OCR Maths M1

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1	(i)	R is smooth	B1 1	
	(ii)	$T + T\cos 60^o = 1.6\cos 45^o$ Tension is 0.754 N **AG**	M1 A1 A1 3	For resolving forces horizontally to obtain an equation in T (requires 3 relevant terms and at least one force resolved)
	(iii)	$mg = T\sin 60^o + 1.6\sin 45^o$ $m = 0.182$	M1 A1 ft A1 3	For resolving forces vertically to obtain an equation for m (requires 3 relevant terms with both T and the 1.6 N force resolved) ft sin/cos mix from (ii)
				SR $m = T\sin 60^o + 1.6\sin 45^o$ M1 $m = 1.78$ B1

2	(i)	$0.2g + T - 0.4 = 0.2a$ $0.3g - T - 0.25 = 0.3a$	M1 A1 A1 A1 4	For applying $F = ma$ (requires at least ma, T and air resistance in linear combination in at least one equation). At least one equation with not more than one error. SR $0.2g - T - 0.4 = 0.2a$ **and** $0.3g + T - 0.25 = 0.3a$ B1
	(ii)	$0.5g - 0.65 = 0.5a$ or $5T - 0.7 = 0$ $a = 8.5$ **and** $T = 0.14$ (positive only)	M1 A1 ft A1 3	For obtaining an equation in T or a only, either by eliminating a or T from the equations in (i) or by applying $F = ma$ to the complete system For a correct equation in a only or T only ft opposite direction of T only

3	(i)	Momentum before=$0.1\times4 - 0.2\times3$ Momentum after = $-0.1u + 0.2(3.5 - u)$ $0.1\times4 - 0.2\times3 = -0.1u + 0.2(3.5 - u)$ $u = 3$ (positive value only)	B1 B1 M1 A1 4	or Loss by $P = 0.1\times4 + 0.1u$ or Gain by $Q = 0.2(3.5 - u) + 0.2\times3$ For using the principle of conservation of momentum
				SR If mgv used for momentum instead of mv, then $u = 3$ B1
	(ii)	$0 = 3^2 - 10s_1$ and $0 = 0.5^2 - 10s_2$ 0.9 + 0.025 Distance is 0.925 m cao	M1 A1 ft M1 A1 4	For using $v^2 = u^2 + 2as$ with $v = 0$ (either case) or equivalent equations ft value of u from (i) For using $PQ = s_1 + s_2$

4	(i) α	$2 = 0.8u + ½\ a(0.8)^2$ $8 = 2u + ½\ a2^2$ or $6 = 1.2(u + 0.8a) + ½\ a(1.2)^2$ or $6 = 1.2(2\times2\div0.8 - u) + ½\ a(1.2)^2$ $u = 1.5$ Acceleration is 2.5 ms^{-2}	M1 A1 M1 A1 M1 A1 A1 7	For using $s = ut + ½\ at^2$ for the first stage For obtaining another equation in u and a with relevant values of velocity, displacement and time For eliminating a or u
	(i) β	$2 = 0.8v - ½\ a(0.8)^2$ $6 = 1.2v + ½\ a(1.2)^2$ Acceleration is 2.5 ms^{-2} (v = 3.5) $u = 1.5$	M1 A1 M1 A1 M1 A1 A1 7	For using $s = vt - ½\ at^2$ for the first stage For using $s = ut + ½\ at^2$ for the second stage For obtaining values of a and v and using $v = u + at$ for first stage to find u
	(i) γ	$2\div0.8$ ms^{-1} and $6\div1.2$ ms^{-1} = 2.5 ms^{-1} and 5ms^{-1} $t_1 = 0.4$ and $t_2 = (0.8 +) 0.6$ $5 = 2.5 + a\ (1.4 - 0.4)$ Acceleration is 2.5 ms^{-2}	M1 A1 B1 M1 A1	For finding average speeds in both intervals For finding mid-interval times For using $v = u + at$ between the mid-interval times

		$2.5 = u + 2.5 \times 0.4$ or $5 = u + 2.5 \times 1.4$ $u = 1.5$	M1 A1	7	For using $v = u + at$ between t = 0 and one of the mid-interval times
	(ii)	$2.5 = 9.8\sin\alpha$ $\alpha = 14.8^o$	M1 A1ft	2	For using $(m)a = (m)g\sin\alpha$ ft value of acceleration

5	(i)	 $F = 2 + 7\cos\alpha$ $F = 3.96$ (may be implied) $N = 7\sin\alpha$ $N = 6.72$ (may be implied) $3.96 = \mu\ 6.72$ Coefficient is 0.589 or 33/56 cao	M1 A1 A1 M1 A1 M1 A1	7	For resolving forces on A vertically (3 terms) For resolving forces on A horizontally (2 terms) For using $F = \mu N$
	(ii)	$T\cos\beta = 7\cos\alpha$ $T\cos\beta = 7 \times 0.28$ (= 1.96 **AG)**	M1 A1	2	For resolving forces at P vertically (2 terms)
	(iii)	 $T\cos\beta - mg = 0$ Mass is 0.2 kg	M1 A1 A1	3	For resolving forces on B vertically (2 terms)

6	(i)(a)	$V = P\cos 20^o - 0.04g$ $P = 0.417$	B1 M1 A1	3	 For setting $V = 0$
	(i)(b)	$R = P\sin 20^o$ Magnitude is 0.143 N	M1 A1ft	2	For using R = horizontal component of P ft value of P
	(i)(c)	$0.143 = 0.04a$ Acceleration is 3.57 ms^{-2}	M1 A1ft	2	For using Newton's second law ft magnitude of the resultant
	(ii)	$R^2 = 0.08^2 + (0.04g)^2$ Magnitude is 0.400 N (or 0.40 or 0.4) $\tan\theta$ = +/-0.04g/0.08 or $\tan(90^o - \theta)$ = +/-0.08/0.04g Angle made with horizontal is 78.5^o or 1.37 radians, or angle made with vertical is 11.5^o or 0.201 radians Downwards or below horizontal	M1 A1 M1 A1 B1	5	For using $R^2 = P^2 + W^2$ For using $\tan\theta = Y/X$ or $\tan(90^o - \theta) = X/Y$ Direction may alternatively be shown clearly on a diagram or given as a bearing

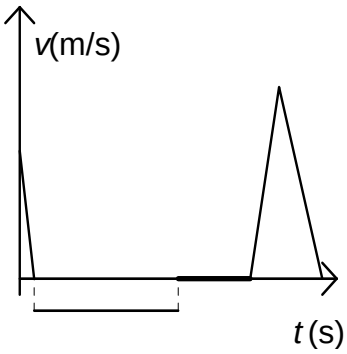
7	(i)	½ 200×16 + 300× ½ (16 + 25) + ½ 100×25 (=1600 + 6150 + 1250) Distance is 9000m	M1 A1 A1 3	For using the idea that the area of the quadrilateral represents distance
	(ii)	a = (0 – 25)/(600 – 500) Deceleration is 0.25 ms^{-2}	M1 A1 2	For using the idea that gradient (= vel ÷ time) represents acceleration Or for using v = u + at Allow acceleration = - 0.25 ms^{-2}
	(iii)	Acceleration is $(1200t - 3t^2)\times 10^{-6}$	M1 A1 2	For using $a(t) = \dot{v}(t)$
	(iv)	0.25 – 0.2475 Amount is +/- 0.0025 ms^{-2}	M1 A1ft 2	For using 'ans(ii) – $\lvert a_Q(550)\rvert$' ft ans(ii) only
	(v)	$1200t - 3t^2 = 0$ t = (0 or) 400 **AG**	M1 A1 2	For solving $a_Q(t) = 0$ or for finding $a_Q(400)$ Or for obtaining $a_Q(400) = 0$
	(vi)	½ 200×16 + 200× ½ (16 + 22) $s_Q(t) = (200t^3 - t^4/4)\times 10^{-6}$ (+C) 6400 – 5400 Distance is 1000 m	M1 A1 M1 A1 M1 A1 6	For correct method for $s_P(400)$ For using $s_Q(t) = \int v_Q\,dt$ For using correct limits and finding $\lvert s_Q(400) - s_P(400)\rvert$

1	**(i)**	$0.3g - T = 0.3a$ and $T - 0.4g = 0.4a$	M1 A1		For using Newton's second law (either particle) condone 0.3ga,0.4ga and !(LHS) Both correct. ***SR*** Accept $T - 0.3g = 0.3a$ etc as correct only if consistent with a shown as upwards for P on c's diagram
		$-0.1g = 0.7a$ $a = -1.4$ See appendix for substituting $a = -1.4$	M1 A1	[4]	Eliminating T AG
	(ii)	$0 = 2.8t - \frac{1}{2}\,1.4t^2$ $0 = t(2.8 - 0.7t)$ Time taken is 4 s ***OR***	M1 M1 A1	[3]	For using $s = ut + \frac{1}{2}\,at^2$ with $s = 0$ Solving QE
		$(0.3 + 0.4)a = (0.3 - 0.4)g$ $a = -1.4$	M2 A1 A1	[4]	From correct equation only For using $(m_1 + m_2)a = (m_1 - m_2)g$
	(i)	$0 = 2.8 + -1.4t$ $t = 2.8/1.4$ Time taken is 4 s	M1 M1 A1	[3]	No application of *SR* shown above AG For using $v = u + at$ with $v = 0$
	(ii)				Solve for t, and double or any other complete method for return time

2	**(i)**	$T\sin\alpha = 0.08 \times 1.25$ $= 0.1$	M1 A1	[2]	Newton's second law condone cos, and $0.08g$ for mass but not part of force
	(ii)	$T\cos\alpha = 0.08g$ $T^2 = 0.1^2 + 0.784^2$ or $\alpha = 7.3^o$ $T = 0.79$	M1 A1 M1 A1 A1	[5]	Resolving forces vertically, condone sin May be implied by $T^2 = 0.1^2 + 0.784^2$ For eliminating α or T $\alpha = 7.3^o$ or better Accept anything rounding to 0.79

3	**(i)**	$a = 7.2 - 0.9t$ $T = 8$ See also special case in appendix.	M1 A1 M1 A1	[4]	For using $a = \mathrm{d}v/\mathrm{d}t$ For attempting to solve $a(t) = 0$
	(ii)	$v(T) = 28.8$ See also special case in appendix.	B1	[1]	AG (From $7.2\times 8 - 0.45\times 8^2$)
	(iii)	$s = 3.6t^2 - 0.15t^3 \quad (+C)$ $s = 153.6\ (+C)$ s at constant speed = 662.4 Displacement is 816 m	M1 A1 DM1 A1 B1ft A1ft	[6]	For using $s = \int v\,dt$ For finding $s(T$ or 31) or using limits (0) to T or (0) to 31 (dep on integration) Condone $+C$ For using $(31 - \text{cv } T) \times 28.8$ cv 153.6 + cv 662.4 (non-zero numerical)

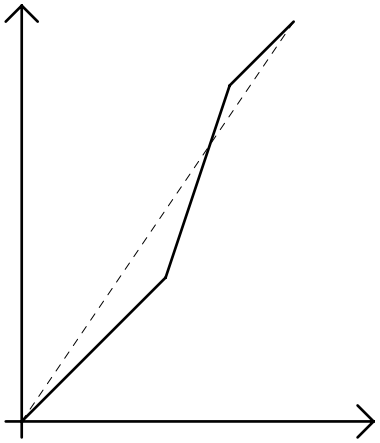
4	**(i)**	$F = 12\cos 15^o$	M1	Resolve horizontally (condone sin)
		Frictional component is 11.6 N	A1 [2]	Accept $12\cos 15^o$
	(ii)	$N + 12\sin 15^o = 2g$	M1	Resolve vert 3 forces (accept cos)
		Normal component is 16.5 N	A1 [2]	AG
	(iii)	$11.591\ldots = \mu\ 16.494\ldots$	M1	For using cv $F = \mu$ cv N
		Coefficient is 0.7(0)	A1ft [2]	Ft cv F to 2 sf. μ = 0.7027....
	(iv)	$N = 2g$	B1	
		$F = 19.6 \times 0.7027\ldots$	M1	
			M1	For using Newton's second law
		$20 - 13.773\ldots = 2a$	A1ft	cv Tractive - cv Friction (e.g. from (i))
		Acceleration is 3.11 ms^{-2}	A1 [5]	Accept either 3.11 or 3.12 only
		MISREAD (omits "horizontal")	MR-1	All A and B marks now ft. Subtract "MR-1" <u>from initial B1 or final A1 (not A1ft in main scheme).</u>
		$N = 2g$ - 20sin15	B1ft	
		F = 0.7027 x 14.4	M1	Equals 14.42...
			M1	Equals 10.1....
		20cos15- 10.14 = $2a$	A1ft	For using Newton's second law
		Acceleration is 4.59 ms^{-2}	A1ft [4]	cv Tractive - cv Friction Accept 4.59, 4.6(0)

5	**(i)**		Graph with 5 straight line segments and with v single valued.	B1	'Wait' line segment may not be distinguishable from part of the t axis. Attempt at all lines segments fully straight.
			Line segment for car stage	B1	Mainly straight, ends on t-axis
			Line segment for walk stage	B1	Horizontal below t-axis. Ignore linking to axis.
			Line segment for wait stage	B1	Can be implied by gap between walk and motor-cycle stages
			2 line segments for motor-cycle stage	B1 [5]	Inverted V not U, mainly straight. Condone vertex below x intercept.
	(ii)	$d = 12/8$		M1	Using gradient represents accn
		Deceleration is 1.5 ms^{-2}		A1 [2]	Or a = -1.5 ms^{-2}
	(iii)			M1	Using area represents displacement.
		$t_{walk} = 420/0.7$		B1	Accept 600
		$t_{motorcycle} = 42$		B1	Ignore method
		$T = 8 + 600 + 250 + 42 = 900$		A1 [4]	

6	**(i)**	$T_A\cos\alpha - T_B\cos\beta = W$	M1		For resolving 3 forces vertically, condone Wg, sin
		$T_A = T_B$ (= T)	B1		May be implied or shown in diagram
		$\cos\alpha > \cos\beta \Rightarrow \alpha < \beta$	A1	[3]	AG
	(ii)(a)	$T\sin\alpha + T\sin\beta = 14$	M1		Resolve 3 forces horiz accept cos
		$\sin\alpha = 0.6$ and $\sin\beta = 0.8$	DM1		
		Tension is 10 N	A1	[3]	
	(ii)(b)	$10\cos\alpha - 10\cos\beta = W$	M1		Must use cv T, and W (not Wg)
		$\alpha = 36.9^o$, $\beta = 53.1^o$	DM1		Or $\cos\alpha = 0.8$ and $\cos\beta = 0.6$
					SR -1 for assuming $\alpha + \beta = 90^o$
		$W = 2$	A1 ft	[3]	ft for $T/5$ (accept 1.99)
		See appendix for solution based on resolving along RA and RB.			
	(iii)	R is below B	B1		Accept R more than 0.5 m below A
		Tension is 1 N	B1 ft	[2]	ft for $W/2$ accept $W/2$

7	(i)	Initial momentum $= 0.15\times 8 + 0.5\times 2$	B1	(or loss in A's momentum = 0.15×8 B1 and gain in B's momentum = $0.5(v-2)$ B1)
		Final momentum = $0.5v$	B1	
		$0.15\times 8 + 0.5\times 2 = 0.5v$ (or $0.15\times 8 = 0.5\times(v - 2)$)	M1	For using the principle of conservation of momentum
		$v = 4.4$	A1 [4]	
		$(m)g\sin\alpha = (\pm)(m)a$	M1	condone inclusion of g in all terms
		$a = (\pm)4.9$	A1	***SR*** Awarded even if g in all terms
		EITHER (see also part (ii))		
		$0 = 4.4^2 - 2\times 4.9s$	M1	Condone cos
		s = 1.97 or 1.98 m	A1ft	
		OR		
		$v^2 = 4.4^2 - 2\times 4.9\times 2$	M1	For using $v^2 = u^2 + 2as$ with $v = 0$
		$v^2 = -0.24$	A1ft	
		OR (see also part (ii))		Accept $s < 2$ iff $s = 4.4^2/(2\times 4.9)$
		$t = 4.4/4.9$ (=0.898) with either $s = 4.4\times 0.898 - 0.5\times 4.9\times 0.898^2$ or $s = (4.4 + 0)/2\times 0.898$	M1	For using $v^2 = u^2 + 2as$ with $s = 2$
		s = 1.97 or 1.98 m	A1ft [4]	Accept $v^2 < 0$
				Both parts of method needed
				Accept $s < 2$
	(ii)	$2 = \frac{1}{2}4.9\, t_A^2$	M1	cv for acceleration
		$t_A = 0.904$	A1	Accept 0.903=<time=<0.904
		EITHER		
		$2 = (-4.4)t_B + \frac{1}{2}\, 4.9t_B^2$	M1	Appropriate use of $s = ut + \frac{1}{2}at^2$
		$t_B = (4.4 \pm \sqrt{(4.4^2 + 4\times 2.45\times 2)})/4.9$	M1	Correct method for solving QE
		$t_B = 2.17$	A1	2.171...
		$t_B - t_A = (2.17 - 0.9) = 1.27$ s	A1	
		OR	M1	
		$t_{up} = 4.4/4.9$ (=0.898)	M1	Or using s_{up} to find t_{up}
		$(2 + 1.98) = 0.5\times 4.9\times t_{down}^2$	A1	$s = ut + \frac{1}{2}at^2$ with cv s in part (i)
		$t_{down} = 1.27$	A1	Not the final answer
		$t_B - t_A = (0.9 + 1.27 - 0.9) = 1.27$s		
		OR		
		$0 = 4.4t - \frac{1}{2}\, 4.9t^2$	M1	$s = ut + \frac{1}{2}at^2$ with $s = 0 = 1.796$
		(i.e. approx 1.8 s to return to start)	M1	
		$2 = 4.4t + 4.9t^2$	A1	
		$t = 0.376$	A1 [5]	
		$t_B - t_A = 1.796 + 0.376 - 0.9 = 1.27$s		

1		Momentum before = $3M$ - 1200×3 Momentum after = 1200×5	B1 B1		Ignore g if included; accept inconsistent directions (or loss of momentum of loaded wagon = $3M$ B1 gain of momentum of unloaded wagon = 1200(5 + 3) B1)
		$3M - 3600 = 6000$ $3(1200 + m) - 3600 = 6000$ $m = 2000$	M1 A1 A1	5	Equation with all terms; accept with g For any correct equation in m, M
2	**(i)**	$2.5 = 6.5\sin\theta$ $\theta = 22.6^{o}$	M1 A1 A1	3	For resolving forces in the **i** direction or for relevant use of trigonometry AG Accept verification
	(ii)	$R = 6.5\cos22.6^{o}$ $R = 6$	M1 A1 A1	3	For resolving forces in the **j** direction or for using Pythagoras or relevant trigonometry.

