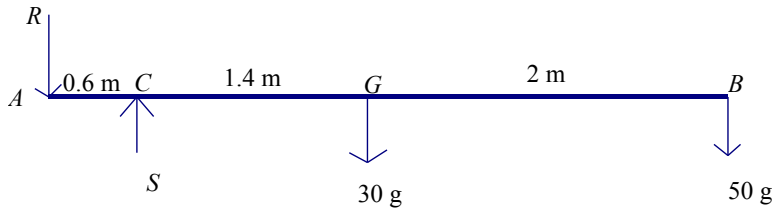
Mechanics M1 Mark scheme

Question	Scheme		Marks
1	$76 = 4u + \frac{1}{2}a.4^2$ or $76 = \frac{1}{2}\left(u + \overline{u+4a}\right)\times 4$	Use of $s = ut + \frac{1}{2}at^2$ for $t = 4, s = 76$ and $u \neq 0$ (use of $u = 0$ is M0)	M1
	$(38 = 2u + 4a)$	Correctly substituted equation	A1
	$295 = 10u + \frac{1}{2}a.10^2$ or $295 = \frac{1}{2}\left(u + \overline{u+10a}\right)\times 10$ or $295 = (u+10a)\times 10 - \frac{1}{2}a\times 100$	Use of $s = ut + \frac{1}{2}at^2$ for $t = 10, s = 295$ or $s = u't + \frac{1}{2}at^2$ for $t = 6, s = 219, u' \neq u$	M1
	$(59 = 2u + 10a)$ or $219 = (19+2a)\times 6 + \frac{1}{2}a\times 6^2$ or $219 = (38-u)\times 6 + \frac{1}{2}a\times 6^2$ or $219 = (u+4a)\times 6 + \frac{1}{2}a\times 6^2$ or $219 = \frac{1}{2}\left(\overline{u+4a} + \overline{u+10}\right)\times 6$ or $219 = (u+10a)\times 6 - \frac{1}{2}a\times 36$	Correctly substituted equation	A1
	Solve simultaneous for u or for a. This marks is not available if they have assumed a value for u or a in the preceding work - it is dependent on the first 2 M marks.		DM1
	$u = 12$		A1
	$a = 3.5$		A1
			(7)
	Alternative		
	$t = 2,\ v_2 = \frac{76}{4} = 19$ $t = 7,\ v_7 = \frac{219}{6} = 36.5$	Find the speed at $t = 2, t = 7$ Both values correct Averages with no links to times is M0	M1 A1
	$36.5 = 19 + 5a \Rightarrow a = 3.5$	Use of $v = u + 5a$ with their u,v Correct a	M1 A1
	$19 = u + 2a$	Complete method for finding u Correct equation in u	DM1 A1
	$u = 19 - 7 = 12$		A1
			(7)
			(7 marks)

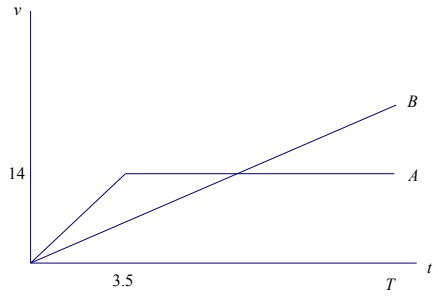
Question	Scheme		Marks
2(a)	$mu - 2kmu = -\frac{1}{2}mu + kmu$ or $m\left(\frac{1}{2}u + u\right) = -km(-u - 2u)$	Use of CLM or Equal and opposite impulses Need all 4 terms dimensionally correct. Masses and speeds must be paired correctly Condone sign errors Condone factor of g throughout.	M1
	Unsimplified equation with at most one error		A1
	Correct unsimplified equation		A1
	$k = \frac{1}{2}$	From correct working only	A1
			(4)
(b)	For $P: I = \pm m(\frac{1}{2}u \pm -u)$ For Q: $I = \pm km(u \pm -2u)$	Impulse on P or impulse on Q. Mass must be used with the correct speeds e.g. $km \times \frac{1}{2}u$ is M0 If working on Q, allow equation using their k. Terms must be dimensionally correct. Use of g is M0	M1
	$\frac{3mu}{2}$	Only From correct working only	A1
			(2)
			(6 marks)

