation is not true.	A1
	Different t values oe so never collide*	A1* (3)
	ALT 1:	
	$(10 - 24t)^2 + (12t - 15)^2 = 0$ (i.e. $720t^2 - 840t + 325 = 0$)	M1
	$(-840)^2 - 4 \times 720 \times 325 (= -230,400) < 0$	A1
	Or roots $\frac{7 \pm 4i}{12}$ (calculator)	
	No real roots oe so never collide* A1*	
	N.B. Must see justification for 'no real roots' to score either of the A marks.	
	ALT 2:	
	Finds minimum value of $720t^2 - 840t + 325$ or its square root using derivative or completing the square or calculator	M1
	80 or $\sqrt{80}$ or $\overrightarrow{AB} = -4\mathbf{i} - 8\mathbf{j}$ (at $t = \frac{7}{12}$)	A1
	so never collide* A1*	
7(e)	$10 - 24t = 12t - 15$ oe	M1
	$t = \frac{25}{36}$ or 0.69 or better	A1
	$\overrightarrow{AB} = \left[(10 - 24 \times \frac{25}{36})\mathbf{i} + (12 \times \frac{25}{36} - 15)\mathbf{j} \right]$ (km)	M1
	$AB = 20 \frac{\sqrt{2}}{3}$, 9.4 or better (km)	A1 (4)
		(13)

	Notes	
7(a)	M1: Condone sign errors and sin/cos confusion but both components must be resolved. Allow if they use $\cos(\frac{3}{5})$ or similar. If $12\mathbf{i} + 16\mathbf{j}$ appears without working, award M1A0.	
	A1: cao	
7(b)	M1: Correct structure, condone slips	
	A1ft: ft on their answer to (a)	
7(c)	M1: Allow $\mathbf{r} - \mathbf{s}$. $\mathbf{r}$ and $\mathbf{s}$ must be substituted.	
	A1*: Correct given answer, correctly obtained N.B. Need to see $\overrightarrow{AB}$ at the start or finish for the A1* and answer must be exactly as printed, ignoring [] and km.	
7(d)	M1: They may use $\mathbf{r} = \mathbf{s}$ with both $\mathbf{i}$ and $\mathbf{j}$ cpts equated.	
	A1: Need both t values. Accept 0.42 or better and 1.25.	
	A1*: Correct conclusion	
7(e)	M1: Correct method	
	A1: cao	
	M1: Sub their calculated t value into $\overrightarrow{AB}$ or $\overrightarrow{BA}$, seen or implied, oe. Note that this is an independent M mark.	
	A1: cao	



	Allow column vectors throughout apart from in the answers to (b) and (c).		
7a	$ \mathbf{a} = \sqrt{1^2 + (-4)^2}$ or $\sqrt{1^2 + 4^2}$	M1	Complete method to find the magnitude using the correct vector or the correct vector with just a sign error. They may use $\mathbf{a} = \frac{\mathbf{v}_p - \mathbf{v}_q}{p - q}$ for two specific times p and q , allow subtraction either way round and slips in arithmetic
	$= \sqrt{17}$. Accept $4.1(\text{km h}^{-2})$ or better	A1	$= 4.123105\dots (\text{km h}^{-2})$ Must come from a correct $\mathbf{a}$ (if seen.)
		(2)	
7b	$\frac{(\mathbf{i} - 5\mathbf{j}) - (4\mathbf{i} + \mathbf{j})}{3}$	M1	Condone subtraction the wrong way round
	$= -\mathbf{i} - 2\mathbf{j} \quad (\text{km h}^{-2})$	A1	Must be in $\mathbf{i}$ and $\mathbf{j}$
		(2)	
7c	$4\mathbf{i} + \mathbf{j} - 2(-\mathbf{i} - 2\mathbf{j})$ OR $\mathbf{i} - 5\mathbf{j} - 5(-\mathbf{i} - 2\mathbf{j})$	M1	Or equivalent for their $\mathbf{a}$
	$= 6\mathbf{i} + 5\mathbf{j} \quad (\text{km h}^{-1})$	A1	Must be in $\mathbf{i}$ and $\mathbf{j}$. Isw if they find the speed.
			N.B. In (b) and (c), penalise the use of column vectors in the answers ONCE.
		(2)	
7d	Express both velocities in component form, with $\mathbf{i}$'s and $\mathbf{j}$'s collected, using their answers to (b) and (c) for $\mathbf{v}_B$.	M1	$\mathbf{v}_A = (2+t)\mathbf{i} + (3-4t)\mathbf{j}$ $\mathbf{v}_B = (6-t)\mathbf{i} + (5-2t)\mathbf{j}$ Seen or implied. Allow slips. N.B. This mark can be earned in part (e).
	Correct use of Pythagoras to form an equation in T_1 (or t) only, with or without square roots.	M1	For given $\mathbf{v}_A$ and their $\mathbf{v}_B$
	$(6-T_1)^2 + (5-2T_1)^2 = (2+T_1)^2 + (3-4T_1)^2$ $(T_1^2 + T_1 - 4 = 0)$	A1ft	Correct unsimplified equation in T_1 (or t), without square roots. Follow their answers from (b) and (c)
	$\frac{-1+\sqrt{17}}{2}$ only	A1	cao accept exact equivalent
		(4)	
7e	Use ratios to form an equation in T_2 (or t) only	M1	Allow reciprocal on one side N.B. Allow if $\mathbf{i}$'s and $\mathbf{j}$'s are left in