3	**(i)**		B1 B1 B1 B1 B1	Line segment *AB* (say) of +ve slope from origin Line segment *BC* (say) of steeper +ve slope and shorter time interval than those for *AB*. ***SR***: If the straight line segments are joined by curves, this B1 mark is not awarded Line segment *CD* (say) of less steep slope compared with *BC*. (An (x, t) graph is accepted and the references to more/less steep are reversed.) May be implied; any 2 correct
		Time intervals 80, 40, 40 t = 80, 120, 160		
	(ii)	Line joining (0, 0) and (160, 360)	B1 ft 6	
	(iii)	v = 360/160 s = 120 + 4.5(t – 80) 2.25t $t = 106\frac{2}{3}$ (107) ***SR*** Construction method Plotting points on graph paper t between 104 and 109 inclusive	M1 M1 A1 M1 A1 5 M1 A1	Woman's velocity (= 2.25) For equation of man's displacement in relevant interval Accept omission of -80 Woman's displacement, awarded even if t is interpreted differently in man's expression Accept also 106.6, 106.7 but not 106 Candidates reading the <u>displacement</u> intersection from graph, then dividing this distance by the woman's speed to find t, also get v = 360/160 M1 as above for the woman's velocity.
4	**(i)**	Displacement is 20 m	B1 1	20+c (from integration) B0
	(ii)	 $s(t) = 0.01t^3 – 0.15t^2 + 2t$ (+A) 10 – 15 + 20 + A = 20 Displacement is $0.01t^3 – 0.15t^2 + 2t + 5$	 M1 A1 M1 A1 4	For using $s(t) = \int v(t)dt$ Can be awarded prior to cancelling For using s(10) = cv (20) AG
	(iii)	 a = 0.06t – 0.3 0.06t – 0.3 = 0.6 t = 15 Displacement is 35 m	M1 A1 DM1 A1 B1 5	For using $a(t)$ = dv/dt For starting solving $a(t)$ = 0.6 depends on previous M1

5	**(i)**		M1		For using $F = 5$ and $F = \mu R$
		$R = mg$	M1		
		$m = 2.55$	A1	3	Accept 2.5 or 2.6
	(ii)a	$P\cos\alpha = 6$	B1		
			M1		For resolving vertically with 3 distinct forces
		$R = P\sin\alpha + 25$	A1ft		Or $P\sin\alpha$ + (cv m)g
		$0.2R = 6$	B1		For using $F = 6$ and $F = \mu R$. Can be implied by $0.2(P\sin\alpha + 25) = 6$
		$0.2(P\sin\alpha + 25) = 6$	M1		For an equation in $P\sin\alpha$ (=5)after elimination of R
		$\alpha = 39.8^o$	A1		Accept a r t 40^o
	(ii)b	$P^2 = 6^2 + 5^2$ or $P\cos 39.8^o = 6$ or $P\sin 39.8^o = 5$	M1		For eliminating or substituting for α with cv(6). Evidence is needed that 5 is the value of $P\sin\alpha$ (rather than the original frictional force)
		$P = 7.81$	A1	8	Accept a r t 7.8
6	**(i)**	10500 + 3000 + 1500	M1		For summing 3 resistances
		Driving force below 15000 gives retardation	A1	2	Accept generalised case or specific instance
	(ii)	35000 – 15000 = 80000a	M1		Newton's second law for whole train
		Acceleration is 0.25 ms^{-2}	A1	2	AG Accept verification
	(iii)		M1		For applying Newton's second law to E only, at least 2 forces out of the relevant 3.
		35000 – 10500 – 8500 = 0.25m	A1		
		Mass is 64000 kg	A1	3	
	(iv)		M1		For applying Newton's second law with all appropriate forces
		-15000 – 15000 = 80000a	A1		a = -0.375
		OR -3000-10500-15000=(80000 - m)a			
			M1		For applying Newton's second law to B only, only 1 force
		-1500 = ma	A1		Or cv(a)
		Mass is 4000 kg	A1	5	
	(v)	-15000 – 10500 $\pm$ T = 64000(-0.375)	B1ft		Follow through cv (m_E, a), or accept use of m_E, a
		$T = \pm 1500$ ➔ forward force on E of 1500 N	B1	2	
		OR (working with A and B)			
		-1500 – 3000 $\pm$ T = (80000 - 64000)(-0.375)	B1ft		Follow through cv (m_E, a), or accept use of m_E, a
		$T = \pm 1500$ ➔ forward force on E of 1500	B1		

7	**(i)**	$0 = 6 + (\pm)1.5a$	M1		For using $v = u + at$ with $v = 0$

		$a = (\mp)4\text{ms}^{-2}$	A1		
		$-mg\sin15^o - F = ma$	M1		For applying Newton's second law with 2 forces
		$-0.1\times 9.8\sin15^o - F = 0.1\times(-4)$	A1		
		$R = 0.1g\cos15^o$	B1		
		$0.146357\ldots = \mu\, 0.946607\ldots$	M1		For using $F = \mu R$
		Coefficient is 0.155	A1	7	Anything between 0.15 and 0.16 inclusive
	(ii)	$mg\sin15^o > \mu mg\cos15^o$ (or $\tan 15^o > \mu$)	M1		For comparing weight component with frictional force (or tan 'angle of friction' with μ)
		➔ particle moves down	A1	2	Awarded if conclusion is correct even though values are wrong
	(iii)	$(6 + 0)\div 2 = s \div 1.5$	M1		For using $(u + v)\div 2 = s \div t$
		$s = 4.5$	A1		
		$mg\sin15^o - F = ma$	M1		For using Newton's second law with 2 forces
		$0.25364\ldots - 0.146357\ldots = 0.1a$	A1		Values must be correct even if not explicitly stated. Note that the correct value of friction may legitimately arise from a wrong value of μ and a wrong value of R
		$v^2 = 2(1.07285\ldots)4.5$	M1		For using $v^2 = 2as$ with any value of a
		Speed is 3.11 ms^{-1}	A1	6	Accept anything rounding to 3.1 from correct working

1	**(i)**	Net force on trailer is +/-(700 - R_T)	B1		
			M1		For applying Newton's second law to the trailer with 2 terms on LHS (no vertical forces)
		700 - R_T = 600 x 0.8	A1ft		ft cv (+/-(700 - R_T))
		Resistance is 220N	A1	4	
	(ii)		M1		For applying Newton's second law to the car or to the whole, with a =+/- 0.8 (no vertical forces)
		2100 – 700 – R_C = 1100 x 0.8	A1ft		
		or			ft cv(220)
		2100 – (R_C + 220) = (1100 + 600)x 0.8			
		Resistance is 520N	A1	3	

2	**(i)**		M1		For resolving forces vertically
		15 x 0.28 and 11x 0.8	A1		Allow use of = 16.3 and =53.1
		Y= 15x0.28 + 11x0.8 - 13	A1ft		Ft cv(15 x 0.28 and 11x 0.8)
		Component is zero AG	A1	4	**SR** 15sin + 11sin -13 = 0 gets M1A0A1ftA0
	(ii)		M1		For resolving forces horizontally
		X = 15 x 0.96 – 11 x 0.6	A1		Allow use of = 16.3 and =53.1
		Magnitude is 7.8N	A1	3	Accept 7.79, -7.8
	(iii)	Direction is that of the (+ve) x -axis	B1	1	Do not allow horizontal, 90° from vertical. Do not award if = 16.3 and =53.1 have been used.

3	**(i)**	T = 0.3g	B1		At particle (or 0.3g -T= 0.3a)
		F = T	B1		Or F = cv(T at particle) (or T - F = 0.4a)
		R = 0.4g	B1		
			M1		For using F = μ R
		Coefficient is 0.75	A1	5	
	(ii)		M1		For resolving 3 relevant forces on B horizontally, a=0
		X = 0.3g + 0.3g	A1ft		Ft X = 0.3g + cv(μ) cv(R)
		X = 5.88N	A1	3	

4	**(i)**	Momentum before collision = +/-(0.8 x 4 - 0.6 x 2)	B1		Or momentum change L $0.8x4 +/- 0.8v_L$ Accept inclusion of g in both terms
		Momentum after collision = $+/-0.8v_L$ + 0.6 x 2	B1		Momentum change N 0.6x2 + 0.6x2 Accept inclusion of g in both terms
			M1		For using the principle of conservation of momentum even if g is included throughout
		Speed is 1 ms^{-1}	A1	4	Accept -1 from correct work (g not used).
	(ii)(a)	0.6x2 - 0.7x0.5	M1		Must be a difference. **SR** 0.6x1 - 0.7x0.5 M1
		Total is 0.85$kgms^{-1}$	A1		Must be positive
		Total momentum +ve after the collision. If N continues in its original direction, both particles have a negative momentum.	DM 1		Or 0.6v + 0.7w is positive, confirming that the momentum is shared between two particles. No reference need be made to the physically impossible scenario where M and N both might continue in their original directions.
		N must reverse its direction.	A1	4	
	(ii)(b)	0.6x2 - 0.7x0.5 (= 0.85) = 0.7v	A1ft		ft cv (0.85). Award M1 if not given in ii(a).
		Speed is 1.21ms^{-1}	A1	2	Positive. Accept (a.r.t) 1.2 from correct work
5	**(i)**	$1.8t^2/2$ (+C)	M*1		For using $v = \int a dt$
		(t = 0,v = 0) C = 0	B1		May be awarded in (ii). Accept c written and deleted.
		Expression is $1.8t^2/2$	A1	3	also for $1.8t^2$ +c
	(ii)		M1		For using $s = \int v dt$
		$0.9t^3/3$ (+K)	A1		**SR** Award B1 for (s = 0, t = 0) K = 0 if not already given in (i), or +K included and limits used.
		0.3 x 64	M1		For using limits 0 to 4 (or equivalent)
		19.2m AG	A1	4	
	(iii)	u = 0.9 x 4^2	D* M1		For using 'u' = v(4)
		s = 14.4 x 3 + ½ 7.2 x 3^2	M1 A1		For using s = ut + ½ x7.2t^2 with non-zero u (s = 75.6)
		19.2 + 75.6	M1		For adding distances for the two distinct stages
		Displacement is 94.8m	A1	5	
		OR $v = \int 7.2 dt$	D*		For finding v(4)
		t = 0, v = 14.4, c = 14.4 $s = \int 7.2t + 14.4 dt$	M1		Integration and finding non-zero integration constant Nb Using t=4, v=14.4 gives c = -14.4 $s = \int 7.2t - 14.4 dt$
		t = 0, s = 0, k = 0			Integration and finding integration constant. Nb t=4 with s=19.2 and v=7.2t-14.4 gives k=19.2
		$s=3.6x3^2+14.4x3$	M1 A1		Substituting t = 3 (OR 7 into $s = 3.6t^2$ - 14.4t + 19.2) (s=75.6) (OR s = 3.6 $x7^2$ - 14.4x7 + 19.2)
		19.2 + 75.6 = 94.8 Displacement is 94.8m	M1 A1		Adding two distinct stages OR s = 3.6 $x7^2$ - 14.4x7+19.2 =94.8 final M1A1
6	**(i)**	½ $25v_m = 8$ or ½Tv_m+½$(25 – T)v_m$ =	B*1		Do not accept solution based on isosceles or right angled triangle

	8			
	Greatest speed is 0.64 ms^{-1}	D*B 1	2	
(ii)		M1		For using v = u + at or the idea that gradient represents acceleration
	V = 0.02 x 40	A1		
	V = 0.8	A1	3	
(iii)		M1		For using the idea that the area represents displacement. nb trapezium area is 16+8+8
		M1		For A = ½ $(L_1 + L_2)$h or other appropriate breakdown
	½ (70 + T) x 0.8 = 40 - 8	A1ft		½ (30 + T) x 0.8 = 40 - 8- ½ x 40 x 0.8 ft cv(0.8)
	Duration is 10s	A1	4	
(iv)		M1		For using v = u + at or the idea that gradient represents acceleration
	0=0.8+a(30–10)	A1ft		ft cv(10) and cv(0.8)
	Deceleration is $0.04ms^{-2}$	A1	3	Accept -0.04 from correct work
	Or	M1		Using the idea that the area represents displacement.
	40-8-½ x 40 x 0.8-10x0.8	A1ft		Ft cv(0.8 and 10)
	$=0.8(30-10)-a(30–10)^2/2$	A1		Accept -0.04 from correct work. d=-0.04 A0
	Deceleration is $0.04ms^{-2}$			

7	**(i)**	$R = 0.5g\cos 40^o$	B1		$R = 3.7536$
		$F = 0.6 \times 0.5g\cos 40^o$	M1		For using $F = \mu R$
		Magnitude is 2.25N AG	A1	3	
	(ii)		M1		For applying Newton's second law (either case) //slope, two forces
		$-/+0.5g\sin 40^o - F = 0.5a$	A1		Either case
		(a) Acceleration is $-10.8ms^{-2}$	A1		Accept 10.8 from correct working (both forces have the same sign)
		(b) Acceleration is $1.79ms^{-2}$	A1	4	Accept -1.79 from correct working (the forces have opposite sign) Accept ! 1.8(0)
	(iii)a)	$0 = 4 + (-10.8)T_1$	M1		Requires appropriate sign
		$T_1 = 0.370(3)$	A1		Accept 0.37
	b)		M1		For complete method of finding distance from A to highest point using a(up) with appropriate sign
		$0 = 4^2 + 2(-10.8)s$ or	A1		ft a(up) and/or T_1
		$s = (0 + 4) \times 0.37/2$ or $s = 4(0.370) + \frac{1}{2}(-10.8)(0.370)^2$	ft		(s = 0.7405)
			M1		For method of finding time taken from highest point to A and not using a(up)
		$0.7405 = \frac{1}{2}(1.79)T_2^2$	A1ft		ft a(down) and cv(0.7405) ($T_2 = 0.908$ approx)
		$0.370 + 0.908$	M1		Using $T = T_1 + T_2$ with different values for T_1, T_2
		$= 1.28s$	A1	8	3 significant figures cao

1(i)	X = 5 Y = 12	B1 B1 [2]	X=-5 B0. Both may be seen/implied in (ii) No evidence for which value is X or Y available from (ii) award B1 for the pair of values 5 and 12 irrespective of order
(ii)	$R^2 = 5^2 + 12^2$ Magnitude is 13 N $\tan\theta = 12/5$ Angle is 67.4^o	M1 A1 M1 A1 [4]	For using $R^2 = X^2 + Y^2$ Allow 13 from X=-5 For using correct angle in a trig expression **SR:** p=14.9 and Q=11.4 giving R=13+/-0.1 B2, Angle = 67.5+/-0.5 B2

2(i)	250 + ½ (290 – 250) t = 270	M1 A1 [2]	Use of the ratio 12:12 (may be implied), or v = u+at
(ii)	½ x40x12+210x12+½x20x12–½x20x12 or ½ x40x12+210x12 or ½ x(210+250)x12etc Displacement is 2760m	M1 M1 A1 [3]	The idea that area represents displacement Correct structure, ie triangle1 + rectangle2 + triangle3 - |triangle4| with triangle3 = |triangle4|, triangle1 + rectangle2, trapezium1&2, etc
(iii)	appropriate structure, ie triangle + rectangle + triangle + |triangle|, triangle + rectangle + 2triangle, etc Distance is 3000m	M1 A1 [2]	All terms positive Treat candidate doing (ii) in (iii) and (iii) in (ii) as a mis-read.

3(i)	$R + T\sin72^o = 50g$	M1 A1 [2]	An equation with R, T and 50 in linear combination. R + 0.951T = 50g
(ii)	$T = 50g/\sin72^o$ T = 515 (AG) T = mg m = 52.6	M1 A1 B1 B1 [4]	Using R = 0 (may be implied) and $T\sin72^o = 50(g)$ Or better Accept 52.5
(iii)	$X = T\cos72^o$ X = 159	B1 B1 [2]	Implied by correct answer Or better

4(i)	*In Q4 right to left may be used as the positive sense throughout.* 0.18 x 2 – 3m = 0 m = 0.12	M1 A1 A1 [3]	For using Momentum 'before' is zero 3 marks possible if g included consistently
(iia)	Momentum after = -0.18 x 1.5 + 1.5m 0.18 x 2 – 3m = -0.18 x 1.5 + 1.5m m = 0.14	B1 M1 A1 [3]	 For using conservation of momentum 3 marks possible if g included consistently
(iib)	0.18 x 2 – 3m = (0.18 + m)1.5 m = 0.02 0.18 x 2 – 3m= - (0.18 + m)1.5 m = 0.42	B1ft B1 B1ft B1 [4]	ft wrong momentum 'before' 0 marks if g included

5(i)		M1	Using $v^2 = u^2 +/- 2gs$ with v = 0 or u = 0
	$8.4^2 - 2gs_{max} = 0$	A1	
	Height is 3.6m (AG)	A1	
		[3]	
(ii)		M1	Using $u^2 = +/- 2g(\text{ans(i)} - 2)$
	u = 5.6	A1	
		[2]	
(iii)	EITHER (time when at same height)	M1	Using $s = ut + \frac{1}{2}at^2$ for P *and* for Q, a = +/-g, expressions for s terms must differ
	$s+/-2 = 8.4t - \frac{1}{2}gt^2$ and		Or $8.4t (-\frac{1}{2}gt^2) = 5.6t (-\frac{1}{2}gt^2) +/- 2$
	$(s+/-2) = 5.6t - \frac{1}{2}gt^2$	A1	Correct sign for g, cv(5.6), +/-2 in only one equation
	t = 5/7 (0.714)	A1	cao
		M1	Using v = u +at for P *and* for Q, a = +/-g, cv(t)
	$v_P = 8.4 - 0.714g$ and $v_Q = 5.6 - 0.714g$	A1	Correct sign for g, cv(5.6), candidates answer for t (including sign)
	$v_P = 1.4$ and $v_Q = -1.4$	A1	cao
		[6]	
	OR (time when at same speed in opposite directions)	M1	Using v = u+at for P *and* for Q, a = +/-g
	v = 8.4 -gt and -v =5.6-gt	A1	Correct sign for g, cv(5.6)
	v = 1.4 {or t = 5/7 (0.714)}	A1	Only one correct answer is needed
	(with v = 1.4)	M1	Using $v^2 = u^2 + 2as$ for P *and* for Q, a = +/-g, cv(v)
	$1.4^2 = 8.4^2 - 2gs_P$ and $(-1.4)^2 = 5.6^2 - 2gs_Q$	A1	Correct sign for g, cv(5.6), candidate's answer for v (including - for Q)
	$s_P = 3.5$ and $s_Q = 1.5$	A1	cao
	{(with t=5/7)	M1	Using $s = ut + \frac{1}{2}at^2$ for P *and* for Q, a = +/-g, cv(t)
	$s = 8.4x0.714 - \frac{1}{2}gx0.714^2$ and $s = 5.6x0.714 - \frac{1}{2}gx0.714^2$	A1	Correct sign for g, cv(5.6), candidate's answer for t (including sign of t if negative)
	$s_P = 3.5$ and $s_Q = 1.5$	A1	cao}
	OR (motion related to greatest height and verification)	M1	Using v = u+at t for P *and* for Q, a = +/-g
	0 = 8.4 -gt and 0 =5.6-gt		
	t = 6/7 and t = 4/7	A1	Both values correct
	$v_P = 8.4 - 0.714g$ and $v_Q = 5.6 - 0.714g$		mid-interval t (6/7+4/7)/2 = 0.714
	$\{0 = v_P - g/7$ and $v_Q = 0 + g/7\}$		{Or semi-interval = 6/7-4/7)/2=1/7}
	$v_P = 1.4$ and $v_Q = -1.4$	A1	cao
	$s_P = 8.4x0.714 - \frac{1}{2}gx0.714^2$ and $s_Q = 5.6x0.714 - \frac{1}{2}gx0.714^2$	M1	$s = ut + \frac{1}{2}at^2$ for P *and* for Q, correct sign for g, cv(5.6) and cv(t)
	$\{s_P = 0/7 - \frac{1}{2}(-g)x(1/7)^2$ and $s_Q = 0/7 + \frac{1}{2}gx(1/7)^2\}$	A1	{$s = vt - \frac{1}{2}at^2$ for P *and* $s = ut + \frac{1}{2}at^2$ for Q}
	$s_P = 3.5$ $s_Q = 1.5$		
	$\{s_P = 0.1$ $s_Q = 0.1\}$	A1	cao

continued

5(iii)	OR (without finding exactly where or when)	M1	Using $v^2 = u^2 + 2as$ for P *and* for Q, a = +/-g, cv(5.6), different expressions for s.
co*nt*	$v_P^2 = 8.4^2 - 2g(s+/-2)$ and		Correct sign for g, cv(5.6), (s+/-2) used only once cao. Verbal explanation essential
	$v_Q^2 = 5.6^2 - 2g[(s+/-2)]$	A1	Using v = u+at t for P *and* for Q, a = +/-g
	$v_P^2 = v_Q^2$ for all values of s so that the speeds are always the same at the same heights.	A1	Correct sign for g, correct choice for velocity of zero, cv(5.6)
		M1	
	0 = 8.4 -gt and 0 =5.6-gt	A1	
	$t_P = 6/7$ and $t_Q = 4/7$ means there is a time interval when Q has started to descend but P is still rising, and there will be a position where they have the same height but are moving in opposite directions.	A1	cao. Verbal explanation essential

