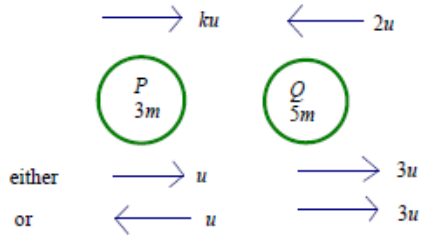
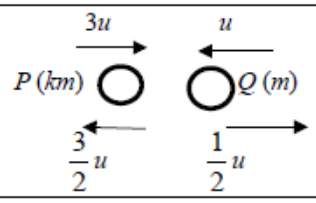
Mark Scheme

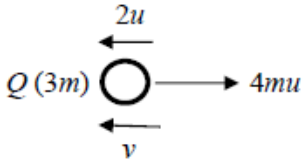
Q1.

Q	Solution	Mark	Notes
			
(a)	$\pm 5m\left(3u-\left(-2u\right)\right)$	M1	Use of $I=m\left(v-u\right)$ seen or implied, with correct terms. Condone sign errors. M0 if g included
	$25mu$	A1	Must be positive
		(2)	
(b)	Use of CLM	M1	Or equal and opposite impulses. Requires all terms dimensionally correct. Condone sign errors.
	$3mku-10mu=3mu+15mu$ or $3mku-10mu=-3mu+15mu$	A1	Correct unsimplified equation for either case.
	$\Rightarrow k=\frac{28}{3}$ or $k=\frac{22}{3}$	A1	One correct value. Any equivalent form. Accept decimal to 1dp or better.
	Equation for second value	M1	Their equation from M1 above with the final direction of P reversed.
	Second value correct.	A1	Any equivalent form. Accept decimal to 1dp or better.
		(5)	
		[7]	

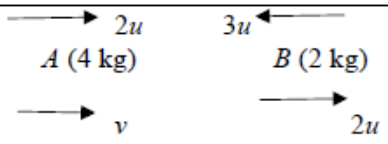
Q2.

Question Number	Scheme	Marks
(a)		
	CLM: $km\times 3u - mu = -km\times\frac{3}{2}u + m\times\frac{1}{2}u$	M1 A1 A1
	$k = \frac{1}{3}$	A1
		(4)
(b)	$I = m\left(\frac{1}{2}u - -u\right)$ **OR** $I = \frac{1}{3}m\left(\frac{3}{2}u - -3u\right)$	M1 A1
	$I = \frac{3}{2}mu$ must be positive	A1
		(3)
		(7)
	Notes for question	
(a)	M1 Correct no. of terms, dim correct, condone sign errors but structure must be correct – allow consistently cancelled m's or extra g's	
	A1 Correct equation with one error	
	A1 Correct equation	
	A1 Allow 0.33 or better	
(b)	M1 Condone sign errors but must have masses and speeds paired correctly and must be attempting a difference of momenta. Allow M1 if k is not substituted. M0 if g included	
	A1 Allow $\pm m\left(\frac{1}{2}u - -u\right)$ **OR** $\pm\frac{1}{3}m\left(\frac{3}{2}u - -3u\right)$ (no ft on k)	
	A1 cao Allow them to change a negative expression into a positve one	
	N.B. If they do (b) first, and obtain an impulse of magnitude I, then they do (a) : $I = km(\frac{3u}{2} - -3u)$, apply CLM scheme to their equation.	

Q3.

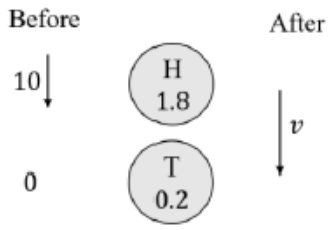
Question Number	Scheme	Marks
		
(a)	$-4mu = 3m(v-2u)$ **or** $4mu = 3m(-v+2u)$ **or** $-4mu = 3m(-v-2u)$ **or** $4mu = 3m(v+2u)$	M1A1
	speed is $\frac{2}{3}u$, $0.67u$ or better	A1
		(3)
(b)	Same as its original direction or direction is unchanged or just 'unchanged' or 'same direction' or 'it is the same'.Allow 'opposite to P's original direction' or 'towards P' Apply isw if they add 'east' or 'to the left' etc ('motion of Q is unchanged'is B0)	DB1
		(1)
		(4)
	Notes for question	
(a)	M1 impulse-momentum equation, dimensionally correct, correct no. of terms, condone sign errors but must be attempting a difference of momenta. Allow if they use m instead of $3m$.	
	A1 Correct equation (v may be replaced by $-v$)	
	A1 cao (must be positive)	
(b)	DB1 Dependent on obtaining either $\frac{2}{3}u$ or $-\frac{2}{3}u$ for v in (a).	

Q4.