	$\Rightarrow \frac{5-2T_2}{6-T_2} = \frac{3-4T_2}{2+T_2}$ (allow t at this stage)	A1ft	Or equivalent ft on their $\mathbf{v_B}$
	$\Rightarrow 3T_2^2 - 14T_2 + 4 = 0$ *	A1*	Obtain correct answer from full and correct working with no errors. Must see at least $10 + 5T_2 - 4T_2 - 2T_2^2 = 18 - 24T_2 - 3T_2 + 4T_2^2$ OR $10 + T_2 - 2T_2^2 = 18 - 27T_2 + 4T_2^2$ (Allow t at this stage but must be T_2 in final answer) $\Rightarrow 3T_2^2 - 14T_2 + 4 = 0$ *
		(3)	
		(13)	

Question Number	Scheme	Marks
7(a)	$T = ma$ (allow $-a$)	B1
		(1)
7(b)	$4mg \sin \alpha - T - F = 4ma$ OR $4mg \sin \alpha - F = 5ma$ (allow $-a$) (allow $-a$)	M1A1
	$F = \frac{1}{4}R$	B1
	$R = 4mg \cos \alpha$	M1A1
	Solve for T in terms of mg only	DM1
	$T = \frac{8mg}{25}$ oe	A1
		(7)
7(c)	$2T \sin \frac{1}{2}\alpha$ oe e.g. $\sqrt{T^2 + T^2 - 2T^2 \cos \alpha}$ using cos rule Or $\frac{T \sin \alpha}{\sin(90^\circ - \frac{1}{2}\alpha)}$ using sine rule Or $\sqrt{(T - T \cos \alpha)^2 + (T \sin \alpha)^2}$ using components and Pythag.	M1 A1
	Substitute for T and trig	M1
	$\frac{8mg\sqrt{10}}{125}$ oe, $2m$ or $2.0m$ or $1.98m$ or $0.2mg$ or better	A1
		(4)
7(d)	e.g. Tension will be the same <u>throughout a section</u> of the string.	B1 (1)
		(13)
Notes for question 7		
7(a)	B1 cao The equation must appear in (a) to earn the B1.	
7(b)	M1 Equation of motion for P parallel to the plane, correct no. of terms, condone sign errors and sin/cos confusion	
	A1 Correct equation	
	B1 $F = \frac{1}{4}R$ seen – could just be on the diagram	
	M1 Resolve perpendicular to the plane for P , correct no. of terms, condone sign errors and sin/cos confusion	
	A1 Correct equation	
	DM1 Dependent on both M marks, for solving for T – must be in terms of mg only (must be of form kmg)	
	A1 cao	
7(c)	M1 If using resolving, condone cos/sin confusion and sign errors but must have correct angle	
	A1 Any correct unsimplified expression in terms of T and α	
	M1 For substituting in their T (must be of form kmg) and correct values for their trig	
	A1 cao	
7(d)	B1 B0 for ‘tension is the same throughout the string’ B0 if incorrect extras	