6(i)		M1	For differentiating s
	$v = 0.004t^3 - 0.12t^2 + 1.2t$	A1	Condone the inclusion of +c
	$v(10) = 4 - 12 + 12 = 4ms^{-1}$ (AG)	A1	Correct formula for v (no +c) and t=10
		[3]	stated sufficient
(ii)		M1	For integrating a
	$v = 0.8t - 0.04t^2$ (+ C)	A1	
	8 - 4 + C = 4	M1*	Only for using v(10) = 4 to find C
	$v = 0.8x20 - 0.04x20^2$ (+ C)	M1	
	v(20) = 16 – 16 = 0 (AG)	DA1	Dependant on M1*
		[5]	
(iii)		M1	For integrating v
	$S = 0.4t^2 - 0.04t^3/3$ (+K)	A1	Accept $0.4t^2 - 0.013t^3$ (+ ct +K, must be linear)
	s(10) = 10 – 40 + 60 = 30	B1	
		M1	For using S(10) = 30 to find K
	40 – 40/3 + K = 30 ➔ K = 10/3	A1	Not if S includes ct term
	S(20) = 160 – 320/3 + 10/3 = 56.7m	B1	Accept 56.6 to 56.7, Adding 30 subsequently is not isw,
	OR	[6]	hence B0
	s(10) = 10 – 40 + 60 = 30	B1	
		M1	For integrating v
	$S = 0.4t^2 - 0.04t^3/3$	A1	Accept $0.4t^2 - 0.013t^3$ (+ ct +K, must be linear)
		M1	Using limits of 10 and 20 (limits 0, 10 M0A0B0)
	S(20) - S(10) = 26.6, 26.7	A1	For 53.3 - 26.7 or better (Note S(10) = 26.7 is fortuitously correct M0A0B0)
	displacement is 56.7m	B1	Accept 56.6 to 56.7

7(i)	$R = 1.5g\cos 21^o$	B1	
		M1	For using $F = \mu R$
	Frictional force is 10.98N (AG)	A1 [3]	Note 1.2gcos21=10.98 fortuitously, B0M0A0
(ii)		M1	For obtaining an N2L equation relating to the block in which F, T, m and a are in linear combination or For obtaining an N2L equation relating to the object in which T, m and a are in linear combination
	$T + 1.5g\sin 21^o - 10.98 = 1.5a$	A2	-A1 for each error to zero
	$1.2g - T = 1.2a$	A2	-A1 for each error to zero
		[5]	Error is a wrong/omitted term, failure to substitute a numerical value for a letter (excluding g), excess terms. Minimise error count.
(iii)	$T - 1.5a = 5.71$ and $1.2a + T = 11.76$	M1	For solving the simultaneous equations in T and a for a.
	$a = 2.24$ (AG)	A1 [2]	Evidence of solving needed
(iva)	$v^2 = 2 \times 2.24 \times 2$	M1	For using $v^2 = 2as$ with cv (a) or 2.24
	Speed of the block is $2.99 ms^{-1}$	A1 [2]	Accept 3
(ivb)		M1	For using T = 0 to find a
	$a = -3.81$	A1	
	$v^2 = 2.99^2 + 2 \times (-3.81) \times 0.8$	M1	For using $v^2 = u^2 + 2as$ with cv(2.99) and s = 2.8 - 2 and any value for a
	Speed of the block is $1.69 ms^{-1}$	A1 [4]	Accept art 1.7 from correct work

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1	70 x 9.8 or 70g 70 x 0.3 686 + 21 707 N	B1 B1 M1 A1 [4]	=686 =21 + cvs [70(9.8+0.3) gets B1B1M1]

2	+/-(40 x 4 - 60 x 3) +/-([40 + 60] v +/-(40 x 4 - 60 x 3) = +/-([40 + 60] v Speed = 0.2 ms^{-1} Same as heavier or opposite lighter/"she"	B1 B1 M1 A1 B1 [5]	Difference of terms, accept with g Sum of terms, accept with g. Accept inclusion of g in equation. Not if g used. ***SR*** 40x4-60x3=[40 + 60] v; v=0.2, as heavier, award 5 marks "Left" requires diagram for B1 If same direction before collision award B0B1M1A0B0

3i	 $\sqrt{(12^2 + 15^2)}$ 19.2 N tanθ =12/15, tanθ =15/12, sinθ =12/19.2,cosθ =15/19.2 Bearing = 038.7°	M1 A1 A1 M1 A1 A1 [6]	Applies Pythagoras, requires +. trig and R included between X and Y Accept cv 19.2 Accept 039 or 39 or art 39 from below (not given if X and Y transposed)
3ii	*E* = 19.2 Bearing = 180 + 38.7 = 219°	B1ft B1ft [2]	ft cv 19.2 180+cv 38.7(-360) or correct answer

4i	v = dx/dt $v = 4t^3 - 8 \times 2t$ $v(2) = 4x2^3 - 8x2x2$ = 0 AG $x(2) = 2^4 - 8 \times 2^2 + 16 = 0$ AG	M1 A1 M1 A1 B1 [5]	Uses differentiation, may be seen in (ii) Accept with +c Substitutes 2 in cv v, explicit A0 if +c Substitutes 2 in displacement, explicit
4ii	a = dv/dt $a = 12t^2 - 16$ $a(2) = 12 \times 2^2 - 16 = 32\ ms^{-2}$	M1 A1 A1 [3]	Uses differentiation of v formula Accept with +c A0 with +c

5ia	250a = -150 $a = -0.6\ ms^{-2}$ AG	M1 A1 [2]	Values used in N2L for trailer F=+/-150 Or -ve convincingly argued
5ib	 900 x -0.6 = D -600 or (900+250)x-0.6 = D -600 -150 D = 60 N	M1 A1 A1 [3]	Applies N2L to car or car/trailer with correct number of forces (including T if T=0 used later)
5ic	$15^2 = 18^2 + 2x(-0.6)s$ s = 82.5 m	M1 A1 [2]	Uses $v^2 = u^2 + 2(+/-0.6)s$ with 15, 18 Positive, allow from $18^2 = 15^2 + 2x0.6s$
5iia	 (900+250)a = 980 - 600 -150	M1 A1	Applies N2L to car+trailer with F(driving) F(resisting), F(wt cmpt-allow without g), or each part, as above and T. 900a = 980 - 600 +/- 900x9.8sin3 - T
5iib	+ /-(900+250)x9.8sin3 $a = 0.713\ ms^{-2}$	A1 A1 [4]	250a = T - 150 +/- 250x9.8sin3 Allow (art) 0.71 from correct work
	  250 x 0.713 = T - 150 + 250x9.8sin3 T = 200 N	M1 A1 A1 [3]	N2L for trailer, cv a, with correct number of forces of correct type. Or for car 900x0.713 = -T-600 + 900x9.8sin3 + 980 Anything rounding to 200 (3sf)

6i	$4.9 = \mu \times 14.7$	M1	Uses $F = \mu R$
	$\mu = 1/3$ AG	A1	Allow 0.333 or 0.3 recurring
		[2]	
6iia		M1	3 force vertical equation
	$R + 4.9\sin30 = 14.7$	A1	
	$R = 12.25$ N	A1	Accept 12.2 or 12.3
	$F = 12.25 \times 1/3$	M1	Uses $F = \mu R$ with new R {may be seen in
	$F = 4.08(333..)$ N [or 49/12 N]	A1	{part b
		[5]	
6iib	$m = 14.7/9.8 = 1.5$kg	B1	
		M1	N2L horizontally with 2 relevant forces, including 4.9sin/cos30
	$4.9\cos30 - 4.08(333..) = 1.5a$	A1	Allow cv(F) ***SR*** Award A1 if m=14.7 used
	$a = 0.107$ ms^{-2}	A2	***SR*** A1 for 0.11, 0.109
6iii		[5]	or art 0.011 from m = 14.7
	$\mu R = (14.7 - 4.9\cos30)/3$	B1	3.49, accept 3.5
	Horizontal component of force = $4.9\sin30$	B1	2.45, accept 2.4 or 2.5
	Horizontal component of force < ③R	M1	Comparing two values
	Friction = 2.45 N	A1	Not 2.4 or 2.5; Explicit (M1 essential)
		[4]	

7i	$s = 0.5 \times 1.4 \times 0.8^2$	M1	Uses $s = 0.5x1.4t^2$
	$s = 0.448$ m	A1	Not 0.45
	$v = 1.4 \times 0.8$	M1	Uses $v = 1.4t$
	$v = 1.12$ ms^{-1}	A1	
		[4]	
7ii	$0^2 = 1.12^2 - 2 \times 9.8s$	M1	Uses $0^2 = u^2 - 2gs$ or $u^2 = 2gs$
	$s = 0.064$ m	A1	Allow verification
	$0 = 1.12 - 9.8t$ ($t = 0.114$s)	M1	or $0.064 = 1.12t - 4.9t^2$
	$t = (0.114 + 0.8) = 0.914$s	A1	Allow 0.91 {or $0 = 1.12t - 4.9t^2$ and halve t
		[4]	
7iii	Scalene triangle, base on t axis	B1	NB Award A1 for 0.91 on t axis if total
	right edge steeper and terminates on axis, or crosses	B1	time not given in (ii)
	axis at t = 0.91	[2]	
7iv		M1	Uses N2L for A or B with attempt at 2 forces
		A1	Either
	$1.4xA = 9.8xA - 5.88$ or $1.4xB = 5.88 - 9.8xB$	A1	
	$A = 0.7$	A1	Not 0.53
7va	$B = 0.525$	[4]	
		M1	Uses tension and 0.5g without particle weights
	$T = 0.5 \times 9.8 + 2 \times 5.88$		
7vb	$T = 16.66$ N	A1	Allow 16.7
		[2]	
	$T = 4.9$ N	B1	
		[1]	

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1(i)	900a = 600 -240	M1	N2L with difference of 2 forces, accept 360
	$a = 0.4\ ms^{-2}$ AG	A1	
		[2]	
(ii)	$9 = 5 + 0.4t$	M1	$v = u + 0.4t$ or $v = u + (cv\ 0.4)t$
	$t = 10$ s	A1	
	$9^2 = 5^2 + 2x0.4s$	M1	or $s=(u+v)t/2$ or $s=ut+0.5xcv(0.4)t^2$
	$s = 70$ m	A1	
		[4]	

2(i)	Resolves a force in 2 perp. directions	M1*	*Uses vector addition or subtraction*
	Uses Pythagoras $R^2 =$	D*M1	*Uses cosine rule* $R^2 =$
	$(14\sin30)^2 +$	A1	$14^2 + 12^2 -$
	$(12+14\cos30)^2$	A1	$2x14x12\cos150$
	{or $R^2 = (12\sin30)^2 + (14+12\cos30)^2$ }		
	$R = 25.1$ AG	A1	cso (Treat $R^2 = 14^2+12^2 + 2x14x12\cos30$
(ii)		[5]	as correct)
	Trig to find angle in a valid triangle	M1	Angle should be relevant
	tanB=7/24.1,sinB=7/25.1,cosB=24.1/25.1	A1	*sinB/14 = sin150/25.1*. Others possible.
	B = 016, (0)16.1° or (0)16.2°	A1	Cosine rule may give (0)16.4, award A1
		[3]	

3(i)	$a = 6/5$	M1	Acceleration is gradient idea, for portion of graph
	$a = 1.2\ ms^{-2}$	A1	Accept 6/5
(ii)		[2]	
	s = (6x10/2) {or (6x5/2)	M1	Area under graph idea or a formula used correctly
	x2 x4}	M1	Double {Quadruple} journey
(iii)	s = 60 m	A1	
		[3]	
		M1	v=u+at idea, t not equal to 17 (except v=1.2t-24)
	$v = -6 + 1.2(17-15)$	A1	$0 = v + cv(1.2)(20-17)$, $v^2 - 2.4v - 21.6 = 0$, etc
	$v = -3.6\ ms^{-1}$	A1	***SR*** v=3.6 neither A1, but give both A1 if final answer given is -3.6
		[3]	

4(i)		M1	Difference of 2 horizontal components, both < 15
	$F = 15\sin50 - 15\sin30 = 3.99$ N	A1	Not 4 or 4.0
	Left	B1	Accept reference to 30 degree string
		[3]	May be given in ii if not attempted in i
(ii)		M1	Equating 4 vertical forces/components
	R = f(30, 15cos50, 15cos30)	A1	30g is acceptable
	R = 30-15cos50-15cos30	A1	=7.36(78..), treat 30g as a misread
	$\mu = 3.99/7.36(78\ )$	M1	Using $F = \mu R$, with cv(3.99) and cv(7.36(78..))
	$\mu = 0.541$ or 0.542 or 0.543	A1	Accept 0.54 from correct work, e.g. 4/7.4
		[5]	

5(i)	2400x5 - 3600x3	B1	Award if g included
	2400v + 3600v	B1	Award if g included
	2400x5 - 3600x3 = 2400v + 3600v	M1	Equating momentums (award if g included)
	$v = 0.2\ ms^{-1}$	A1	Not given if g included or if negative.
	B	B1	
		[5]	
(ii)(a)	+/-(-2400v + 3600v)	B1	*No marks in(ii) if g included*
	2400x5 - 3600x3 = -2400v + 3600v	M1	Equating momentums if "after" signs differ
	$v = 1\ ms^{-1}$	A1	Do not accept if - sign "lost"
(b)	I = 2400 x (5+/-1) or 3600 x (3+/-1)	M1	Product of either mass and velocity change
	$I = 14400\ kgms^{-1}$	A1	Accept -14400
		[5]	

6(i)	$x = 0.01t^4 - 0.16t^3 + 0.72t^2$.		
	$v = dx/dt$	M1	Uses differentiation, ignore +c
	$v = 0.04t^3 - 0.48t^2 + 1.44t$.	A1	or $v = 4(0.01t^3) - 3(0.16t^2) + 2(0.72t)$
	$v(2)=1.28$ ms^{-1} AG	A1	Evidence of evaluation needed
		[3]	
(ii)	$a = dv/dt$	M1	Uses differentiation
	$a = 0.12t^2 - 0.96t + 1.44$	A1	or $a = 3(0.04t^2) - 2(0.48t) + 1.44$
	$t^2 - 8t + 12 = 0$ AG	A1	Simplifies $0.12t^2 - 0.96t + 1.44 = 0$, (or verifies the roots of QE make acceleration zero)
		[3]	
(iii)	$(t - 2)(t - 6) = 0$	M1	Solves quadratic (may be done in ii <u>if used to find v(6)</u>)
	$t = 2$	A1	Or *Factorises v into 3 linear factors* M1
	$t = 6$	A1	$v = 0.04t(t-6)^2$ A1 *Identifies t=6* A1
	$v(6) = 0$ ms^{-1}	B1	Evidence of evaluation needed
		[4]	
(iv)		B1	Starts at origin
		B1	Rises to single max, continues through single min
		B1	Minimum on t axis, non-linear graph
	Away from A	B1	
		[4]	
(v)	AB $=0.01x6^4 - 0.16x6^3 + 0.72x6^2$	M1	Or integration of v(t), with limits 0, 6 or substitution,
	AB = 4.32 m	A1	using cv(6) from iii
		[2]	

7(i)	(R=)0.2x9.8cos45	M1	Not F = 0.2x9.8cos45 or 0.2x9.8sin 45 unless followed
	F=1xR=1x.2x9.8cos45=1.386 N AG	A1	by (eg) Fr =1x F = 1.386 when M1A1
		[2]	
(ii)	Any 1 application of N2L // to plane with correct mass and number of forces	M1	Must use component of weight
	0.4a=0.2gsin45+0.2gsin45-1.38(592..)	A1	
	a = 3.465 ms^{-2} AG	A1	
	0.2a = 0.2gsin45 - T or		Accept with 3.465 (or close) instead of a
	0.2a = T +[0.2gsin45 - 1.38(592..)]	M1	Accept omission of [term] for M1
	T = 0.693 N	A1	Accept 0.69
		[5]	
	OR		
	Any 1 application of N2L // to plane with correct mass and number of forces		Must use component of weight
	0.2a = 0.2gsin45 - T or	M1	Either correct
	0.2a = T +[0.2gsin45 - 1.38(592..)]	A1	Both correct. Accept omission of [term] for A1 only
	Eliminates a or T	M1	
	a = 3.465 ms^{-2} AG	A1	
	T = 0.693 N	A1	
(iii)	$v^2 = 2$ x 3.465 x 0.5	M1	Using $v^2 = 0^2 + 2$xcv(3.465)s
	v = 1.86 ms^{-1}	A1	
		[2]	
(iv)	For Q		
	(0.2)a = (0.2)gsin45 - (1)(0.2)gcos45.	M1	Attempting equation to find a for Q
	a=0 [AG]	A1	Accept from 0.2gsin45 - 1.386
	T = (3/1.86) =1.6(12)	B1	Accept 2 sf
	For P		
	a = 9.8sin45	B1	a= 6.93
	$2.5 = 1.86(14..)t + 0.5$ x $(9.8\sin45)t^2$	M1	Using $2.5 = cv(1.86)t + 0.5cv(6.93)t^2$ [not 9.8 or 3.465]
	t = 0.6(223)	A1	Accept 1sf
	time difference 1.612 - 0.622 = 0.99(0) s	A1	Accept art 0.99 from correct work
		[7]	

4728 Mechanics 1

1 (i)	0.5x6 = 0.5x0.8 + 4m m = 0.65	M1 A1 A1 [3]	Uses CoLM If g used throughout, possible 3 marks
(ii)	0.5x6 = - 0.5x0.8 + 4m m = 0.85	M1 A1 A1 [3]	After momentums opposite signs If g used throughout, 0 marks
2 (i)	T = 400 N D = 400 + 900 = 1300 N	B1 M1 A1 [3]	Order immaterial Or T + 900; sign correct
(ii)	500x0.6 = T - 400 T = 700 N 1250x0.6 = D - 900 -700 D = 2350 N *OR* (500 + 1250)x0.6 = D - 400 - 900 D = 2350 N	 M1 A1 A1 M1 A1ft A1 M1 A1 A1 [6]	(Award M marks even if g included in ma terms. M marks require correct number forces) Uses N2L one object only Uses N2L other object ft cv(T from (ii)); allow T instead of its value Uses N2L for both objects
3 (i)	5cos30 or 5 sin 60 or 4.33 5cos 60 or 5sin30 or 2.5	B1 B1 [2]	Order immaterial, accept +/-. May be awarded in (ii) if no attempt in (i)
(ii)	7-4.33 (= 2.67) and 9 - 2.5 (= 6.5) $R^2 = 2.67^2 + 6.5^2$ R = 7.03 tanθ = 6.5/2.67 θ = 67.6, 67.7degrees	M1* A1 D*M 1 A1 D*M 1 A1 [6]	Subtracts either component from either force 3sf or better Valid trig for correct angle 3sf or better
4 (i)	20cos 30 20cos30 = 3a a = 5.77 ms^{-2}	M1 M1 A1 [3]	Resolves 20 (accept 20 sin30) Uses N2L horizontally, accept g in ma term
(ii)	R = 3x9.8 + 20 sin 30 (= 39.4) F = 20cos 30 (= 17.3) 17.3 = 39.4μ μ = 0.44	M1 A1 B1 M1 A1 [5]	Resolves vertically (accept -, cos if sin in i); correct no. terms Correct (Neither R nor *F* need be evaluated) Uses F = μR