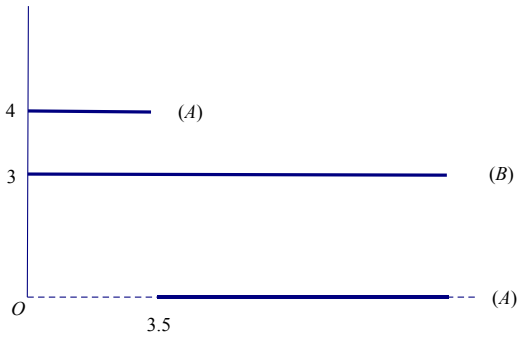
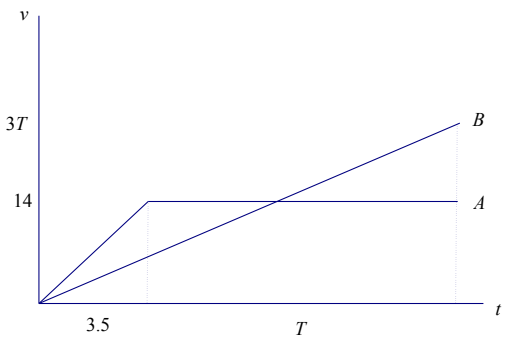
Question	Scheme		Marks
3(a)	$7^2 = 2 \text{ x } 9.8h$	Use of $v^2 = u^2 + 2as$ with $u = 0, v = 7$ or alternative complete method to find h	M1
	$h = 2.5$	Condone $h = -2.5$ in the working but the final answer must be positive.	A1
			(2)
(b)	$9 \text{ x } 7 = 10.5\, u$	Use CLM to find the speed of the blocks after the impact. Condone additional factor of g throughout.	M1
	$u = 6$		A1
	$0^2 = 6^2 - 2a \text{ x } 0.12$	Use of $v^2 = u^2 + 2as$ with $u = 6, v = 0$ Allow for their u and $v = 0$ Allow for $u = 7, v = 0$ Accept alternative *suvat* method to form an equation in a. Condone use of 12 for 0.12	M1
		Correctly substituted equation in a with $u = 6, s = 0.12$ $(\text{implied by } a = 150)$	A1
	$(\downarrow)\ 10.5g - R = 10.5 \text{ x } (-a)$	Use of $F = ma$ with their $a \neq \pm g$. Must have all 3 terms and 10.5 Condone sign error(s)	M1
	$(\downarrow)\ 10.5g - R = 10.5 \text{ x } (-150)$	Unsimplified equation with a substituted and at most one error (their a with the wrong sign is 1 error)	A1
		Correct unsimplified equation with a substituted	A1
	$R = 1680$ or 1700		A1
			(8)
	Alternative for the last 6 marks:		
	$\frac{1}{2} \times 10.5 \times 6^2 + 10.5 \times 9.8 \times 0.12 = R \times 0.12$	Energy equation (needs all three terms)	M2
		-1 each error A1A1A0 for 1 error, A1A0A0 for 2 errors	A3
	$R = 1680$ or 1700		A1

Question	Scheme		Marks
4(a)			
	$M(A)$ $(30\text{g} \times 2) + (50\text{g} \times 4) = 0.6S$	Moments equation. Requires all terms and dimensionally correct. Condone sign errors. Allow M1 if g missing	M1
	$M(C)$ $(0.6\times R)=(1.4\times 30\text{g})+(3.4\times 50\text{g})$ $M(G)$ $(2\times R)=(1.4\times S)+(2\times 50\text{g})$ $M(B)$ $(4\times R)+(2\times 30g)=(3.4\times S)$	Correct unsimplified equation	A1
	$(\uparrow)\ R+30g+50g=S$ $(R+784=S)$	Resolve vertically. Requires all 4 terms. Condone sign errors	M1
	Correct equation (with R or their R) NB: The second M1A1 can also be earned for a second moments equation		A1
	$R=3460$ or 3500 or $\frac{1060g}{3}$ (N) Not 353.3g	One force correct	A1
	$S=4250$ or 4200 or $\frac{1300g}{3}$ (N) Not 433.3g	Both forces correct If both forces are given as decimal multiples of g mark this as an accuracy penalty A0A1	A1
			(6)
(b)	$M(C)$ $(30\text{g} \times 1.4) + (M\text{g} \times 3.4) = 0.6 \times 5000$	Use $R=5000$ and complete method to form an equation in M or weight. Needs all terms present and dimensionally correct. Condone sign errors. Accept inequality. Use of R and S from (a) is M0	M1
		Correct equation in M (not weight) $(\text{implied by } M=77.68)$	A1
	$M=77$ kg	77.7 is A0 even is the penalty for over-specified answers has already been applied	A1
			(3)