Question Number	Scheme	Marks
8(a)	$\mathbf{r} = (13\mathbf{i} + 5\mathbf{j}) + t(3\mathbf{i} - 10\mathbf{j})$	M1 A1
		(2)
8(b)	$\mathbf{s} = (3\mathbf{i} - 5\mathbf{j}) + t(15\mathbf{i} + 14\mathbf{j})$	M1 A1
	$\overrightarrow{AB} = \mathbf{s} - \mathbf{r}$	M1
	=	
	$\overrightarrow{AB} = (12t - 10)\mathbf{i} + (24t - 10)\mathbf{j} \text{ km}^*$	A1 *
		(4)
8(c)	$AB^2 = (12t - 10)^2 + (24t - 10)^2 \quad (720t^2 - 720t + 200)$	M1
	Differentiate and equate to 0 OR Complete square OR use $t = \frac{-b}{2a}$	M1
	$1440t - 720 = 0$ oe $720(t - \frac{1}{2})^2 + 20$	A1
	Solve for t Use $(t - \frac{1}{2})^2 \geq 0$ $t = \frac{720}{2 \times 720}$	DM1
	Substitute their value of t into their AB expression	M1
	$\sqrt{20}$ oe (km) 4.5 or better	A1
	OR for last 5 marks:	
	Complete method	M1
	$720t^2 - 720t + 200 = D^2$ i.e. $720t^2 - 720t + 200 - D^2 = 0$	A1
	(For real t , $720^2 \geq 4 \times 720(200 - D^2)$)	DM1
	Solve for D , ($D \geq \sqrt{20}$)	M1
	$\sqrt{20}$ oe (km) 4.5 or better	A1
		(6)
8(d)	Use $\overrightarrow{AB} = -4\mathbf{i} + 2\mathbf{j}$ at $t = \frac{1}{2}$ to obtain a relevant angle e.g. 26.56° ..	M1
	Allow e.g. $\tan \alpha = \frac{1}{2}$ or $\tan^{-1} \frac{1}{2}$	
	Bearing is 297° or better	A1
		(2)
		(14)
	Notes for question 8	
	Accept column vectors through out apart from the answer for (b)	
8(a)	M1 Expression with correct structure	
	A1 cao	
8(b)	M1 Expression with correct structure	
	A1 cao	
	M1 Allow difference in either order	
	A1* Correct given expression correctly obtained	
	N.B. $\overrightarrow{AB} = (-10 + 12t)\mathbf{i} + (-10 + 24t)\mathbf{j}$ is A0	
8(c)	M1 Correct expression (with or without square root)	
	M1 Attempt to differentiate (at least one power decreasing by 1) or to complete the square	
	A1 Correct equation or expression	
	DM1 Dependent on previous M for finding the critical value for t	
	OR For the completing the square method, for 'ignoring' the $(t - \frac{1}{2})^2$ term.	

QUESTION NUMBER	SCHEME	MARKS
6(a)	$\frac{(20\mathbf{i} + 34\mathbf{j}) - (15\mathbf{i} + 36\mathbf{j})}{0.5}$ oe	M1
	$(10\mathbf{i} - 4\mathbf{j})^*$	A1*
		(2)
6(b)	$(15\mathbf{i} + 36\mathbf{j}) + t(10\mathbf{i} - 4\mathbf{j})$	M1 A1
		(2)
6(c)(i)	Verify using $t = 1.5$ in p or q $\mathbf{p} = (15\mathbf{i} + 36\mathbf{j}) + 1.5(10\mathbf{i} - 4\mathbf{j}) = 30\mathbf{i} + 30\mathbf{j}$ $\mathbf{q} = (42 - 8 \times 1.5)\mathbf{i} + (9 + 14 \times 1.5)\mathbf{j} = 30\mathbf{i} + 30\mathbf{j}$	M1 A1 A1
(ii)	$30\mathbf{i} + 30\mathbf{j}$	A1 (B1)
	N.B. The A mark for (ii) is now to be treated as a B mark.	
		(4)
ALT1 (i)	Find t by equating i or j components of p and q Equate i 's $15 + 10t = 42 - 8t \rightarrow t = 1.5$ j 's $36 - 4t = 9 + 14t \rightarrow t = 1.5$	M1 A1 A1
(ii)	$30\mathbf{i} + 30\mathbf{j}$	A1 (B1)
ALT2 (i)	Uses ratio: $\frac{15 + 10t}{36 - 4t} = \frac{42 - 8t}{9 + 14t}$ $\rightarrow t = 1.5$ or -8.5 verifies that components are both 30 at $t = 1.5$	M1 A1 A1
(ii)	$30\mathbf{i} + 30\mathbf{j}$	A1 (B1)
		(4)
6(d)	Position of P at 14:30 is $40\mathbf{i} + 26\mathbf{j}$	B1
	Position of Q when $t = 0.5$ $\mathbf{q} = (42 - 8 \times 0.5)\mathbf{i} + (9 + 14 \times 0.5)\mathbf{j}$ $(= (38\mathbf{i} + 16\mathbf{j}))$	M1
	$15\mathbf{j}$ seen or implied	B1
	New position of Q at time 14:30 $\mathbf{q} = (38\mathbf{i} + 16\mathbf{j}) + 2(15\mathbf{j})$ N.B. M0 if 2.5 is used.	M1
	$\mathbf{q} = 38\mathbf{i} + 46\mathbf{j}$	A1
	$ PQ = \sqrt{(40 - 38)^2 + (26 - 46)^2}$	dM1
	$= \sqrt{404}$ or $2\sqrt{101}$ (km)	A1
		(7)
		(15)