5 (i)	$V = \int 0.8tdt$ $v = 0.8t^2/2$ (+c) t = 0, v =13, (c = 13) $v = 0.4x\ 6^2$ (+c) $v = 27.4\ ms^{-1}$	M1* A1 M1 D*M1 A1 [5]	Attempt at integration Award if c omitted
(ii)	$s = \int 0.4t^2$ (+c)dt $s = 0.4t^3/3 + 13t$ (+k) t=0, s=0, (k=0) $s = 0.\ 4x6^3/3 + 13x6$ s = 106.8 m	M1* A1ft M1 D*M1 A1 [5]	Attempt at integration of v(t) ft cv(v(t) in (i)) Allow if k=0 assumed. Accept 107 m.
(iii)	Fig. 2 Fig.1 has zero initial velocity/gradient Fig. 3 does not have a increasing velocity/gradient	B1 [1] B1 B1 [2]	
6 (i) a	$2.5 = 9.8t^2/2$ t = 0. 714 s or better or 5/7	M1 A1 [2]	Uses $s = 0 +/- gt^2/2$ Not awarded if - sign "lost"
b	$v^2 = 2x9.8x2.5$ *OR* v = 9.8 x 0.714 $v = 7\ ms^{-1}$ or 6.99 or art 7.00	M1 A1 [2]	Uses $v^2 = 0 +/-2gs$ or v = u +/- gt Not awarded if - sign "lost"
(ii)	R = 2x9.8sin60 (= 16.97 = 17) F = 0.2x16.97 (=3.395 or 3.4) Cmpt weight = 2x9.8cos60 (= 9.8) 2a = 9.8 - 3.395 $a = 3.2\ ms^{-2}$ Distance down ramp = 5 m $v^2 = 2x3.2x5$ v = 5.66 or 5.7	B1 M1 A1ft B1 M1 A1ft B1 M1 A1ft [9]	With incorrect angle, e.g R = 2x9.8cos60 (=9.8) B0 F = 0.2x9.8 (=1.96) M1A1√ Cmpt wt = 2x9.8sin60 (=16.97) B0 2a = 16.97 - 1.96 M1 a = 7.5 A1√ ft cv(R and Cmpt weight) $v^2 = 2x7.5x5$ v = 8.66 or 8.7 A1√ ft cv(√ (10a))
7 (i)	 p = 4 - 2x0.4 (= 3.2) q = 1 - 2x0.4 (= 0.2) 0.7x3.2 - 0.3x0.2 = (1x)v $v = 2.18\ ms^{-1}$	M1 A1 A1 M1 A1 A1 [6]	Use of v = u - 0.4t Accept q = -0.2 from -1+2*0.4 Uses CoLM on reduced velocities

(ii) a		B1 B1 B1 [3]	Straight line with larger y intercept slopes towards t axis, but does not reach it. Straight line with negative y intercept slopes towards t axis, and gets to t axis before other line ends. **SR** if t=2 in ii give B1 if line stops before axis
b	0 = 1 - 0.4t t = 2.5 s P = 4x3 - 0.5x0.4x3^2 Q = 1x2.5 - 0.5x0.4x2.5^2 PQ = 10.2 + 1.25 = 11.45 m	M1 A1 M1 A1 A1 A1 [6]	Finds when Q comes to rest (any method) Uses s = ut - $0.4t^2/2$ (nb $0^{(2)} = 1^{(2)} - 0.4Q^2/2$ B1; convincing evidence (graph to scale, or calculation that Q comes to rest and remains at rest at t less than 3, M1A1;graph A1 needs –ve v intercept) **SR** if t=2 in iib, allow M1 for s= ut - $0.4t^2/2$ And A1 for PQ=8.4

Alternative for Q3 where 7 N and 9N forces combined initially

3 (i)	5cos30 or 5 sin 60 or 4.33 5cos 60 or 5sin30 or 2.5	B1 B1 [2]	Order immaterial, accept +/-. May be awarded in (ii) if no attempt in (i)
(ii)	$Z^2 = 7^2 + 9^2$ (= 130, Z = 11.4017...) cos(angle of Z with y axis) = 9/11.4017.. angle of Z with y axis = 37.8746... Angle opposite R in triangle of forces = 180 -(37.8746+90+30) = 22.125 (Accept 22) $R^2 = 5^2 + 11.4017^2$ - 2x5x11.4017cos22.125 R (= 7.0269) = 7.03 N $11.4017^2 = 5^2 + 7.0269^2$ - 2x5x7.0269cosA (A = 142.33) Angle between R and y axis = 142.33-30-90 (=22.33) θ (= 90-22.33) =67.7 degrees	 M1* A1 D*M1 A1 D*M1 A1 [6]	Z is resultant of 7N and 9N forces only R is resultant of all 3 forces Complete method Cosine rule to find R Or Sine Rule. A is angle between R and 5N forces Complete method θ is angle between R and x axis

4728 Mechanics 1

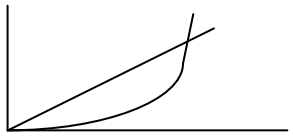
1 i	$x^2 + (3x)^2 = 6^2$ $10x^2 = 36$ $x = 1.9(0)$ (1.8973..)	M1 A1 A1 [3]	Using Pythagoras, 2 squared terms May be implied Not surd form unless rationalised $(3\sqrt{10})/5$, $(6\sqrt{10})/10$
ii	$\tan\theta = 3x/x$ (= 3×1.9/1.9) = 3 $\theta = 71.6^o$ (71.565..)	M1 A2 [3]	Must target correct angle. Accept $\sin\theta = 3\times1.9/6$ or $\cos\theta = 1.9/6$ which give $\theta=71.8^o$, $\theta=71.5^o$ respectively, A1. **SR** $\theta = 71.6^o$ from $\tan\theta = 3x/x$ if x is incorrect; x used A1, no evidence of x used A2
2 i		B1 B1 [2]	Inverted V shape with straight lines. Starts at origin, ends on t-axis, or horizontal axis if no labelling evident
ii	 $6 = 3v/2$ $v = 4$ ms^{-1}	M1 A1 A1 [3]	Not awarded if special (right angled, isosceles) triangle assumed, or $s = (u+v)t/2$, or max v at specific t.
iii	T accn = 4/2.4 or s accn = 16/(2x2.4) T accn = 1 2/3 s or s accn = 10/3 Deceleration = 4/(3 - 1 2/3) or 16/2(6-10/3) Deceleration = 3 ms^{-2}	M1* A1 D*M1 A1 [4]	Uses $t = v/a$ or $s = v^2/2a$. May be implied Accept 4/(3 - 1.67) or 16/2(6-3.33) Accept 3.01; award however $v = 4$ obtained in (ii). $a = -3$ gets A0.
3 i	0.8gsin30 0.8x0.2 $0.8\times9.8\sin30 - T = 0.8\text{x}0.2$ $T = 3.76$ N AG	B1 B1 M1 A1 [4]	Not for 3.92 stated without justification Or 0.16 Uses N2L // to slope, 3 non-zero terms, inc *ma* Not awarded if initial B1 withheld.
ii	$3.76 - F = 3\times0.2$ $F = 3.16$ $3.16 = \mu\text{x}3\times9.8$ $\mu = 0.107$ (0.10748)	M1 A1 A1 M1 A1 [5]	Uses N2L, B alone, 3 non-zero terms Needs *correct value* of T. May be implied. Uses $F=\mu R$ (Accept with $R = 3$, but not with R=0.8g(cos30), F=0.6, F=3.76, $F = f$(mass P)) Not 0.11, 0.108 (unless it comes from using g=9.81 consistently through question.

4 i	$v^2 = 7^2 - 2\times9.8\times2.1$ $v = 2.8$ ms^{-1}	M1 A1 A1 [3]	Uses $v^2 = u^2 - 2gs$. Accept $7^2 = u^2 + 2gs$
ii	$v = 0$ $0^2 = 7^2 - 2\times9.8s$ $s = 2.5$ m	B1 M1 A1 [3]	Velocity = 0 at greatest height Uses $0 = u^2 - 2gs$. Accept $7^2 = 2\times9.8s$.
iii	$v = -5.7$ (or $t = 0.71$ oef to reach greatest height) $-5.7 = 7 - 9.8t$ or $5.7 = (0+) 9.8T$ $t = 1.3(0)$ s (1.2959..)	B1 M1 A1 [3]	Allows for change of direction Uses $v = u +$ or $- gt$. Not 1.29 unless obtained from g=9.81 consistently
5 i	$0.5\times6 = 0.5v + m(v+1)$ $3 = 0.5v + mv + m$ $v(m + 0.5) = -m + 3$ AG	M1 A1 A1 [3]	Uses CoLM. Includes g throughout MR-1
ii	Momentum before = +/- $(4m - 0.5\times2)$ +/- $(4m - 0.5\times2) = mv + 0.5(v+1)$ $4m - 0.5\times2 = mv + 0.5(v+1)$ $v(m+0.5) = 4m - 1.5$	B1 M1 A1 A1 [4]	Includes g throughout MR-1 Needs opposite directions in CoLM on "before" side only. RHS in format am + b or b + am. Ignore values for a and b if quoted.
iii	$4m - 1.5 = - m + 3$ $5m = 4.5$ $m = 0.9$ kg AG $0.9 + v(0.9+0.5) = 3$ or $4\times0.9 - 1.5 = v(0.9+0.5)$ $v = (3-0.9)/(0.9+0.5) = 2.1/1.4$ $v = 1.5$ ms^{-1}	M1 A1 M1 A1 [4]	Attempts to obtain eqn in 1 variable from answers in (i) and (ii) Ignore $m = -0.5$ if seen Substitutes for m=0.9 in any m, v equation obtained earlier.
6 ia	Perp = 10cos20 (= 9.3967 or 9.4) // = 10sin20 (= 3.4202)	B1 B1 [2]	Includes g, MR -1 in part (i). Accept –ve values.
b	$\mu = 10\sin20/10\cos20 = \tan20$ (= 3.42/9.4) $\mu = 0.364$ (0.36397..) AG	M1 A1 [2]	Must use $\|F\| = \mu\|R\|$ Accept after inclusion of g twice
ii	*No misread, and resolving of 10 and T required* $R = 10\cos20 + T\cos45$ $F = T\cos45 - 10\sin 20$ or $T\cos45 = \mu R + 10\sin20$ $T\cos45 - 3.42 = 0.364(9.4 + T\cos45)$ $0.707T - 3.42 = 3.42 + 0.257T$ $0.45T = 6.84$ $T = 15.2$ N (15.209..)	M1* A1 M1* A1 D*M1 A1 A1 [7]	3 term equation perp plane, 2 unknowns $9.4 + 0.707T$ (accept $9.4+.71T$) 3 term equation // plane, 2 unknowns $0.707T - 3.42$ (accept $0.71T - 3.4$) Substitutes for F and R in F=0.364R *Award final A1 only for T = 149 N after using 10g for weight*

7 i	$a = \mathrm{d}v/\mathrm{d}t$ $a = 6 - 2t$ ms^{-2}	M1 A1 [2]	Differentiation attempt. Answer 6-t implies division by t
ii	$s = \int v\mathrm{d}t$ $s = \int 6t - t^2 \ \mathrm{d}t$ $s = 3t^2 - t^3/3$ (+c) $t = 0$, $v = 0$, $c = 0$ $t = 3$, $s = 3\text{x}3^2 - 3^3/3$ $s =$ 18 m AG	M1* A1 B1 D*M1 A1 [5]	Integration attempt on v Award if limits 0,3 used Requires earlier integration Does not require B1 to be earned.
iii	Distance remaining (= 100 -18) = 82 Total time = 3 + 82/9 T = 12.1 s (12 1/9)	B1 M1 A1 [3]	 Numerator not 100 Not 109/9
iv	Distance before slows = 18 + (22 - 3)x9 Distance while decelerating = 200 - 189 = 11 11 = 9t - 0.3t^2 or 11 = (9+8.23)t/2 or 8.23 = 9-0.6t t = 1.28 (1.2765.., accept 1.3) T = 23.3 s (23.276..)	M1* A1 D*M1 A1 D*M1 A1 A1 [7]	(=189 m) Two sub-regions considered Accept 10.99. 10.9 penalise -1PA. Uses $s = ut$ - 0.5x0.6t^2, or $v^2 = u^2$-2x0.6s with $s=(u+v)t/2$ or $v=u+at$ Finds t. (If QE, it must have 3 terms and smaller positive root chosen.)

4728 Mechanics 1

1 i	$v = 4.2 + 9.8 \times 1.5$ $v = 18.9$ ms^{-1}.	M1 A1 [2]	Uses $v = u + gt$ 18.9(15) from $g = 9.81$
ii	$s = 4.2 \times 1.5 + 9.8 \times 1.5^2/2$ or $18.9^2 = 4.2^2 + 2 \times 9.8s$ $s = 17.325$ m	M1 A1 [2]	Uses $s = ut + gt^2/2$ or $v^2 = u^2 + 2gs$ Accept 17.3
iii	$v^2 = 4.2 + 2 \times 9.8 \times (17.3(25) - 5)$ $v = 16.1$ ms^{-1}	M1 A1 [2]	$18.9^2 = u^2 + 2 \times 9.8 \times 5$ $u = 16.1$ ms^{-1}. Accept answers close to 16.1 from correct working
2 i	Resolves a force in 2 perpendicular directions Uses Pythagoras $R^2 = (12+19\cos 60)^2$ $+ (19\sin 60)^2$ $R = 27.1$ N $\{R = \sqrt{((19+12\cos 60)^2 + (12\sin 60)^2)} = 27.1\}$	M1 DM1 A1 A1 A1 [5]	*Diagram for vector addition/subtraction* *Uses Cosine Rule* $R^2 = 12^2 + 19^2 -$ $2 \times 12 \times 19\cos 120$ $R = 27.1$
ii	Trig on a valid triangle for correct angle $\tan\theta = (19\sin 60)/(12 + 19\cos 60)$ etc Angle is 37.4^o, 37.5°	M1 A1 A1 [3]	Either Pythagoras or vector add/sub triangle $\sin\theta/19 = \sin 120/(27.1)$ etc
3ia	$+/-(9m + 2 \times 0.8)$ $\{+/-(3.5\times 0.8 - 2\times 0.8)\}$ $+/-(-3.5m + 3.5 \times 0.8)$ $\{+/-(9m + 3.5m)\}$ $+/-(9m + 2 \times 0.8) = +/-(-3.5m + 3.5 \times 0.8)$ $m = 0.096$ kg	B1 B1 M1 A1 [4]	Before mom, or mom change Q, OK with g After mom, or mom change P, OK with g Equates moms, or changes, accept with g Do not award if g used
ib	$+/-0.096(9+/-3.5)$ *OR* $+/-0.8(3.5 -2)$ $+/-1.2$ kgms^{-1}	M1 A1ft [2]	Using before & after speeds of P or Q, no g ft $12.5 \times$ cv(0.096)
ii	$(0.8+0.4)v$ or $0.8v + 0.4v$ $3.5 \times 0.8 + 0.4 \times 2.75 = (0.8+0.4)v$ $v = 3.25$ ms^{-1}	M1 A1 A1 [3]	Using Q and R common speed after, no g $2.8 + 1.1 = 1.2v$
4ia	$0.3g\cos 60$ and $0.3g\sin 60$ $0.4g\cos 60$ and $0.4g\sin 60$ Calculates either relevant difference Perp = $0.1g\cos 60$ and Para = $+/- 0.1g\sin 60$	B1 B1 M1 A1 [4]	Accept use of "m = 0.1 kg" for M1 and $0.1g\cos 60$ (B1) $0.1g\sin 60$ (B1) = 0.49 and = 0.849 (accept 0.85 and 0.84)
ib	$0.1g\sin 60 = \mu 0.1g\cos 60$ $= 1.73$ ($= \sqrt{3}$)	M1 A1 [2]	$F = \mu R$, $F > R > 0$ From correct R, F values

4 ii	$0.5g - T = 0.5a$ $T - 0.4g = 0.4a$ $a = 1.09\ ms^{-2}$ $T = 4.36$ N	M1 A1 B1 B1 [4]	N2L for either particle no resolving, at least 1 unknown Formula round the pulley, M0A0. But award M1 for $T-0.4g = 0.4 \times 1.09$ etc later Both equations correct
5 i	$11 = 3 + 20a$ $(a = 0.4)$ $8 = 3 + (11-3)t/20$ $t = 12.5$	M1 M1 A1 [3]	Uses $v = u + at$, no zero terms Their $a>0$. $t/20 = (8-3)/(11-3)$ is M1M1
ii	$s(A,20) = 8 \times 20$ (=160) $s(B,20) = (3+11) \times 20/2 =$ $3 \times 20 + 0.4 \times 20^2/2$ (=140) $8T = (3+11) \times 20/2 + 11 \times (T-20)$ or $(160 - 140) = 11t - 8t$ $T = 26\ 2/3$	B1 B1 M1 A1 A1 [5]	Or $s(A) = 8T$ or as stage of $s(B)=(3+11)\times20/2 + 11\times(T-20)$ 3 part equation balancing distances Accept 26.6 or 26.7
iii		B1 B1 B1 [3]	Linear rising graph (for A) starting at B's start Non-linear rising graph for B below A's initially. Accept 2 straight lines as non-linear. Single valued graphs graphs intersect and continue
6 i	$a = 2 \times 0.006t - 0.18$ $a = 0.012t - 0.18$	M1 A1 [2]	Differentiates v (not v/t) Award for unsimplified form, accept +c, not +k
ii	$0.012t - 0.18 = 0$ $t = 15$ $0.006 \times 15^2 - 0.18 \times 15 + k = 0.65$ $k = 2$ AG	M1* A1 D*M1 A1 A1 [5]	Sets $a = 0$, and solves for t Substitutes t(v(min)) in v(t)
iii	$s = 0.006t^3/3 - 0.18t^2/2 + 2t$ (+c) $(s = 0.002t^3 - 0.09t^2 + 2t$ (+c)) $t = 0$, $s = 0$ hence $c = 0$ $L = 0.002 \times 28.4^3 - 0.09 \times 28.4^2 + 2 \times 28.4$ $L = 30.0$ m	M1A1 B1 M1 A1 [5]	Integrates v (not multiplies by t). Award if +c omitted, accept kt Explicit, not implied (or uses limits 0, 28.4) Substitutes 28.4 or 14.2 in s(t), (and k=2) Accept a r t 30(.0), accept +c

7 i	(Fr =) 0.15 × 600gcos10 (Wt cmpt =) 600gsin10 600 × 0.11 = T - 0.15 × 600gcos10 - 600gsin10 (66 = T - 868.6 – 1021) T = 1960 N	B1 B1 M1 A1 A1 [5]	Implied by Fr = 0.15×600gcos10 (=868.6..) N2L. T with at least 1 resolved forces and 600 × 0.11 1955.6..
ii a	a(up) = +/-(600gsin10+.15×600gcos10)/600 a(up) = +/-3.15 ms^{-2} AG	M1 A1 [2]	2 resolved forces and 600a or "unit mass" Disregard sign, accept 3.149
b	UP $v^2 = 2 \times 0.11 \times 10$ v = 1.48 when cable breaks t = 1.48/3.149 (t = 0.471 time for log to come to rest) $s = 1.48^2/(2 \times 3.149)$ s = 0.349 distance for log to come to rest DOWN a(down) = (600gsin10-0.15×600gcos10)/600 10+0.349= $0.254t^2/2$ t = 9.025 T = (9.025 + 0.471) = 9.5 s	M1 A1 M1 M1 A1 B1 M1 A1 A1 [9]	 Correct, need not be accurate Or 1.48 = 0 + 3.15t Correct, need not be accurate = 0.254 Needs a< 3.15, s>10. Or V^2= 2×0.254× (10+0.349) [V= 2.29..], V=0.254t Correct, need not be accurate Accept 9.49

1 i	t = 5/1.2 t = 4.17 s	M1 A1 [2]	5=1.2t or 0=5-1.2t 4 1/6 s, 4.166 or better, 4.16 recurring.
ii	$s = (-5)^2/2x1.2$ s = 10.4 m *OR (using(i))* $s = 5x4.17 – 1.2x4.17^2/2$ s = 10.4 m *OR (using(i))* s = (5 (+ 0))/2 x 4.17 s = 10.4 m	M1 A1 [2] M1 A1 M1 A1	$s = 5^2/2x1.2$ or $5^2 = 2x1.2s$ or $0 = 5^2 - 2x1.2s$ Accept 10 5/12, but not 10 Time must be > 0. Accept |t| from (i) Award if |-4.17| used.
iii	Fr = 3x1.2 R = 3x9.8 μ = (3x)1.2/(3x)9.8 μ = 0.122 *OR* R = 3x9.8 Mass x acceleration = +/- 3x1.2 +/-μ x29.4 = +/- 3x1.2 μ = 0.122	B1 B1 M1 A1 [4] B1 B1 M1 A1	Accept 3.6, +/- Accept 3g, +/- Ratio of 2 positive numerical force terms Not 0.12 Accept 3g, +/- Either both positive or both negative.