Question	Scheme		Marks
4(c)	The weight of the diver acts at a point.	Accept "the mass of the diver is at a point".	B1
			(1)
			(10 marks)

Question	Scheme		Marks
5(a)	$(2\mathbf{i}-3\mathbf{j})+(p\mathbf{i}+q\mathbf{j})=(p+2)\mathbf{i}+(q-3)\mathbf{j}$	Resultant force = $\mathbf{F}_1+\mathbf{F}_2$ in the form $a\mathbf{i}+b\mathbf{j}$	M1
	$\frac{p+2}{q-3}=\frac{1}{2}$ or $\left.\begin{matrix}p+2=n\\q-3=2n\end{matrix}\right\}$ for $n\neq 1$	Use parallel vector to form a scalar equation in p and q.	M1
		Correct equation (accept any equivalent form)	A1
	$4+2p=-3+q$	Dependent on no errors seen in comparing the vectors. Rearrange to obtain given answer. At least one stage of working between the fraction and the given answer	DM1
	$2p-q+7=0$	**Given Answer**	A1
			(5)
5(b)	$q=11\Rightarrow p=2$		B1
	$\mathbf{R}=4\mathbf{i}+8\mathbf{j}$	$(2+p)\mathbf{i}+8\mathbf{j}$ for their p	M1
	$4\mathbf{i}+8\mathbf{j}=2\mathbf{a}$ $(\mathbf{a}=2\mathbf{i}+4\mathbf{j})$	Use of $\mathbf{F}=m\mathbf{a}$	M1
	$\lvert\mathbf{a}\rvert=\sqrt{2^2+4^2}$	Correct method for $\lvert\mathbf{a}\rvert$ Dependent on the preceding M1	DM1
	$=\sqrt{20}=4.5$ or 4.47 or better (m s^{-2})	$2\sqrt{5}$	A1
			(5)
	Alternative for the last two M marks:		
	$\lvert\mathbf{F}\rvert=\sqrt{16+64}\left(=\sqrt{80}\right)$	Correct method for $\lvert\mathbf{F}\rvert$	M1
	$\sqrt{80}=2\times\lvert\mathbf{a}\rvert$	Use of $\lvert\mathbf{F}\rvert=m\lvert\mathbf{a}\rvert$ Dependent on the preceding M1	DM1
			(5)
			(10 marks)

Question	Scheme		Marks
6(a)	$v = u + at \Rightarrow 14 = 3.5a$	Use of *suvat* to form an equation in a	M1
	$a = 4$		A1
			(2)
(b)		Graph for A or B	B1
		Second graph correct and both graphs extending beyond the point of intersection	B1
		Values 3.5, 14, T shown on axes, with T not at the point of intersection. Accept labels with delineators.	B1
	NB: 2 separate diagrams scores max B1B0B1		**(3)**
(c)	$\frac{1}{2}T.3T$, $\frac{(T+T-3.5)}{2}.14$	Find distance for A or B in terms of T only. Correct area formulae: must see $\frac{1}{2}$ in area formula and be adding in trapezium	M1
	One distance correct		A1
	Both distances correct		A1
	$\frac{1}{2}T.3T = \frac{(T+T-3.5)}{2}.14$ $\frac{1}{2}T.3T = \frac{1}{2}\times 4\times 3.5^2 + 14(T-3.5)$	Equate distances and simplify to a 3 term quadratic in T in the form $aT^2 + bT + c = 0$	M1
	$3T^2 - 28T + 49 = 0$	Correct quadratic	A1
	$(3T-7)(T-7) = 0$	Solve 3 term quadratic for T	M1
	$T = \frac{7}{3}$ or 7	Correct solution(s) - can be implied if only ever see $T = 7$ from correct work.	A1
	but $T > 3.5$, $T = 7$		A1
			(8)
(d)	73.5 m	From correct work only. B0 if extra answers.	B1
			(1)