Notes for question 6	
	N.B. Allow use of column vectors throughout apart from the A marks in (a) and (b).
(a)	
M1	Complete method to find an expression for the velocity. Allow if they use 30 minutes. Give M1A0, if there are missing brackets.
A1*	Reaches the given answer from fully correct working.
(b)	
M1	Finds an expression for p in terms of t with the correct structure
A1	Correct answer in terms of i , j and t .
(c)	
(i) M1	Substitutes $t = 1.5$ into the given q or their p
A1	P equation correct
A1	Q equation correct
	N.B. p or q = $30\mathbf{i} + 30\mathbf{j}$ alone can imply a correct equation in each case.
(ii) A1(B1)	$30\mathbf{i} + 30\mathbf{j}$ seen
	ALT 1
(i) M1	Equates coefficients of i or j using the given q and their p
A1	Correct equation for i leading to $t = 1.5$
A1	Correct equation for j leading to $t = 1.5$
	N.B. Allow both A marks if they only write $t = 1.5$ once.
(ii) A1(B1)	$30\mathbf{i} + 30\mathbf{j}$ seen
	ALT 2
(i) M1	Uses ratio of components to form equation.
A1	Two t values
A1	Verifies that components are both 30 at $t = 1.5$
(ii) A1(B1)	$30\mathbf{i} + 30\mathbf{j}$ seen
(d)	
B1	Position of P at 14:30
M1	Use $t = 0.5$ to find the new position of Q at 12:30
B1	Correct expression seen for new velocity of Q
M1	Complete method to find the new position of Q at 14:30, using their new v for Q .
A1	Correct position,
dM1	Use of Pythagoras to find the distance. Dependent on both previous M marks.
A1	Correct surd answer

Question Number	Scheme	Marks	
	Allow column vectors throughout		
8(a)	$\sqrt{3^2 + 12^2}$	M1	
	$\sqrt{153}, 3\sqrt{17}, 12$ or better (km h ⁻¹)	A1	
		(2)	
8(b)	$(-9\mathbf{i} + 6\mathbf{j}) + t(3\mathbf{i} + 12\mathbf{j})$	M1	A1
	$(16\mathbf{i} + 6\mathbf{j}) + t(p\mathbf{i} + q\mathbf{j})$		A1
	$\overrightarrow{AB} = \mathbf{b} - \mathbf{a} = (16\mathbf{i} + 6\mathbf{j}) + t(p\mathbf{i} + q\mathbf{j}) - ((-9\mathbf{i} + 6\mathbf{j}) + t(3\mathbf{i} + 12\mathbf{j}))$	M1 A1	
	$= [25 + t(p - 3)]\mathbf{i} + t(q - 12)\mathbf{j}$		
	Compare with: $[(25 - 12t)\mathbf{i} - 9t\mathbf{j}]$ or e.g. use $\mathbf{b} = \overrightarrow{AB} + \mathbf{a}$ to obtain an equation in p only and an equation in q only. May be implied by correct answers only. ($-12 = p - 3$ and $-9 = q - 12$) N.B. This mark may not be available if they go wrong and the t 's don't cancel.	M1	
	$p = -9, q = 3$	A1	
		(7)	
8(c)	$(25 - 12t)^2 + (-9t)^2 = 15^2$ ($225t^2 - 600t + 400 = 0$)	M1A1	
	$t = \frac{4}{3}$	A1	
	$\pm(9\mathbf{i} - 12\mathbf{j})$ Note that this a method mark.	DM1	
	$\tan \theta = \frac{9}{12}$	M1	
	$\theta = 37^\circ$	A1	
	Bearing is 323° to nearest degree	A1	
		(7)	
		(16)	