2 i	+/-(0.4x3 - 0.6x1.5) +/-(0.4x0.1 + 0.6v) (0.4x3 - 0.6x1.5) = +/-(0.4x0.1 + 0.6v) speed |v| = 0.433 ms^{-1} *OR* +/- (0.4x3 – 0.4x0.1) = +/- 1.16 (0.6v + 0.6x1.5) = 0.6v + 0.9 1.16 = +/-(0.6v + 0.9) speed |v| = 0.433 ms^{-1}	B1 B1 M1 A1 [4] B1 B1 M1 A1	+/- 0.3 Nb the terms have same signs Equating their total mom before & after Accept 13/30 or 0.43 recurring, but not 0.43 Momentum change of P Momentum change of Q Equating momentum changes 0.26/0.6 = v
ii	+/-(0.4x0.1 - 0.6v) (0.4x3 - 0.6x1.5) = +/-(0.6v - 0.4x0.1) v = 0.567 PQ = 0.1x3 +0.567x3 PQ = 2 m *OR* +/- 0.4x3 + 0.4x0.1 and +/- 0.6v + 0.6x1.5 1.24 = +/- 0.6v + 0.9 v = 0.567 etc	B1 M1 A1 M1 A1 [5] B1 M1 A1	Nb the terms have different signs Must use +/- same before momentum as in (i) May be implied, or in any format (0.1 + 0.567)x3 Accept 2.00(1), 2.0, 2.00 Both must be correct Equating change in momentum May be implied, or in any format

3 i	H = +/-(9 - 5cos60) H = 6.5 N AG	M1 A1 [2]	+/-(9 + 5cos120)
ii	V = +/-(12 - 5sin60) V = 7.67 N	M1 A1 [2]	+/-(12 + 5cos150) Accept 7.666 or better, or 7.6 recurring
iii	$R^2 = 6.5^2 + 7.67^2$ R = 10.1 N tan A = 6.5/7.67 or 7.67/6.5 A = 40(.3) or 49.7 Bearing = 320°	M1 A1 M1 A1 A1 [5]	Uses Pythagoras on forces V(ii) and 6.5 10.053.. Uses trigonometry in relevant triangle May be implied by final answer As this is not a final answer, exact accuracy is not an issue Or better

4 i	$3.2 - 0.2t^2 = 0$ $t = 4$ s	M1 A1 [2]	Puts 0 for v and attempts to solve QE Accept dual solution +/-4
ii	$a = -2x0.2t$ $a = -0.4x4$ $a = -1.6$ ms^{-2}	M1* D*M1 A1 [3]	Differentiates v Substitutes +ve t(i) in derivative of v Negative only
iii	$s= 3.2t - 0.2t^3/3$ (+c) $t = 0$, $s = 0$ so $c = 0$ $s(4) = 3.2x4 -0.2x4^3/3$ $s = 8.53$ m	M1* A1 B1 D*M1 A1 [5]	Integrates v, not multiplication by t Or correct use of limits 0 and 4 Accept without/loss of c 8 8/15 Accept with/without c

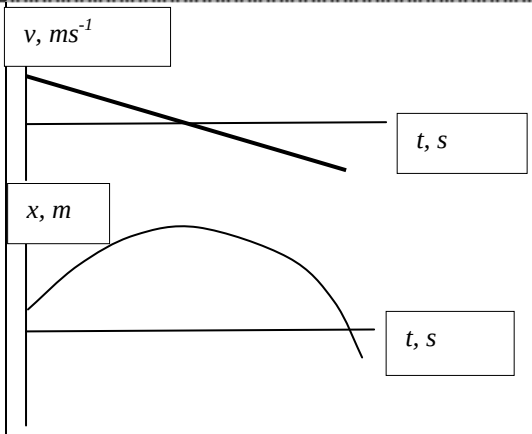
5 i	+/-3x20/2 30 m	M1 A1 [2]	Use area of <u>scalene</u> triangle(s). Not suvat. Accept -30
ii	 (t+4)x3/2 = 30 or 3t/2 = 30 - 4x3 t = 16 or t = 12 T = 76	M1 A1 A1 A1 [4]	Equates <u>scalene</u> trapezium area to distance (i) [(T-60)+4]x3/2 =30, award A2
iii	T(accn) = 3/0.4 (=7.5 s) decn = 3/([76-60] - 4 - 7.5) decn = (+/-) 2/3 ms^{-2} *OR* S(accn) = 3^2/(2x0.4) (= 11.25 m) decn = 3^2 / [2x(30 – 3x4 – 11.25)] decn = (+/-) 2/3 ms^{-2}	B1 M1 A1 [3] B1 M1 A1	 Or 3 = decn x ([76-60] - 4 - 7.5) (+/-) 0.667 or better - accept 0.6 recurring (+/-) 0.667 or better - accept 0.6 recurring

6 i a	T - 0.85g sin30 = 0.85a 0.55g - T = 0.55a a = 1.225/1.4 a = 0.875 T = 4.91	B1 B1 M1 A1 A1 [5]	Either equation correct Both eqns correct and consistent ‘a’ direction Solves 2 sim eqn 4.908 or better – has to be positive
b	F = 2Tcos30 F = 8.5(02..)	M1 A1ft [2]	Or Pythagoras or cosine rule cv(4.91)x√3
ii	 $v^2 = 1.3^2 + 2x0.875x1.5$ (=4.315) a = +/-gsin30 0 = 4.315 -2x4.9s (s = 0.44…) S = 1.94	M1 A1ft B1 M1 A1 A1 [6]	Uses $v^2 = u^2 + 2a(1.5)$, u non-zero, a from (i) v = 2.077....(v^2 =1.69+3xcv(0.875)) a = +/-4.9 Uses $0^2= u^2$+/-2as, with a not g or (i), u not1.3 May be implied – need not be 3sf

7 i	Fr = 4 + 5sin60 Fr = 8.33 R = 12 - 5cos60 R = 9.5 μ = (4 + 5sin60)/(12 - 5cos60) μ = 0.877	M1 A1 M1 A1 M1 A1 [6]	All 4 + component 5 (4 + 4.333(01)) May be implied +/-(All 12 – component 5 (12 – 2.5)) May be implied, +ve from correct work Friction/Reaction, Fr>4, R<12, both positive
ii	Upper block μ = 5sin60/(9-5cos60) (=4.3/6.5) μ = 0.666	 M1 A1 [2]	 (Component 5)/(9-component 5)
iii	Upper mass = 9/g (9/g)a = 5sin60 - 0.1(9 - 5cos60) a = 4.01 Lower mass Tractive force = 4 + 0.1(9-5cos60) (= 4.65) Max Friction = 0.877(3+(9-5cos60) (= 8.33) Tractive force < Max Friction a = 0 *OR for Lower Mass* ma = 4+0.1(9-5cos60)-0.877(3+9-5cos60) -ve a caused by friction impossible, hence a = 0	B1 M1 A1 M1 A1 A1 [6] M1 A1 A1	0.918(36..) N2L 0.918(36..)a= 4.33(01..) – 0.1x6.5 where friction = 0.1x(9-component 5) Compares TF (tractive force) and max friction N2L with 3 force terms:

1 i	ΔMom P = 0.5(2.4 + 0.2) ΔMom P = +/-1.3 kgms^{-1}	M1 A1 [2]	+/- 0.5(2.4 ± 0.2)	MR P/Q +/-0.8(1.5+/-0.2) M1A0
ii	Momentum before = 0.5x2.4 – 0.8x1.5 0.5x2.4+/ – 0.8x1.5 = +/-(-0.5x0.2 +/- 0.8v) Speed = 0.125 ms^{-1} OR ΔMom Q =+/- (+/-0.8v – 0.8x1.5) 1.3 = +/-(0.8v – 0.8x1.5) Speed = 0.125 ms^{-1}	B1 M1 A1ft A1 [4] B1 M1 A1ft A1	+/-(0.5x2.4 – 0.8x1.5) Uses mom before = mom after Cv(Expression for before momentum) 1/8, +ve (not 0.13) Uses ΔMom P = ΔMom Q Cv(ans(i)) = +/-(+/-0.8v – 0.8x1.5) 1/8, +ve (not 0.13)	Cont MR 0.5x2.4-0.8x1.5 Uses mom before = mom after 0.5x2.4+/-0.8x1.5 = +/-(0.8x0.2+/-0.5v) 0.32 B1 M1A1A1 ft

2 i	10CorSα = 8 10cosα = 8 α = 36.9° OR 10CorSα = F 10sinα = 6 α = 36.9° OR tanθ = F/8 tanα = 6/8 α = 36.9°	M1 A1 A1 [3] M1 A1ft A1 M1 A1ft A1	Component of 10 = 8 Accept 37 36.8 and 37 from 36.7 Using value of F(ii) Using F(=6) from (ii) OR tanθ = 8/F, using value of F from (ii)	CorS is Cos or Sin (passim) Do not accept 36.7
ii	 F = 10sin36.9 F = 6 N OR F^2 +8^2 = 10^2 F = 6 N	M1 A1ft A1 [3] M1 A1 A1	F = 10CorSα Allow 10Cos53.1 Accept 6.01 (or from 10Cos53.1) or 6.0 Pythagoras, 3 squared terms	 anything rounding to 6.0 from correct working. Accept F^2 = 8^2+ 10^2

3 i	$v^2 = (+/-5)^2 + 2x9.8x2.5$ Speed (or v) = 8.6(0) ms^{-1} OR $0 = 5^2 – 2x9.8xs$ with $v^2 = (0) +2x9.8(s+2.5)$ $v^2 = 2x9.8x(2.5+1.28)$ Speed = 8.6(0) ms^{-1}	M1 A1 A1 [3] M1 A1 A1	Uses $v^2 = u^2 \pm 2gs$, u non-zero Accept √74 Do not accept -8.6(0) s = 1.2755... 19.8x3.7755.. Or rounds to 8.6	It is common to see the upwards and downwards motion treated separately. Both parts must be attempted for M1, and both parts must be attempted accurately with cvs for the A1
ii	8.6 = -5 + 9.8t Time = 1.39 s OR $9.8t^2 - 10t - 5 = 0$ Time = 1.39 s OR 2.5 = (8.6-5)t/2 Time = 1.39 s OR t = 5/9.8 + 8.6/9.8 Time = 1.39	M1 A1ft A1 [3] M1 A1 A1 M1 A1ft A1 M1 A1ft A1	Uses v(from (i)) = +/-5 +/- 9.8t Cv(8.60 from (i)) +/-2.5 = 5t +/- $gt^2/2$ 2.5 = +/- (5 - Speed from (i)) x t / 2 Cv(8.60 from (i)) Times to top and ground found and added Cv(8.60 from (i))	It is common to see the upwards and downwards motion treated separately. Both parts must be attempted for M1, and both parts must be attempted accurately with cvs for the A1
iii a) b)		B1 B1 B1 B1 [4]	Straight descending line to t axis Continues straight below t axis Inverted “parabolic” curve, starts anywhere on t=0 Ends below t = 0 level, need not be below t axis	Ignore values written on diagrams

4 i	2 – F = 0.8x0.2 F = Tcos10 T = 1.87 N OR 2 – Tcos10 = 0.8x0.2 T = 1.87 N	M1 M1 A1 [3] M1 M1 A1	N2L 2 force terms and ma (F = 1.84 N) F = TCorS10 1.8683.. N2L 2 force terms and ma TCorS10	m is the block mass, award if T not F
ii	R - 0.3x9.8 + TCorS10 = 0 R = 0.3x9.8 – 1.87sin10 R = 2.62 Tcos10 – Fr = 0.3x0.2 Fr = 1.78 μ = 1.78 / 2.62 OR 1.78 = 2.62 μ μ = 0.68	M1 A1ft A1ft M1 A1ft M1 A1 [7]	3 term equation, vertically cv(T(i)) 2.61(5..) seen or implied N2L 2 forces for P, component of T cv(T(i)) seen or implied both terms same sign	Treat as a mis-read R-0.8x9.8-TCorS10 = 0 leading to R=8.16 (i.e.works on block[2/3] OR N2L 2 forces for P+Q: 2 – Fr = (0.8+0.3)x0.2 R, Fr unequal to T From correct value of T = 1.87 only

5 ia	s(P) = 4.9T + 0.5x 4.9T^2 y(Q) = (0) + 0.5x9.8T^2	M1 A1 A1 [3]	s=ut+0.5at^2 used along plane or vertically, with u = 4.9 or 0, and a = 4.9 or 9.8 appropriately Accept use of t or T Allow g in Y(Q)	
b	(m)x4.9 = (m)gsinθ θ = 30	M1* A1 [2]	Allow CorSθ	Sinθ =(0.5x9.8T^2)/(4.9T + 0.5x 4.9T^2) gets M1, but in ic. Beware circular argument.
c	y(Q)/s(P) = sinθ OR y(Q) = s(P) sinθ 0.5x9.8(2/3)^2 / (4.9x2/3 + 2.45(2/3)^2 = 0.5 OR 0.5x9.8T^2 / (4.9T + 2.45T^2) = sin30 T= 2/3 s AG	M1 D*M1 A1 [3]	Uses appropriate trigonometry to relate distances Verification needs explicit value of sin(cv(θib)) Ratio of distances considered using cv (30)	This may appear in b) 0.5x9.8(2/3)^2 = (4.9x2/3 + 2.45(2/3)^2 x 0.5 OR 0.5x9.8T^2 = (4.9T + 2.45T^2) x sin30
ii	v = 4.9 + 4.9x2/3 OR v = (0) + 9.8x2/3 v = 8.17 ms^{-1} w = 9.8x2/3 = 6.53 ms^{-1}	M1 A1 A1 [3]	Uses v = u + at, with appropriate u, a values once 8.2 6.5	

6 i	$x = \int t^2 - 9\ dt$ $x = t^3/3 - 9t\ (+c)$ Finds x(2) Displacement = 15⅓ m OR $x(2) = [t^3/3 - 9t]_0^2$ Displacement = 15⅓ m	M1* A1 D*M1 B1 [4] D*M1 B1	Uses integration of v(t) Award if +c omitted Allow + c or c omitted Accept 15.3, 46/3. Must be +ve Uses limits$[]_0^2$ on integrated x(t) Must be +ve	 Awarded if c omitted or assumed 0
ii	t=0 s=0 or s=46/3 hence x(0) or c= 0 or 46/3 Solves $t^2 - 9 = 0$ $t = (\pm)3$ $x(3) = 3^3/3 - 9x3\ (+ 15.3)$ x(3) = -18 (or -2.67) Dist = 18 m	B1* M1* A1 D*M1 M1 D*B1 [6]	Needs explanation, may be seen in part i May be implied Value of t when direction of motion changes Substitutes cv(t) >2 in integrated x(t) Evaluates c – 18 may be implied award if .. Accept 18(.0) [c=0 assumed]	B1* awarded if limits 0 and 3 used correctly Awarded if limits used correctly
iii	$a = d(t^2 - 9)/dt$ $a = 2t$ $10 = 2t$ $t = 5$ $x(5) (= 5^3/3 - 9x5 + 15.3) = 12$ m OR $[t^3/3 - 9t]_2^5 = 12$ m	M1* A1 D*M1 A1 A1 [5] A1	Uses differentiation of v(t)	

7	Wt cmpts: // plane 0.6gsin30	B1	+/-2.94	
i	Perp plane 0.6gcos30	B1	+/-5.09(22.) = R	
		M1	N2L // plane, 2 force terms and ma (allow no g)	
	0.6gsin30 +/- X = 0.6x10	A1ft	Both weight cmpt and accn signs same	Accept Fr for X
	X = +/-3.06	A1	May be implied (Fr =0.6x10-0.6gsin30 used)	
	μ = 3.06 / 5.09(22..)	M1	Uses μ = Fr/R both terms same sign	Accept Fr = |X|
	μ = 0.601	A1	0.6	
	OR		[7]	
	3.06 = μ x 5.09(22..)	M1	Uses Fr = μR both terms same sign	Accept Fr = |X|
	μ = 0.601	A1	0.6	
ii	$C^2 = 3.06^2 + 5.09^2$	M1	Pythagoras with Fr and R, to find hypotenuse	
a)	C = 5.94 N	A1	Accept 5.9, 5.95 but not 6(.0)	
	$\tan\theta$ = 3.06/5.09(22..)	M1*	Or $\tan\theta = \mu$	
	Angle = (31) + 90	D*M1		
	Angle = 121°	A1	Not 120	
	OR		[5]	
	$\tan\varphi$ = 5.09(22..)/3.06	M1*	$\tan\varphi = 1/\mu$	
	Angle = 180 – (59)	D*M1		
	Angle = 121°	A1	Not 120	
b)	C (= 0.6x9.8) = 5.88 N	B1	5.9	No working needed as C is vertical
	Angle = 60°	B1		No working needed as C is vertical
		[2]		

Question			Expected Answer	Mark	Rationale/Additional Guidance
1			$R^2 = 8^2 + 15^2$ R = 17 N cosθ = 15/17 θ = 28.1°	M1 A1 M1 A1 [4]	Uses Pythagoras 3 squared terms, addition Uses trig appropriately and targets either angle Accept 28°, 0.49 rad
2	i	**Also if in ii**	T – 0.45g = 0.45x0.98 T = 4.85(1) N	M1 A1 [2]	N2L on 0.45 kg, weight - tension and +/-0.98m Not 4.9, 4.8 (4.851 is exact, but 4.85 acceptable) {g=9.81→ T=4.85 or 4.86 or better}
	ii	**Also If in i**	mg – 4.85(1) = 0.98m m = 4.85(1)/(9.8-0.98) or m(g – 0.98) = 4.85(1) m = 0.55 *OR* 0.98 = g (m-0.45)/(m+0.45) m = (g+0.98)/(g-0.98) x 0.45 m = 0.55	M1 A1ft A1 [3] M1 A1 A1	N2L on Q, weight – tension, tension=T(i), and 0.98m Simplified to a single term in m, ft cv(T(i)) art 0.550 {g=9.81→ m=0.55(0) or better} a = g x Δ(masses)/Σ(masses)
	iii		$v^2 = (0 +) 2x0.98x0.36$ v = 0.84 ms^{-1}	M1 A1 [2]	Uses $v^2 = u^2 + 2as$, a not 9.8, 2as>0, u = 0 or omitted
	iv		$0 = 0.84^2 – 2x9.8s$ (s = 0.036) S = 0.036 + 2x0.36 = 0.756 m	M1 A1 A1 [3]	$0 =(cv(iii))^2 – 2gs$, or t=cv(iii)/g <u>and</u> $s = ut+/-gt^2/2$ May be implied by final answer (eg 0.396) Must be 3 sf (exact) {g=9.81→ s=0.756 or better}