Question	Scheme		Marks
6(e)		(*A*) Condone missing 4	B1
		(*B*) Condone graph going beyond $T = 7$ Must go beyond 3.5. Condone no 3.	B1
		(*A*) Condone graph going beyond $T = 7$ Must go beyond 3.5. B0 if see a <u>solid</u> vertical line. Sometimes very difficult to see. If you think it is there, give the mark.	B1
			(3)
	Condone separate diagrams.		
	Alternative for (c) for candidates with a sketch like this: 	Treat as a special case. B1B1B0 on the graph and then max 5/8 for (c) if they do not solve for the *T* in the question.	B1 B1 B0
	$\frac{1}{2}\times 3\times(T+3.5)^2 = \frac{1}{2}\times 4\times 3.5^2 + 14T$	Use diagram to find area	M1
		One distance correct	A1
		Both distances correct	A1
	$12T^2 - 28T - 49 = 0$	Simplify to a 3 term quadratic in *T*	M1
		Correct quadratic	A1
	$(2T-7)(6T+7) = 0$	Complete method to solve for the *T* in the question	M1
	$T = \frac{7}{2}$ or $\frac{-7}{6}$	Correct solution(s) - can be implied if only ever see Total = 7	A1
	Total time = 7		A1
			(8)
			(17 marks)

Question	Scheme		Marks
7(a)	$F = 0.25R$		B1
	$\sin\alpha = \frac{3}{5}$ or $\cos\alpha = \frac{4}{5}$ $\sin\beta = \frac{4}{5}$ or $\cos\beta = \frac{3}{5}$	Use of correct trig ratios for α or β	B1
	$R = 4g\cos\alpha$ (31.36)	Normal reaction on P Condone trig confusion (using α)	M1
		Correct equation	A1
	$T + F = 4g\sin\alpha$	Equation of motion for P. Requires all 3 terms. Condone consistent trig confusion Condone an acceleration not equated to 0 : $T + F - 4g\sin\alpha = 4a$	M1
	$(T + 7.84 = 23.52)$ $(T = 15.68)$	Correct equation	A1
	$T = mg\sin\beta$	Equation of motion for Q Condone trig confusion Condone an acceleration not equated to 0: $T - mg\sin\beta = -ma$	M1
	$(T = 7.84m)$	Correct equation	A1
	Solve for m	Dependent on the 3 preceding M marks Not available if their equations used $a \neq 0$	DM1
	$m = 2$		A1
	NB Condone a whole system equation $4g\sin\alpha - F = mg\sin\beta$ followed by $m = 2$ for 6/6 M2 for an equation with all 3 terms. Condon trig confusion. Condone an acceleration $\neq 0$ A2 (-1 each error) for a correct equation:		
			(10)
7(b)	$F = \sqrt{T^2 + T^2}$ or $2T\cos 45°$ or $\frac{T}{\cos 45}$	Complete method for finding F in terms of T Accept $\sqrt{(R_h)^2 + (R_v)^2}$	M1
	Correct expression in T		A1
	Substitute their T into a correct expression. Dependent on the previous M mark		DM1
	$F = \sqrt{2}\frac{8g}{5} = 22$ or 22.2 (N)	Watch out - resolving vertically is not a correct method and gives 21.9 N.	A1
			(4)

Question	Scheme		Marks
7(c)	Along the angle bisector at the pulley	Or equivalent - accept angle + arrow shown on diagram. (8.1° to downward vertical) Do not accept a bearing	
			(1)
			(15 marks)