	Notes for question 8	
8(a)	M1 Use of Pythagoras with square root	
	A1 cao	
8(b)	M1 Correct structure for either	
	A1 cao	
	A1 cao	
	M1 Allow a – b	
	A1 for a correct unsimplified expression for either b – a or a – b	
	M1 for an equation in <i>p</i> only and an equation in <i>q</i> only	
	A1 cao	
8(c)	M1 Use of Pythagoras to give an equation in <i>t</i> only Allow with a square root.	
	A1 Correct unsimplified quadratic equation	
	A1 $t = 1.3$ or better	
	DM1 Use of their <i>t</i> to find $\overrightarrow{AB}$ or $\overrightarrow{BA}$, dependent on previous M. May be implied. Allow if they use one of their two incorrect <i>t</i> values.	
	M1 For an equation in a relevant angle for their AB . Could be implied by a relevant angle seen on a diagram which could need checking with a calculator	
	A1 Correct relevant angle e.g. $37^\circ, 53^\circ, 127^\circ, etc$ or better	
	A1 cao	



Question Number	Scheme	Marks
	Allow column vectors throughout except for the answer to (b).	
8(a)	Use trig to get an equation in a relevant angle e.g $\tan \alpha = 1$ or uses isosceles triangle. M0 if not using the velocity of Q	M1
	135°	A1
		(2)
8(b)	$\mathbf{p} = t(15\mathbf{i})$	M1 A1
	$\mathbf{q} = 200\mathbf{j} + t(20\mathbf{i} - 20\mathbf{j})$ oe	A1
	$\overrightarrow{PQ} = \mathbf{q} - \mathbf{p} = 200\mathbf{j} + t(20\mathbf{i} - 20\mathbf{j}) - t(15\mathbf{i})$ (M0 if they put $\mathbf{p} = \mathbf{q}$) Need to see at least this line of working.	M1
	$\overrightarrow{PQ} = 5t\mathbf{i} + (200 - 20t)\mathbf{j}$ (m) *	A1*
		(5)
8(c)	$\overrightarrow{PQ} = 50\mathbf{i}$ at $t = 10$ (Allow M1 if they find $\mathbf{p} = 150\mathbf{i}$ and $\mathbf{q} = 200\mathbf{i}$ at $t = 10$) N.B. This mark could be implied by a correct diagram	M1
	270°	A1
		(2)
8(d)	$5t = 200 - 20t$	M1
	$t = 8$	A1
	$\overrightarrow{PQ} = (5 \times 8)\mathbf{i} + (200 - 20 \times 8)\mathbf{j}$	M1
	$PQ = \sqrt{40^2 + 40^2} = 40\sqrt{2}$ (m), 57 or better	M1A1
		(5)
8(e)	$(5t)^2 + (200 - 20t)^2 = 200^2$	M1
	$425t^2 - 8000t = 0$	A1
	$t = 0$ or $\frac{320}{17} = 18.82\dots$ Accept 19 or better Apply isw	A1
		(3)
		(17)
	Notes for question 8	
8(a)	M1 e.g. use of cos or sin or the cosine rule	
	A1 cao	
8(b)	M1 Correct structure for either	
	A1 oe	
	A1 oe	
	M1 Allow $\mathbf{p} - \mathbf{q}$	
	A1* Correct given answer correctly obtained, allow omission of m.	
8(c)	M1 Clear attempt to find $\overrightarrow{PQ}$ at $t = 10$ or $\mathbf{p}$ and $\mathbf{q}$ at $t = 10$	
	A1 cao	
8(d)	M1 Equating components to give an equation in t only, with no vectors	
	A1 cao	
	M1 Substituting their t value into their $\overrightarrow{PQ}$	
	M1 Finding the magnitude, with square root	

	A1 cao	
8(e)	M1 Use of Pythagoras – allow with square root – to obtain an equation in t .	
	A1 Correct unsimplified 2 term quadratic in t .	
	A1 For both answers	