			Frequent mis-read "horizontal/vertical" MR version in {}		Allow all A1 marks in (i) and (ii) *except final A1 in (ii).*
3	**i**		R = 0.8g – 6cos60 {R = 0.8g – 6sin60} R = 4.84 {R = 2.64}	M1 A1 [2]	Resolves vertically, (R=) difference of 2 forces inc. component of 6 Accept 4.8 {2.6} {g=9.81→ R=4.848 {2.65}; accept 4.8 {2.6 or 2.7} }
	ii		Fr = 0.2x4.84 (=0.968) { Fr = 0.2x2.64..(=0.5287..)} 6sin60 - 0.968 = 0.8a {6cos60 – 0.5287.. = 0.8a} a = 5.29 ms^{-2} {a = 3.09 ms^{-2} A0}	M1 M1 A1 A1 [4]	Uses F=0.2(cv(i)) or F=0.2x(R found in (ii) by a method which would be given M1 in (i)) Uses N2L, 3 terms inc. component of 6 Fr need not be evaluated Accept 5.3 {g=9.81→ a=5.28 {3.09 A0} Accept 5.3 {3.1 A0}
	iii		Fr = 0.2x0.8x9.8 (= 1.568) 0.8a = -0.2x0.8x9.8 0 = 4.9 – 1.96t t = 2.5 s	B1 M1* D*M1 A1 [4]	Uses Fr = 0.2x0.8g N2L, Fr only, accept use of Fr from (ii) Accept 0.8a = 0.2x0.8x9.8, (a = (-)1.96) Accept 4.9/1.96, not 0 = 4.9 + 1.96t Accept art 2.50 {g=9.81→ t=2.50 Accept art 2.50}
4	**i**		a = 15/6 or d = 15/2 a = 2.5 ms^{-2} d = 7.5 ms^{-2}	M1 A1 A1 [3]	Uses a = speed change/time Accept -7.5
	ii		T = 6+11+2 (=19) x = 15(11+19)/2 or 15x6/2+15x11+15x2/2 x = 225 m	M1 M1 A1 [3]	Accounts for totality of car journey (may be implied) Idea area = distance **SR** Accept 15x(13+17)/2 M1M1
	iii		Walks = 20x(-)2 = (-)40 m Jogs = 40/5 = 8 s T_s = 60 – ({6+11+2} + 20 + 8) T_s = 13 s	M1 A1 M1 A1 [4]	Finds distance walked T_s + ({6+11+2} + 20 + 8) = 60, needs all time elements

5	**i**		$V_P = 3 – 2.5x0.4$ (= 2) $V_Q = 2.5x0.4$ (= 1) +/-(0.5x2 - 0.2x1) (=+/-0.8) 0.5x2 - 0.2x1 = 0.5v + 0.2x3.2 (v = 0.32) 0.32 ms^{-1} up	M1 A1 B1 M1 A1 [5]	Calculation of either speed, either directions, |a|=2.5 Both magnitudes correct (disregard signs) Momentum before Uses conservation of momentum in collision (not both $v_P = 3$ and $v_Q = 0$) Accept "same", value positive
	ii		$V_Q = 3.2 – 2.5x0.6$ (=1.7) $V_R = 2.5x(0.4+0.6)$ (= 2.5) 0.2x1.7 – 0.3x2.5 = (0.2+0.3)v (v = -0.82) 0.82 ms^{-1} down	M1 A1 M1 A1ft A1 [5]	Calculation of either speed with its correct time, |a|=2.5 Both magnitudes correct (disregard signs) Uses momentum conservation in collision (not both $v_Q = 3.2$ and $v_R = 0$) LHS different signs, RHS same signs, ft cv(speeds Q, R) Value positive
6	**i**		"...smooth ring...", "..no friction at ring.."	B1 [1]	If a variety of reasons is offered, "smooth ring" must be the last
	ii		Tcosθ +5 = Tcos(90-θ) Tcosθ +5 = Tsinθ ……..(a) Tsinθ + Tsin(90-θ) = 7 Tsinθ + Tcosθ = 7 ……. (b)	M1 A1 M1 A1 [4]	"Resolves horiz" equation, needs TCorSθ, 3 terms, 2 of which are T resolved "Resolves vert" equation, needs TCorSθ, 3 terms, 2 of which are T resolved {Allow candidates solving for (iii) to begin in (ii)}
	iii		uses (b)+(a) and (b)-(a) for example Tsinθ = 6 or 2Tsinθ = 12, Tcosθ = 1 or 2Tcosθ = 2 $T^2 = 6^2 + 1^{(2)}$ T = 6.08 N Tanθ = 6(/1) θ = 80.5° *OR* (b) gives T=7/(sinθ+cosθ), subs in (a) for example 12cosθ = 2sinθ then mark as 6(iii) below for D*M1 A1 D*M1 A1	M1* A1 D*M1 A1 D*M1 A1 [6] M1* A1	Attempts to solve 2 equations in 2 unknowns Both terms have values correct Accept √37, 6.1 Uses a correct trig identity Accept 81°, 1.4 rad, 1.41 rad Attempts to solve 2 equations in 2 unknowns Correct two term equation in one variable

7	**i**		v = dx/dt $v = 0.3t^2 - 0.6t + 0.2$ a = dv/dt a = 0.6t – 0.6	M1 A1 M1 A1ft [4]	Uses differentiation of x Uses differentiation of v Correct differentiation of candidate's v(t)
	ii		0.6t - 0.6 = 0 (t = 1) $x(1) = 0.1x1^3 - 0.3x1^2 + 0.2x1$ x(1) = 0 AG *OR* $0.1t^3 – 0.3t^2 + 0.2t = 0$ (t=1, and disregard others) a(1) = 0.6x1 -0.6 a(1) = 0	M1* D*M1 A1 [3]	Attempts to solve a=0 Puts solution in x formula Attempts to solve x=0 Puts solution in a formula
	iii		$0.3t^2 - 0.6t + 0.2 = 0$ t = 0.423 s t = 1.58 s	M1 A1 A1 [3]	Attempts to solve 3 term QE v = 0, accept imperfect attempt at formula, completing square or factorisation Accept $1 - 1/\sqrt{3}$, 0.42, 0.422, or better Accept $1 + 1/\sqrt{3}$, 1.6, 1.57, or better
	iv		$x = \int 0.2t^2 - 0.4dt$ $x = 0.2t^3/3 – 0.4t$ (+k) $0.1t^3 – 0.3t^2 + 0.2t = 0.2t^3/3 - 0.4t$ (+k) $t^3 - 9t^2 + 18t = 0$ $t^2 – 9t + 18 = 0$ AG (t-3)(t-6)=0 T = 3 s	M1* A1 D*M1 D*M1 A1 M1 A1 [7]	Uses integration, ignore omission of k $x = 2t^3/30 – 4/10\ t$ (+k), or coeff t^3 0.067 or better Equates expressions for distance 3 terms with different powers of t, no constant Explains T is non-zero, or explains division by t Tries to solve given quadratic, accept imperfect attempt at completing square, formula or factorisation, and chooses smaller positive root A1
			Total	**[72]**	

Continued

Question			Answer	Marks	Guidance
1	(i)		Total momentum before = $0.3 \times 2.2 + 0.5 \times 0.8$ Mom P after = $0.3 \times 2.2/2$ $0.3 \times 2.2 + 0.5 \times 0.8 = 0.3 \times 2.2/2 + 0.5v$ $v = 1.46$ ms^{-1}	B1 B1 M1 A1 **[4]**	Allow inclusion of g 0.33, accept $0.33g$ and negative term Allow $0.33g = 0.5gv - 0.5g \times 0.8$ M1 Allow from inclusion of g
1	(ii)		PQ = $3 \times 1.46 - 3 \times 2.2/2$ PQ = 1.08 m	M1 A1 **[2]**	$3(1.46 - 2.2/2)$ Accept $3 \times 1.46 - 2.2/2$
2	(i)		$36 = 0 +/- a24^2/2$ $a = +/- 0.125$ ms^{-2} OR $U = \pm 24a$ and $0^2 = (24a)^2 \pm 2a36$ $a = \pm 0.125 \text{ms}^{-2} = \pm \frac{1}{8} \text{ms}^{-2}$	M1 A1 **[2]** M1 A1	$s = vt - at^2/2 = 0$ $^+$/- $at^2/2$ OR $s = ut$ $^+$/- $at^2/2$ $^1/_8$ Use both $0 = u \pm 24a$ *and* $0^2 = u^2 \pm 2a36$ $U = 3$ ms^{-1}
2	(ii)		$(180/g)a = Fr$ $Fr = \pm 2.3(0)$ N $\mu = 2.3/180$ $\mu = 0.0128$	M1 A1 M1 A1 **[4]**	Mass = 18.367…kg. Regard $180a = Fr$ as MR May be implied. $Fr = 22.5$ MR –1 Fr and R both +ve or both -ve, $\mu = 22.5/(180 \times 9.8)$ if MR Award if MR
3	(i)		$v = \pm \int -8 + 0.6t \text{ d}t$ $v =$ $^+$/-$(-8t + 0.6t^2/2)$ $(+ c)$ $v = 32.5 - 8t + 0.3t^2$ AG	M1 A1 A1 **[3]**	Integrates accn or decn (Although only $v = -8t + 0.6t^2/2$ $(+ c)$ is correct) ONLY FROM $v = \int -8 + 0.6t \text{ d}t$ OR $v = -\int 8 - 0.6t \text{ d}t$ and explicit $t = 0$, $v = 32.5$ so $c = 32.5$
3	(ii)		$0.3t^2 - 8t + 32.5 = 0$ $t = 5$	M1 A1 **[2]**	Starts to solve 3 term QE, either the given ans in (i) or the candidate's answer in (i) with v set = 0. Needs valid formula or factors which give 2 correct coefficients Accept as one of a pair only if the other value is 65/3 = 21.66....

Question			Answer	Marks	Guidance
3	(iii)		$s = \int 0.3t^2 - 8t + 32.5\ \mathrm{d}t$ $s = 0.3t^3/3 - 8t^2/2 + 32.5t\ (+ c)$ $D = 0.3 \times 5^3/3 - 8 \times 5^2/2 + 32.5 \times 5\ (+ c)$ $D = 75$ AG	M1 A1 M1 A1 **[4]**	Integrates an expression for velocity Accept omission of c Substitutes cv(smaller and +ve ans**(ii)**) or uses limits, $[\ ]_0^{smaller+vecv(ii)}$ Explicit evaluation needed. Accept + c
4	(i)		$(X =)15 - 20\cos 60,\ 15 - 20\sin 30$ *OR* $(Y =)8 - 20\cos 30,\ 8 - 20\sin 60$ $(X =)$ 5 N (34.048.. if in rad mode) $(Y =) -9.32$ N (4.9149.. if in rad mode)	M1 A1 A1 **[3]**	Accept $(X =)$ 15 + 20cos120, $(Y =)$ 8 + 20cos 150, and R A =100° Must be +ve Must be –ve. Allow $8-10\sqrt{3}$
4	(ii)		$R^2 = (+/-9.32)^2 + 5^2$ $R = 10.6$ N $\tan\theta = (+/-9.32)/5$ Angle = 152°	M1 A1 ft M1 A1 **[4]**	Uses Pythagoras on ans**(i)**, neither component 8 or 15 $\sqrt{(X\textbf{(i)}^2 + Y\textbf{(i)}^2)}$ Finds any relevant angle with 8 N or 15 N, neither component 8 or 15 CAO, must be 3sf or better
4	(iii)		(Greatest =) 43 N (Least =) 0 N	B1 B1 **[2]**	
5	(i)		$S_{dec} = 15 \times 4 - 1.75 \times 4^2/2$ $S_{dec} = 46$ $100 - 46 = 15T/2 + 15(10 - 4 - T)$ $(= 15 \times 6 - 15T/2)$ $54 = 90 - 7.5T$ $T = 4.8$	M1 A1 M1 A1ft A1 **[5]**	Or $v = 15 - 1.75 \times 4$ and $s = (15 + v)/2 \times 4$ May be implied Any attempt at combined 3 stage distances being 100 Simplification not essential. ft cv(S_{dec}**(i),** numerical)
5	(ii)		$V_R = d(3t^2 - 0.2t^3)/dt$ $V_R = 6t - 0.6t^2$ $V_R(5)\ (= 6 \times 5 - 0.6 \times 5^2) = 15\ \mathrm{ms}^{-1}$ AG	M1 A1 A1 **[3]**	Attempt at differentiating S_R Accept $V_R = 2 \times 3t - 3 \times 0.2t^2$ Must show explicit substitution

Question			Answer	Marks	Guidance
5	(iii)		$A_R = d(6t - 0.6t^2)/dt$ $6 - 1.2t = -1.75$ $t = 6.46$	M1* D*M1 A1 **[3]**	Attempt at differentiating V_R Must be –1.75 or $1.2t - 6 = 1.75$ (i.e. employs deceleration)
5	(iv)		$S_R(10) = 3 \times 10^2 - 0.2 \times 10^3$ $S_R(10) = 100$ *OR* $3t^2 - 0.2t^3 = 100$ $t = 10$ which is how long the athlete takes to finish	M1 A1 **[2]** M1 A1	Substitutes 10 into S_R formula Sets up and tries to solve equation for robot Needs comment about athlete or both finishing race in 10 s
6	(i)		$R = 0.3g\cos30$ $Fr = 0.15 \times 0.3g\cos30$ $0.3a = -0.3g\sin30 - 0.15 \times 0.3g\cos30$ $a = -6.17$ $0 = 4^2 - 2 \times 6.17s$ $s = 1.3(0)$ m	B1 M1 M1 A1 M1 A1ft **[6]**	$R = 2.546$ N. May be shown on diagram $0.15 \times$ cv(R), $Fr = 0.382$ N2L, two forces inc. $0.3g$CorS30 and friction Accept positive value Using a from above ft(8/ |cv(a)|) CorS30 means cos30 or sin30
6	(ii)		$0.3a = 0.3g\sin30 - 0.382$ $a = 3.63$ $1.3 = 3.63t^2/2$ $t = 0.845$ s	M1 A1 M1 A1 **[4]**	N2L, diff. of two forces inc. $0.3g$CorS30 and friction Using cv(s**(i)**), and a not a**(i)** nor 9.8 Rounds to 0.85 if 2 sig fig. CorS30 means cos30 or sin30
6	(iii)		$V = 3.63 \times 0.845$ *OR* $V = \sqrt{(2 \times 3.63 \times 1.3)}$ *OR* $V = 2 \times 1.3/0.845$ ($V = 3.07$) Mom change = +/-($0.3 \times 4 + 0.3 \times 3.07$) Mom change = +/-2.12 kgms^{-1}	M1 M1 A1 **[3]**	cv(a**(ii)** $\times$ t**(ii)**) *OR* cv($\sqrt{2} \times a$**(ii)** $\times s$**(i)** *OR* cv($2 \times s$**(i)**/ t**(ii)**), a**(ii)** not a**(i)** nor 9.8 +/-(0.3×4 +/– $0.3 \times$ speed(return)), 0<speed(return) < 4, g omitted

Question			Answer	Marks	Guidance
7	(i)	(a)	$0.45a = 0.45g - 2.52$ $a = 4.2$ ms^{-2}	M1 A1 **[2]**	N2L for R. 2 vertical forces. Accept +/-$0.45a = 0.45g$ +/– 2.52 Accept –4.2
7	(i)	(b)	$0.05 \times 4.2 = 0.05g + 2.52 - T$ $T = 0.05 \times 9.8 + 2.52 - 0.05 \times 4.2$ $T = 2.8$ N	M1 A1 ft A1 **[3]**	N2L for Q, 3 vertical forces, $0.05 \times 4.2 = 0.05g$ +/- 2.52 +/– T accn not 9.8; 0.5g is TWO vertical forces ($0.45g + 0.05g$) not MR ft cv(***a*(i)**). Any equivalent form of equation *ACCEPT A COMBINED Q AND R METHOD* $(0.45 + 0.05) \times 4.2 = 0.45g + 0.05g$ +/–T M1 $(0.45 + 0.05) \times 4.2 = 0.45g + 0.05g - T$ A1ft $T = 2.8$ N A1
7	(ii)		$\pm 4.2m = T - mg$ *OR* $\pm 4.2 = (0.05g + 0.45g - mg)/(0.05 + 0.45 + m)$ $4.2m = 2.8 - mg$ *OR* $9.8m + 4.2m = 2.8$ $m = 0.2$	M1 A1 ft A1 **[3]**	N2L for P, difference of 2 vertical forces, accn cv(***a*(i)**) ±cv(***a*(i)**) = (wt P + wt Q – wt R) / sum of masses ft cv(***T*(ib)**) Any equivalent form of equation with cv(a(i))
7	(iii)		*BEFORE R STRIKES SURFACE* $v = 4.2 \times 0.5$ $v = 2.1$ $s = 2.1^2/(2 \times 4.2) = 4.2 \times 0.5^2/2$ *AFTER R STRIKES SURFACE* +/-$0.2a = T - 0.2g$ *OR* +/-$0.05a = 0.05g - T$ +/-$0.2a = T - 0.2g$ *AND* +/-$0.05a = 0.05g - T$ a = +/–5.88 $S = 2.1^2 / (2 \times 5.88)$ *TOTAL JOURNEY* Distance = (0.375 + 0.525) = 0.9m	 M1* A1 M1 M1 A1 A1 D*M1 A1 **[8]**	 Find Speed when R hits surface, using ***a*(i)** Distance R falls (0.525 m). Accept +/-$4.2 \times 0.5^2/2$ N2L for either P (with cv(m)) or Q Correct equations for both P and Q *OR* combination $0.05g$ ($-T + T$) – $0.2g$ = +/–($0.2a + 0.05a$) M1A1 Distance P rises after R hits ground (0.375), a not ***a*(i)** or 9.8

Question			Answer	Marks	Guidance
1	(i)		$F^2 = 17^2 - 8^2$	M1	$F^2 = 17^2$ +/– 8^2
			$F = 15$	A1	Exact accept 15.0
			cosα = 8/17	M1	Correct method for angle between 8 N and 17 N forces
			α = 61.9°	A1	Accept 62° from correct work
				[4]	
1	(ii)		$E = 17$	B1	Exact
			Angle = 118(.1)° OR 242° (241.9°)	B1 FT	180 – cv(α**(i)**) OR 180 +cv(a(**i**)) Must be 3sf or better
				[2]	
2	(i)		$v = 7 - 0.4 \times 9.8$	M1	$v = 7$ +/– 0.4g
			$v = 3.08$ ms^{-1}	A1	Exact, or correct to 3sf from g=9.81(3.076) or 10 (3)
			$s = 7 \times 0.4 - 9.8 \times 0.4^2/2$	M1	s = 7 × 0.4 +/– $g0.4^2/2$
			$s = 2.016$ m	A1	Exact but accept 2.02. g=9.81 (2.0152) or g=10 (2)
			OR	**[4]**	
			$3.08^2 = 7^2 - 2 \times 9.8s$	M1	$(\text{cv}(v))^2 = 7^2$ +/– $2gs$
			$s = 2.016$ m	A1	Exact but accept 2.02. g=9.81 (2.0152) or g=10 (2)
			OR		
			$v^2 = 7^2 - 2 \times 9.8 \times 2.016$	M1	$v^2 = 7^2$ +/– $2g(\text{cv}(s))$
			$v = 3.08$ ms^{-1}	A1	Exact or correct to 3sf. Accept v=3.07 from s=2.02. From g=9.81(3.076 or 3.06 from s=2.02) or 10 (3)
2	(ii)		$H = \pm 7^2/(2 \times 9.8)$ (= ±2.5)	B1	Greatest Height, g=9.81 (2.497 accept 2.5) g=10 (2.45)
			$S = \pm (7 \times 0.9 - \frac{1}{2} \times 9.8 \times 0.9^2)$ (= ±2.331)	B1	Height when $t = 0.9$, g=9.81 (2.32695) g=10 (2.25)
			$D = 2.5 + (2.5 - 2.331)$	M1	2 × greatest height – S(0.9)
			$D = 2.669$ m	A1	Exact but accept 2.67, g=9.81 (2.66705) g=10 (2.65)
			OR (Using $t_U = 7/9.8=0.7143$, $t_D = 0.9–0.7143= 0.1857$ s)	**[4]**	"OR" method uses distance from greatest height.
			$H = \pm (7\text{x}0.7143 - 9.8\text{x}0.7143^2/2)$ (= ±2.5)	B1	OR ±9.8x0.7143^2/2. Gains B1 for H as above
			$s_D = \pm 9.8\text{x}0.1857^2/2$ (= ±0.169)	B1	Equivalent to B1 for S as above
			$D = 2.5 + 0.169$	M1	Greatest height + Descent distance << H
			$D = 2.669$ m	A1	Exact but accept 2.67, g=9.81 (2.66705) g=10 (2.65)

Question			Answer	Marks	Guidance
3	(i)		$(10–8)/5 = T_{dec}$ OR $8 = 10 – 5T_{dec}$	M1	Attempt to find $T_{dec} = \pm 0.4 = \pm 2/5$
			t (= 2 – 0.4) = 1.6	A1	Exact. Accept 1 3/5, not 8/5, www
				[2]	
3	(ii)		$S_B = ½ \times 8 \times 2$	B1	$S_B = 8$
			$S_A = 10 \times 1.6 + ½ \times (10+8) \times 0.4$ OR $S_A = 10 \times 2 – ½ \times (2–1.6) \times (10–8)$	M1	Using area under graph is distance (at least two parts) Complete method for S_A run in the first 2s, using cv(t)
			$S_A = 19.6$	A1	Accept as 16+3.6 or 20-0.40, from t =1.6 (however obtained)
			$AB = 19.6 – 8 + 1$	M1	$AB = +/–(S_A – S_B +/– 1)$
			$AB = 12.6$ m	A1	Exact Or $AB = –12.6$ m
				[5]	
4	(i)		$Fr = 14\cos 30$	B1	12.1(24..)
			$R = 28 – 14\sin 30$	B1	21
			$(14\cos 30) = \mu (28 – 14\sin 30)$	M1	12.1(24..)/21. Allow |component of 14|/|cv(R)| for M1
			$\mu = 0.577$ AG	A1	0.577(35..)
				[4]	
4	(ii)		Mass = 28/g	B1	2.857.. Award here if seen in (i) <u>and</u> used in (ii)
			$Fr = 0.577 \times 28$	B1	16.156 or 0.57735.. x 28 = 16.1658..
			$(28/9.8)a = \pm 0.577 \times 28$	M1	Award also for cv(m), m = 28. Must be only one force (friction), allow Fr(i).
			$a = \pm 5.66$ from exact μ, $a = \pm 5.65$ from μ = 0.577	A1	g=10 (±5.77)
			$0 = u^2 – 2 \times 5.66 \times 3.2$	M1	Valid signs with cv(5.66)
			$u = 6.02$ m s^{-1}	A1	Accept any answer rounding to 6.0 (inc 6.0, not 6) or 6.1 from g=10
				[6]	

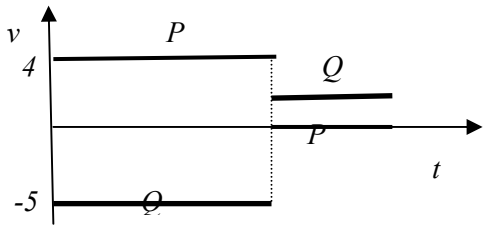
Question			Answer	Marks	Guidance
5	(i)			M1	N2L on P , two vertical forces, accept with 0.4x2.45g
			$T - 0.4g = 0.4 \times 2.45$	A1	Correct terms and signs
			$T = 4.9$ N	A1	Exact, g=9.81 (4.904, accept 4.9) g=10 (4.98, not 5.0)
				[3]	
5	(ii)		$mg - T = \pm 2.45m$	M1	Correct terms (possible incorrect signs), and use of cv(T(i))
			$m = 2/3$ kg	A1 FT	FT cv(T(i))/7.35, g=9.81 (FT cv(T(i))/7.351 = 0.667)g=10 (FT cv(T(i))/7.55 = 0.6596 = 0.66) This may be seen in (i). The M1A1 pair of marks may be awarded only in part (ii) when the candidate uses the value of m which was found in (i).
			$v = 2.45 \times 0.3$ (= 0.735)	B1	Must be positive
			Momentum = (2/3) × (2.45 × 0.3)	M1	Accept ±. cv(m) x cv(v)
			Momentum loss = 0.49 kgms^{-1}	A1	Exact,. but accept any value which rounds to ±0.490. g=9.81 (0.49) g=10 (0.4848=0.485, not 0.48)
				[5]	
5	(iii)		$S = 2.45 \times 0.3^2/2$	M1	Distance while Q descends. Watch for $s = vt\text{-}at^2/2$. If v=0, M0A0
			$S = \pm 0.11(025)$	A1	
			OR		
			$S = (0 + 0.735) \times 0.3 / 2$		M1 Using landing speed from (ii)
			$S = \pm 0.11(025)$		A1
			$0 = (2.45 \times 0.3)^2 \pm 2 \times 9.8s$	M1	Distance P ascends while Q at rest, must use g
			$s = \pm 0.027(56..)$	A1	May be implied, g=9.81 (0.02753) g=10 (0.0270)
			OR (using $t_A = 0.735/9.8 = 0.075$)		Calculating ascend time after string goes slack
			$s = 0.735 \times 0.075 - 9.8 \times 0.075^2 / 2$		M1 Using candidate's values of speed and t_A to find ±s
			$s = \pm 0.027(56..)$		A1 May be implied
			Distance = 0.248 m	A1 FT	2 × |cv(S)| + |cv(s)|. Accept 0.25. g=9.81 (0.248) g=10 (0.247511..)
				[5]	

Question			Answer	Marks	Guidance
6	(i)		$mg = 6.4\cos 40$ $m = 0.5(00)$	M1 A1 **[2]**	One cmpt of 6.4 N force (allow 6.4 x sin/cos 40 or 50), mg not resolved Accept 0.5, g=9.81 (0.49976..=0.5) g=10 (0.49026.. = 0.49)
6	(ii)		$H = 6.4 + 6.4\sin 40$ OR $2 \times 6.4 \cos 25 = 0.5g \cos 65 + H \cos 25$ $H = 10.5$	 M1 A1 **[2]**	Resolves horizontally, all necessary terms (allow e.g. $6.4 \pm 6.4\cos 40$) Resolves parallel to bisector of strings, inc cmpt weight Accept 11
6	(iii)		$R = 32\cos 30 - 6.4\sin 30$ $R = 24.5$ $Fr = 32\sin 30 + 6.4\cos 30$ $Fr = 21.5$ $\mu = (32\sin 30 + 6.4\cos 30)/(32\cos 30 - 6.4\sin 30)$ $\mu = 0.879$ AG	M1 A1 M1 A1 M1 A1 **[6]**	Difference of Wt cmpt and Tension (<u>not</u> H) cmpt May be implied Sum of Wt cmpt and Tension (<u>not</u> H) cmpt May be implied **Either** Fr **or** R obtained from 2 term numerical expressions, in $\|Fr\| = \mu\|R\|$
6	(iv)		$F_{max} = 0.879 \times 32\cos 30$ (= 24.4 N) Wt cmpt down slope = $32\sin 30$ (= 16 N) Remains in eqbm OR $\pm ma = 32\sin 30 - 0.879 \times 32\cos 30$ Finds acceleration Remains in eqbm OR angle of friction = $\tan^{-1} 0.879 = 41°$ Slope is 30° Remains in eqbm	B1* D*M1 A1 **[3]** B1* D*M1 A1 B1* D*M1 A1	May be described simply as F or friction Finding Wt component down slope and comparing with friction Needs Wt cmpt = $16 < F_{max}$ For friction calculation Sets up and solves N2L for a Needs a clearly in direction of friction (impossible) Must be explicit Values of angle of friction and slope stated in 6(iv)

Question			Answer	Marks	Guidance
7	(i)		Before mom = $0.2 \times 4 + 0.3 \times 2.5$ $0.2 \times 4 + 0.3 \times 2.5 = (0.2 + 0.3)v$ $v = 3.1$ ms^{-1}	B1 M1 A1 **[3]**	Accept with g Accept with g Exact. Award if g used and cancelled.
7	(ii)	(a)	$V_0 = 3.1$	B1 FT **[1]**	FT cv(v(i))
7	(ii)	(b)	$s = \int 3.1 - 3t^2 \mathrm{d}t$ $s = 3.1t - 3t^3/3$ (+c) CR = $[3.1t - t^3]_0^{0.3}$ CR = 0.903 m	M1* A1 FT D*M1 A1 **[4]**	Uses integration of velocity(t) FT cv(v(i)) or cv(V_0(iia)) Uses their s(0.3). Award if +c never shown or assumed = 0 Ans <u>not</u> given, so explicit substitution not needed. Allow 0.90, not 0.9
7	(ii)	(c)	$a = d(V_0 - 3t^2)/dt$ $a = -6 \times 0.3$ $a = -1.8$ ms^{-2}	M1* D*M1 A1 **[3]**	Uses differentiation of v Substitutes t = 0.3 (no other value acceptable) Exact. Must be negative (accept deceleration is -1.8). Award if V_0 wrong but not if V_0 omitted.
	(iii)		Mom $C = (0.2 + 0.3)(3.1 - 3 \times 0.3^2)$ Conservation of momentum used, no g $(0.2 + 0.3)(3.1 - 3 \times 0.3^2) = 1.5v - 0.5v$ $v = 1.415$ ms^{-1}	B1 M1 A1FT A1 **[4]**	1.415 Before momentum must be numerical, after momentum needs two terms in v (accept 2v or v) FT cv(before momentum) Exact. Accept 1.41 or 1.42.

Question			Answer	Marks	Guidance
1			$X = 14 - 5$	B1	Or 5 – 14
			$R^2 = (14 - 5)^2 + 12^2$	M1	Pythagoras, R as hypotenuse, 3 squared terms
			$R = 15$ N	A1	
			$\tan\theta = (14 - 5)/12$	M1	Any correct trig, angle between 12 and R targetted.
			$\theta = 36.9°$	A1	Accept 37, 037
				[5]	
2	(i)		$v = \mathrm{d}(t^4 - 2t^3 + 5)/\mathrm{d}t$	M1*	Differentiates displacement, one wrong term max, ignore +c
			$v = 4 \times 1.5^3 - 6 \times 1.5^2$	D*M1	Substitutes $t = 1.5$ in $v(t)$ OR solves $4t^3-6t^2=0$ for a +ve root
			$v = 0$ AG	A1	0+c is A0 unless c is discarded
				[3]	
2	(ii)		$a = \mathrm{d}(4t^3 - 6t^2)/\mathrm{d}t$	M1*	Differentiates velocity, one wrong term max, ignore +c
			$a(1.5) = 12 \times 1.5^2 - 12 \times 1.5$	D*M1	Substitutes $t = 1.5$ in $a(t)$ OR solves $12t^2 - 12t=9$ for a +ve root
			$a = 9$ m s^{-2} AG	A1	9+c is A0 unless c is discarded
				[3]	
3	(i)		TCorS20 = 0.25gCorS30	M1	Equates cmpt T and cmpt wt // plane (doubt, see diagram and/or (ii))
			Tcos20 = 0.25$g$sin30	A1	1.225
			$T = 1.3(0)$	A1	
				[3]	
3	(ii)		R +/– TCorS20 =+/- 0.25gCorS30	M1	Resolves perp plane, accept letter T
			$R + 1.3\sin 20 = 0.25g\cos 30$	A1 ft	ft(cv(T))
			$R = 1.68$ N	A1	
				[3]	
3	(iii)		(m)accn = +/– (m)9.8sin30	M1*	N2L with single force a cmpt wt (accept cos)
			$a = +/-4.9$	A1	
			$u = +/-9.8\sin 30 \times 0.4$	D*M1	
			$u = 1.96$	A1	Must be +ve (accept loss of – sign)
				[4]	

Question			Answer	Marks	Guidance
4	(i)		$(t-3)(t-6)=0$	M1	Solve 3 term QE, 2 correct coefficients if factorising, or using formula $9+/-\sqrt{9}/2$
			$t = 3, 6$	A1	"By inspection" both values M1A1, one value M0A0
				[2]	
4	(ii)		$v = \int (t^2 - 9t + 18)\mathrm{d}t$	M1*	Attempts integration of $a(t)\mathrm{d}t$, maximum one wrong term
			$v = t^3/3 - 9t^2/2 + 18t$ (+ c)	A1	Accept omission of + c
			$3^3/3 - 9 \times 3^2/2 + 18 \times 3 + c = 9$	D*M1	Uses $v(3) = 9$
			$(v =) -13.5$ m s^{-1}	A1	Must be negative, and goes beyond c=-13.5
				[4]	
4	(iii)		$v(1) = 1/3 - 9/2 + 18 - 13.5 = 0.333$	M1	Finds $v(1)$ (=1/3)
			Changed sign so direction of motion has changed	A1	Accurate values (v(0)= -13.5, v(0.5)=-5.58, v(0.9)=-0.702)
				[2]	
5	(i)		$1.4^2 = 2 \times a \times 0.2$	M1	Any use of $a = g$ is M0
			OR		
			$0.2=(0+1.4)t/2$ and $1.4=0+at$		t=2/7 hence $1.4=a \times 2/7$
			$a = 4.9$ m s^{-2}	A1	
			$0.3g - T = +/- 0.3 \times 4.9$	M1	N2L diff of weight and tension. Any use of $a = g$ is M0
			$T = 1.47$ N	A1	
				[4]	
5	(ii)		$+/-4.9m = 1.47 - mg$	M1	N2L for Q using values from (i), a not g; accept $a = g\Delta M/\Sigma M$
			$4.9m = 1.47 - mg$	A1ft	Diff cv(T) and mg correct way round; ft cv(T,a)
					$4.9 = g(0.3 - m)/(0.3 + m)$ M1A1; ftcv(a)
			$m = 0.1$	A1	
				[3]	
5	(iii)		$1.4^2 = 2gs$	M1	Accn = g
			$s = 0.1$	A1	may be implied (eg $H = 0.3$) BoD sign uncertainty
			$H = 0.2 + 0.2 + 0.1$	M1	Needs 0.2 twice
			$H = 0.5$ m	A1	
				[4]	

Question			Answer	Marks	Guidance
5	(iv)	(a)	Tension = $0.5g + 2 \times 1.47$ Tension = 7.84 N	M1 A1 **[2]**	
5	(iv)	(b)	Tension (= $0.5g$) = 4.9 N	B1 **[1]**	
6	(i)		 $0.3x4 - 0.2x5 = +/- (0.3+0.2)v$ $v = 0.4$ m s^{-1}	M1 A1 A1 **[3]**	Cons of momentum, no g*, common v "after" term $0.3x4 + 0.2x5 = +/- (0.3+0.2)v$ is M1A0A0 Must be positive *Allow g if fully cancelled in first line BOD
6	(ii)	(a)	Q (or P at rest) $0.3x4 – 0.2x5 = 0.2v$ $v = 1$ m s^{-1}	B1 M1 A1 A1 **[4]**	If P moves, allow 0.3vwhen considering M1 Cons of momentum, no g*, one "after" term $0.3x4 + 0.2x5 = 0.2v$ is M1A0A0 *Allow g if fully cancelled in first line BOD
6	(ii)	(b)	$4t + 5t = 3.6$ $t = 0.4$ $x_Q = 5x0.4$ (=2) T = (2/1 =) 2 s *OR* (Time =) $x/5 = (3.6 - x)/4$ $x = 2$ m $T = 2/1 = 2$ s	M1 A1 A1 A1 **[4]** M1 A1 A1 A1	Or $9t = 3.6$, Or both $3.6-x = 4t$ and $x= 5t$ Finds initial Q distance. 3.6 x 5 /(4+5) is M1A1A1 Equates pre-collision times x is distance Q travels before collision
6	(ii)	(c)		B1 B1 B1 B1 **[4]**	One horizontal, +ve v intercept One horizontal, –ve v intercept, terminates at same t One along t-axis, starts at same t as +ve line ends, label P One horizontal above t-axis, starts at same t as –ve line ends. (Ignore any values put on graphs)

Question			Answer	Marks	Guidance
7	(i)		Fr = $0.2 \times 0.4g\cos 45$	M1	Fr = 0.554(37..)
			$0.4a = 0.4g\sin 45 - 0.554(37..)$ (= 2.21748..)	M1	N2L, their Fr value and cmpt wt, opposite signs
			$a = 5.54(37..)$	A1	May be implied
			$v^2 = 5^2 + 2 \times 5.54 \times 2$	M1	$v^2 = u^2 + 2as$, a is not $0.2g$. $0<a<g$. Consistent signs
			$v = 6.87$ m s^{-1}	A1	
			$6.87 = 5 + 5.54t$	M1	$2 = 5t + 5.54t^2/2$, a is not $0.2g$. $0<a<g$
			$t = 0.337$ s	A1	
				[7]	
7	(ii)	(a)	+/-$0.4a = -0.4g\sin 45 - 0.55437$ (= 3.3262..)	M1	N2L, Fr and cmpt wt same sign (accept +ve)
			a = +/–8.31(557..)	A1	Accept +ve value
			$0^2 = 5^2 - 2 \times 8.32 \times s$		$5^2 = 2 \times 8.32 \times s$, a is not g or $0.2g$. Consistent signs.
			$s = 1.5(0)$ (so does not reach B)	A1	cso
			OR	**[3]**	
			$v^2 = 5^2 - 2 \times 8.32 \times 2$		
			v^2 = –ve (–8.28) so does not reach B	A1	Some comment on impossibility
7	(ii)	(b)	$v^2 = 2 \times 5.54(37) \times 1.5$	M1*	No A1 to be given for $s = 1.5$ (if last A1 not given in iia), a is not g or $0.2g$ or their a in 7iia allow $a > g$
			v = +/- 4.08	A1	
			Momentum change = +/–0.4(4.08 + 5)	D*M1	Must be a sum of 5 and a speed meaningfully less than 5
			Change = +/–3.63 kg m s^{-1}	A1	
				[4]	

Question			Answer	Marks	Guidance
1	(i)			M1	Momentum for Q/R, no g, at least 3 correct terms
			$0.3u + 0.6 \times 0.8 = (0.3 + 0.6) \times 1$	A1	NB 0.48 in "before" from 0.8×0.6; not $1.5 \times 0.1 + 1.1 \times 0.3$ (A0)
			$u = 1.4$ m s^{-1}	A1	
				[3]	
1	(ii)		$0.1 \times 1.5 + 0.3 \times 1.1 = \pm 0.1v + 0.3 \times 1.4$	M1	P,Q +ve "before", allow P –ve "after". Accept cv (1.4)
			$v = 0.6$	A1	Velocity of P, will be –ve if $-0.1v$ in momentum equation, accept $v = \pm 0.6$
			Momentum change $= \pm 0.09$ kg m s^{-1}	A1	Tolerate loss of – sign if "small – large" has +ve answer
			OR	**[3]**	
			Momentum change $Q = \pm 0.3(1.4 - 1.1) = \pm 0.09$	M1A1	Change for P is the change for Q
			Momentum change $P = \pm 0.09$	A1	
			OR		
			$0.1 \times 1.5 + 0.3 \times 1.1 + 0.6 \times 0.8 = (\pm)0.1v + 0.9(\times 1)$	M1A1	Overall equation
			Momentum change $P = \pm 0.09$	A1	From $\pm$ $(0.9 \times 1 - 0.3 \times 1.1 - 0.6 \times 0.8)$
2	(i)		$U = 0.5g$ *OR* $U - 0.5g = 0$	M1	Consider descent *OR* ascent. $v = u + at$ with consistent signs for non-zero terms. $U + 0.5g = 0$ is M0 hence A0.
			$U = 4.9$ m s^{-1}	A1	Allow use of 4.9 without penalty in (ii) and (iii) even if 0/2 here.
				[2]	
2	(ii)		$U^2 = \pm 2gs$	M1	$v^2 = u^2 + 2as$
			$4.9^2 = \pm 2 \times 9.8 \times s$	A1	
			$s = 1.225$ m	A1	+ve, 49/40, 1.22 or 1.23 BoD loss of – sign in final answer
				[3]	
			OR		
			$s = \pm(ut \pm gt^2/2)$ *OR* $s = \pm gt^2/2$	M1	Rise to/fall from greatest height. $S = \pm(vt \pm g\frac{t^2}{2})$ is similar.
			$s = \pm(4.9 \times 0.5 - g \times 0.5^2/2)$ *OR* $s = \pm g \times 0.5^2/2$	A1	
			$s = 1.225$ m	A1	+ve, 1.22 or 1.23 BoD loss of – sign in final answer
			OR		
			$s = \pm Ut/2$	M1	$s = (u + v)t/2$
			$s = \pm 4.9 \times 0.5/2$	A1	
			$s = 1.225$ m	A1	+ve, 1.22 or 1.23 BoD loss of – sign in final answer

Question			Answer	Marks	Guidance
2	(iii)		$v^2 = 2g(s \pm 0.539)$	M1	Overall descent, zero initial speed
			$v^2 = 2 \times 9.8 \times (0.539 + 1.225)$	A1ft	ft cv (1.225), tolerate sign change from (ii)
			$v = 5.88$ ms^{-1}	A1	Exact, isw rounding of 5.88 to 5.9 if 5.88 seen
			OR	**[3]**	
			$v^2 = u^2 \pm 2g \times 0.539$	M1	Motion from projection level down, non-zero initial speed
			$v^2 = 4.9^2 + 2g \times 0.539$	A1ft	ft cv (4.9), tolerate sign change from (i)
			$v = 5.88$ ms^{-1}	A1	Exact, isw rounding of 5.88 to 5.9 if 5.88 seen
3	(i)	(a)	$\tan\theta = 8/12$	M1	Must be correct angle.
			$\theta = 33.7°$	A1	
				[2]	
			OR correct trig using ans **(i)(b)**		
			$\sin\theta = 8/\text{cv}(14.4)$ or $\cos\theta = 12/\text{cv}(14.4)$	M1	Must be correct angle
			$\theta = 33.7°$	A1	A1 needs 2/2 in (i)(b). $\cos\theta = 12/14.4$ gives $\theta = 33.6$ A1
3	(i)	(b)	$R^2 = 8^2 + 12^2$	M1	Pythagoras, 3 squared terms, R as hypotenuse
			$R = 14.4$ N	A1	Accept $4\sqrt{13}$ not $\sqrt{208}$
				[2]	
3	(ii)	(a)	$12\text{CorS}\theta = \pm 8$	M1	Either angle.
			$12\sin\theta = 8$	A1	If other angle is targeted, this A1 requires "90 –". *OR* $12\cos\theta = 8.94$, $8.94\tan\theta = 8$.
			$\theta = 41.8°$	A1	cao
				[3]	
			OR correct trig using **(ii)(b)**		
			$12\text{CorS}\,\theta = \text{cv}(8.94)$, $\text{cv}(8.94)\tan\theta = 8$, or $8\tan\theta = \text{cv}(8.94)$	M1	Either angle
			$12\cos\theta = 8.94$ or $8.94\tan\theta = 8$	A1	If other angle is targeted, this A1 requires "90 –"
			$\theta = 41.8°$	A1	Both A1 marks require 2/2 in (ii)(b)
3	(ii)	(b)	$R = 12\cos 41.8$	M1	Using candidate's angle from 3iia. *OR* $R^2 = 12^2 - 8^2$, $R^2 + 8^2 = 12^2$
			$R = 8.94$ N	A1	Accept 8.9 or 8.95, $4\sqrt{5}$, not 9 or 9.0 not $\sqrt{80}$. For A1, the trig solution requires 3/3 in (ii)(a)
				[2]	

Question			Answer	Marks	Guidance
4	(i)		$v = 18 + 2.4 \times 5$ $v = 30$	M1 A1 **[2]**	$v = u + at$
4	(ii)		Distance while accelerating = $(18 + 30) \times 5/2$ Distance at constant speed = $30(t - 5)$ $30(t - 5) + (18 + 30) \times 5/2 = 300$ $t = 11$ *OR* Distance while accelerating = $(18 + 30) \times 5/2$ (=120) Distance at constant speed = $300 - cv(120)$ Time at constant speed = $\frac{(300 - cv(120))}{30}$ Time at constant speed = 6 $t = 11$ *OR* Distance = $30t$ Distance = $(30 - 18) \times 5/2$ $30t - (30 - 18) \times 5/2 = 300$ $t = 11$ *OR* Distance while accelerating = $(18 + 30) \times 5/2$ Distance at constant speed = $30(t - 5)$ Distance at constant speed = $300 - 120 = 30(t - 5)$ $t = 11$	B1 B1 M1 A1 A1 **[5]** B1 M1 B1 A1 A1 B1 B1 M1A1 A1 B1 B1 M1A1 A1	Or $30 \times 5 - (30 - 18) \times 5/2$ etc = 120, or 45 + 75. Numerical. Tolerate $30t$. Algebraic. Adds their areas to get 300 $30T = 300 - 120$, $30t + 45 + 75 = 300$, etc Or $30 \times 5 - (30 - 18) \times 5/2$ etc = 120, or 45 + 75. Numerical. Subtracts their area from 300 Equivalent to "distance at constant speed algebraic" Rectangle, comprising 300 + area of "missing triangle" "Missing triangle", to be removed Subtracts their areas to get 300 120 May be implied. Tolerate $30t$. Algebraic. *OR* $180 = 30t$ M1, $t = 6$ A1

Question			Answer	Marks	Guidance
4	(iii)		$S = 30^2/(2 \times (\pm 6))$	M1	$0^2 = 30^2 \pm 2 \times 6S$, with candidate's v(i)
			$S = 75$	A1	
			Distance = 375 m	A1ft	300 + cv(75)
				[3]	
			OR	M1	Accept $T = 5$ if no working or from 30/–6, with candidate's v(i)
			$T = 30/6$ and $S = 30T/2$		
			$S = 75$	A1	
			Distance = 375m	A1ft	300 + cv(75)
5	(i)		$d = 3u + 4 \times 3^2/2$ $(= 3u + 18)$	B1	
			$2d = 5u + 4 \times 5^2/2$ $(= 5u + 50)$	B1	*OR* $d = (5 - 3)(u + 3 \times 4) + 4 \times 2^2/2$ for lower half of slope $(d = 2u + 32)$
			$6u + 36 = 5u + 50$	M1	Attempts to solve 2 SE in u and d, at least one with 3 terms. Tolerate u, d switch to x, y for solving reasons
			$u = 14$ ms^{-1}	A1	
			$2d = 5 \times 14 + 4 \times 5^2/2$	M1	Substitutes in 3 term eqn, starts *suvat* again, or solves SEs again.
			OR $d = 3 \times 14 + 18$ *OR* $d = 2 \times 14 + 32$		If u is negative, allow substitution of +ve equivalent.
			Length = 120 m	A1	
				[6]	
5	(ii)		$4(m) = (m)g\sin\theta$	M1	Mass may be omitted on both sides. Allow $4(m) = (m)g\cos\theta$
			$\theta = 24.1°$	A1	
				[2]	
5	(iii)		$6 = mg\cos 24.1$	M1	Or $6 = mg\sin 24.1$, uses numerical answer referring to (ii)
			$m = 0.671$ kg	A1	www
				[2]	
6	(i)		$V = d(0.06t^3 - 0.45t^2 - 0.24t)/dt$	M1	Differentiates displacement
			$V = 0.18t^2 - 0.9t - 0.24$	A1	Accept with $+c$, unsimplified coefficients
			$A = d(0.18t^2 - 0.9t - 0.24)/dt$	M1	Differentiates velocity
			$A = 0.36t - 0.9$	A1	Accept with $+c$, unsimplified coefficients
			$V(0) = -0.24$ m s^{-1}	A1	cao, if coeffs in $V(t)$ wrong A0
			$A(0) = -0.9$ m s^{-2}	A1 ft	ft cv(–0.9), the constant in expression for A. Tolerate wrong coeff t
				[6]	

Question			Answer	Marks	Guidance
6	(ii)		Solves $A = 0$ for t $0.36t - 0.9 = 0$ $t = 2.5$ $x(2.5) = -2.475$ Speed = $\lvert v(2.5) \rvert = 1.365$ m s^{-1}	M1 A1 A1 A1 A1 **[5]**	Not if A(t) includes $+c$ in this section Final answer must be negative. Accept –2.47 and –2.48. Final answer must be positive. Accept 1.36 or 1.37.
6	(iii)		Uses $v = 0$ $0.18t^2 - 0.9t - 0.24 = 0$ $t = 5.25$ s	M1 A1ft A1 **[3]**	 Forms and offers solution of 3 term QE using cv(V(i)) Must select +ve answer explicitly. Accept 5.3, not 5.2
7	(i)		$0.5g - T = \pm 0.5 \times 1.4$ $0.5g - T = 0.5 \times 1.4$ $T = 4.2$ N	M1 A1 A1 **[3]**	N2L for Q, difference of 2 force terms
7	(ii)		$4.2 - F - 0.6g\sin 30 = 0.6 \times 1.4$ *OR* $4.2 - \mu R - 0.6g\sin 30 = 0.6 \times 1.4$ Friction (= $4.2 - 0.6g\sin 30 - 0.6 \times 1.4$) = 0.42 Reaction = 0.6gcos30 $0.42 = 0.6g\cos 30\mu$ *OR* $\mu = 0.42/ 0.6g\cos 30$ $\mu = 0.0825$	M1 A1 B1 M1 A1 **[5]**	N2L for P, 3 forces including a component of weight of P and cv(4.2) May be implied May be implied $F = \mu R$, R a component of weight of P and F has been found using a component of the weight of P. Tolerate F –ve and |–veF|. Accept 0.082, not 0.083.
7	(iii)		$R = (0.6g + 7)\cos 30$ $R = 11.2$ Fr = $7\sin 30 - 0.42$ Fr = 3.08 $\mu = 3.08/11.2$ $\mu = 0.276$ $\mu \geq 0.276$	M1 A1 M1* A1 D*M1 A1 B1 ft **[7]**	Includes weight cmpts of P and B, allow $7g$ 11.154… May be implied Wt cmpt B (allow $7g$) – Fr(ii) must be difference. May be implied. Both quantities +ve, F and R both from 2 term equations Value of μ, accept 0.28, disregard inequality sign ft cv (μ found in (iii)) direction of greater than or equal to sign; isw any work relating to an upper limit for μ

Question			Answer	Marks	Guidance	
1	(i)		$v^2 = 3.5^2 + 2g \times 5$ $v = 10.5$ ms^{-1}	M1 A1 [2]	Uses $v^2 = 3.5^2$ +/– $2g5$	Accept -3.5^2 for $(-3.5)^2$ etc
	(ii)		$5 = 0.87u - g \times 0.87^2/2$ $u = 10.0$ m s^{-1}	M1 A1 A1 [3]	+/-5 = $0.87u$ +/– g 0.87^2 /2	May come from $s = vt - gt^2/2$
	(iii)		Change = $0.2 \times 10.5 + 0.2 \times 10$ Change = 4.1(0) kg m s^{-1}	M1 A1 [2]	Or +/- 0.2(Ans(i) +/– Ans(ii)) It is OK get -4.1 from correct work	
2	(i)		$2.5\sin\theta = 2.4$ $\theta = 73.7$ $2.5\cos\theta = F$ $F = 0.7$ *OR* $2.4^2 + F^2 = 2.5^2$ *or* $F^2 = 2.5^2 - 2.4^2$ $F = 0.7$	M1 A1 M1 A1 [4] M1 A1	2.5CorSθ = 2.4 Accept 74 F = 2.5 SorCθ, opposite to that above Exact, but allow 0.702 (3 sf) $\theta = 73.7$	$2.5\cos\theta = 2.4$ M1 hence $\theta = 16.3$ A0 $2.5\sin\theta = F$ M1 hence F =0.7(00) A1 SC F can then be used to find θ
	(ii)		$2.4 = 0.2a$ $a = 12$ ms^{-2} Bearing (0)90° *OR* "To right"," opposite old 2.4 N force" etc	M1 A1 B1 [3]	N2L, Any horizontal force other than F, 0.7, 2.5 (Do not treat removing/using 2.5 as a MR) 12.0 from 2.5sin73.7 /0.2 Angle value other than exactly 90° or 0° B0 Allow B1 for force dirn, if accn not found	Including g, automatically M0 Horizontal is B0 (ambiguous)

Question			Answer	Marks	Guidance	
3	(i)		$3\ \text{ms}^{-1}$	B1 [1]		MR $(0.6t^3 + 3)$, award B1 here
	(ii)		$x = \int\left(0.6t^2 + 3\right)\mathrm{d}t$ $x = 0.6t^3/3 + 3t\ (+ c)$ Substitutes 1.5 in expression for x $x(1.5) = 5.175$ m	M1* A1 D*M1 A1 [4]	Integrates v Accept with/without + c Needs integration and 2 terms in t Only without +c. Accept 5.17, 5.18	MR $(0.6t^3 + 3)$ $0.6t^4/4 + 3t$ is A0 MR 5.26 only gets A1ft
	(iii)		$a = \mathrm{d}(0.6t^2 + 3)/\mathrm{d}t$ $6 = 2 \times 0.6t$ $v(5) = 18\ \text{ms}^{-1}$	M1* D*M1 A1 [3]	Differentiates v Plus attempt to solve $a(t) = 6$	MR $(0.6t^3 + 3)$ gives t=1.82(57..) v(1.8257..) = 6.65 (3 sf)
4	(i)		Calculation for both "before" Momentum (magnitudes) Compares both terms without arithmetic error Shows direction of after total momentum conflicts with the before velocity/momentum of Q	M1 A1* D*A1 [3]	Must not include g Vector nature of momentum by word or sign (+/-)	Explicit reference to after momentum or conservation of momentum essential.
	(ii)		TMB = +/-(0.2 × 4 + 0.3 × (–2)) $0.8 – 0.6 = 0.2v + 0.3v$ $v = 0.4\ \text{m s}^{-1}$ $0.8 – 0.6 = -0.2v + 0.3v$ $v = 2\ \text{m s}^{-1}$	B1 M1 A1 M1 A1 [5]	Accept inclusion of g Allow if g included in all terms Not awarded if g included Allow if g included in all terms Not awarded if g included	LHS must be difference for both M1 marks SC $0.8 – 0.6 = 0.2v - 0.3v$ M1 Speed = 2 **and** the direction of motion of Q is reversed A1

Question			Answer	Marks	Guidance	
5	(i)		$5/(T-3) = -4$ *OR* $5/(3-T) = 4$ $T = 1.75$	M1 A1 [2]	Accept verification, $4 \times (3 - 1.75)$ M1 $= 5$ A1 *OR* 5/(3-1.75) M1 = 4 A1	
	(ii)	(a)	-4 ms^{-1}	B1 [1]		
		(b)	4 ms^{-1}	B1 [1]		
		(c)	4 ms^{-1}	B1 [1]		
	(iii)		$2 \times (-)4$, 2×4, $(1 \times)4$ $d = (-)5 + (-)8 + 8 + 4$ $d = 25$ m	M1* D*M1 A1 [3]	Calculates any one unknown distance Adds 5 and "3 other" distances or -5 and "3 other" displacements Correctly comes from 4x(1.25+4+1) 3/3	Allow if only one calc. correct Note t=5 to t=9, t=5 to t=10 etc, may be one term
	(iv)		$v = \mathrm{d}(20t - t^2 - 96)/\mathrm{d}t$ $v = 20 - 2t$ $20 - 2t = -4$ $t = 12$ (ignore any solutions less than 10)	M1* A1 D*M1 A1 [4]	Differentiates x, accept $20 - t$ as "differentiation" $20 - 2t + c = -4$ is DM0 Only from $20-2t = -4$. This answer can arise fortuitously from solving $20t - t^2 - 96 = 0$.	 SC Verifying that t=12 gives v= -4 can gain final M1A1 (A special case of trial and refinement)

Question			Answer	Marks	Guidance	
6	(i)		$3 = 8\mu$ $\mu = 0.375$	M1 A1 [2]	Uses $F = \mu R$, Allow R is 8 or 8g, Fr =3 only 3/8 (fraction), not 3÷8 (division)	
	(ii)		$C^2 = 3^2 + 8^2$ C = 8.54 N tanθ =3/8 or tanθ =8/3 θ = 20.6° with vertical or 69.4° with horizontal	M1 A1 M1 A1 [4]	Uses Pythagoras with 3 and 8 or 8g Accept 8.5 or √73 Uses tan with 3 and 8 or 8g Accept 21 or 69, direction clear by words or diagram.	 Or CorS with answer for C isw work after correct angle magnitude found
	(iii)	(a)	T(cos0) – 3 = +/-3 T = 6	M1 A1 [2]	T(cos0) – 3 = 0 is M0 Answer alone is sufficient for M1A1	Tcos0 –3= -3 assumes Fr direction has not changed
	(iii)	(b)	R = +/-(8 – T × SorC30) R = 8 – Tsin30 Fr = +/– (T × CorS30 – 3) Fr = Tcos30 – 3 0.375 = (Tcos30 – 3) / (8 – Tsin30) T = 5.70 *OR* Alternative for last 4 marks Fr = 0.375(8 – Tsin30) Fr = +/– (T × CorS30 - 3) Fr = Tcos30 – 3 0.375(8 – Tsin30) = Tcos30 – 3 T = 5.70	M1 A1 M1 A1 M1 A1 [6] - M1 A1 M1 A1	Accept 8g with cmpt T oe Accept 3 with cmpt T, not T×CorS30+/–3= 0 oe Accept use of μ from (i). For forming an equation in T alone. Accept use of μ from (i). oe For forming an equation in T alone.	(This is required also in the SC case) SC Does not allow for change in direction of Friction Fr = 3 –Tcos30 A1 0.375 = (3-Tcos30) / (8 – Tsin30) M1 T = 0 A0 SC (Alternative) Fr = 0.375(8 – Tsin30) Fr = +/– (T × CorS30 - 3) M1 Fr = 3-Tcos30 A1 0.375(8–Tsin30) = (3-Tcos30) M1 T = 0 A0

Question			Answer	Marks	Guidance	
7	(i)		$s = 0.6 \times 2 + 0.9 \times 2^2/2$ $s = 3$ $AB = 6$ m	M1 A1 A1 [3]	Uses $s = ut + at^2/2$, $u \neq 0$, $a \neq g$ or gCorS30	
	(ii)		$V_M = 0.6 + 0.9 \times 2$ *OR* $V_M{}^2 = 0.6^2 + 2\text{x}0.9\times3$ $a = g\sin30$ $V_B{}^2 = 2.4^2 + 2(9.8\sin30) \times 3$ $V_B = 5.93$ ms^{-1}	 B1 B1 M1 A1 [4]	2.4 5.76 4.9 Uses $v^2 = u^2 + 2as$, $u \neq 0$ or 0.6, $a \neq g$ or 0.9, $s \neq AB$(i) Accept 5.9	Award if found in (i) and used in (ii) If AB(i) = 3, allow its use for final M1A1
	(iii)		$0.3 \times 0.9 = 0.3g\sin30 - T$ $T = 1.2$ N	M1 A1 A1 [3]	N2L, $0.3 \times 0.9 = +/-(0.3g\text{CorS}30 - T)$	$a = 0.9$ essential, $m = 0.3$ but if 0.4 used in (iii) AND 0.3 used in (iv), treat as a single mis-read
	(iv)		$0.4 \times 0.9 = 0.4g\sin30 + 1.2 - Fr$ $Fr = 2.8$ $R = 0.4g\cos30$ $\mu = 2.8/3.39$ $\mu = 0.825$	M1* A1ft A1 B1 D*M1 A1 [6]	N2L, 3 forces inc +/-(0. 4gCorS30 + T) ft cv(T) in (iii) May be shown by mu calculation May be implied, 3.39(48...) 2.8 = 3.39(48) μ, both forces positive Accept 0.82, not 0.83 or 0.826	a = 0.9 or value used in (iii), m=0.4 but if 0.4 used in (iii) AND 0.3 used in (iv), treat as a single mis-read Awarded only if M1 forN2L equation