Question Number	Scheme	Marks
(a)	 CLM: $(4\times 2u)+(-3u\times 2)=4v+(2\times 2u)$ **OR** Equating impulses: $2(2u--3u)=4(-v--2u)$	M1 A1
	$\frac{1}{2}u\left(\text{m s}^{-1}\right)$	A1
		(3)
(b)	The direction of motion is reversed.	B1
		(1)
(c)	For B: $I=\pm 2(2u--3u)$ **OR** For A: $I=\pm 4\left(\frac{u}{2}--2u\right)$	M1 A1
	$I=10u$ Ns or $10u$ kgms^{-1}	A1
		(3)
		(7)

Notes		
(a)		
M1	Dimensionally correct CLM equation or equating of impulses equation. Allow consistent extra g's. Ignore sign errors. May be $+v$ or $-v$	
A1	Correct unsimplified equation	
A1	Cao. Must be **positive.**	
(b)		
B1	Accept *opposite direction.* Do not accept *changed* or *to the left or backwards*, away from B **N.B.** This mark is **dependent** on **correctly** obtaining $\frac{1}{2}u$ or $-\frac{1}{2}u$ in (a)	
(c)		
M1	Dimensionally correct impulse-momentum equation using A or B. Condone sign errors with appropriate velocities. M0 if g is included	
A1	Correct unsimplified equation	
A1	Cao **with** units. Accept kg m/s	

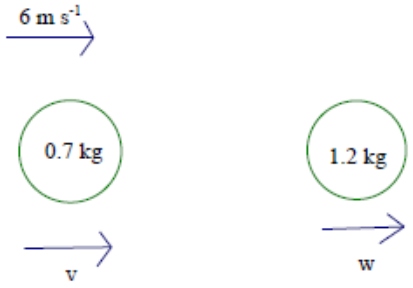
Q5.

QUESTION NUMBER	SCHEME	MARKS
		
(a)	$10\times1.8=(0.2+1.8)v$	M1
	v = 9 (positive)	A1
		(2)
(b)	For tent peg, $I=\pm0.2(v-0)$ or For hammer, $-I=\pm1.8(v-10)$	M1 A1
	1.8Ns **OR** 1.8 kgms^{-1} units needed.	A1
		(3)
(c)	$0=9^2+2a(0.12)$ **OR** $0=9^2-2a(0.12)$	M1A1
	$2g-R=2a$ $R-2g=2a$	M1 A1
	R = 690 or 695	A1
		(5)
	N.B. Using u =10 for 9 can score M0A0M1A1A0 max	
	Using s = 12, can score M1A0M1A1A0 max	**(10)**
ALT 1	$0.12=\frac{(9+0)}{2}t$	M1A1
	$(R-2g)t=2\times9$	M1A1
	R = 690 or 695	A1
ALT 2	$0.12R=\frac{1}{2}\times2\times9^2+2g\times0.12$	M2A2
	R = 690 or 695	A1

	Notes for question	
(a)		
M1	Forms CLM equation, condone sign errors and extra g's and any correct cancellation	
A1	cao	
(b)		
M1	Impulse-momentum equation, dimensionally correct, correct no. of terms. Condone sign errors. **N.B.** M0 if g is included.	
A1	A1 correct unsimplified equation	
A1	A1 cao must include units.	
(c)		
M1	Equation formed to find the acceleration. Must be dimensionally correct and have the correct no. of terms.	
A1	Correct unsimplified equation. Note $a = -337.5$	
M1	Use of $F=ma$. Must be dimensionally correct and have the correct no. of terms.	
A1	Correct equation, a does **not** need to be substituted but should be consistent with their a from first equation. **N.B.** Use the equation for a to **define** the positive direction.	
A1	cao	

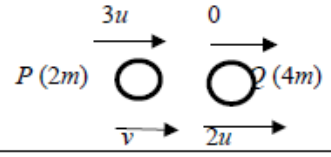
	ALT 1	
M1	Equation(s) formed to find the time	
A1	Correct unsimplified equation. Note $t = \frac{2}{75} = 0.02666..$	
M1	Use of imp-mom equation. Must be dimensionally correct and have the correct no. of terms.	
A1	Correct equation, t does **not** need to be substituted but should be consistent with their t from first equation.	
A1	cao	
	ALT 2	
M2	Use of work-energy equation. Must be dimensionally correct and have the correct no. of terms.	
A2	Correct unsimplified equation, -1 each error.	
A1	cao	

Q6.

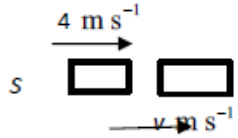
Question	Scheme		Marks
(a)			
	CLM: $0.7\times6=0.7\times v+1.2w$	Requires all terms & dimensionally correct	M1
	$(42=7v+12w)$	Correct unsimplified	A1
	Impact:	Used the right way round Condone sign errors	M1
	$w-v=6e$		A1
	Equation in e and v only: $42-72e=19v$	Dependent on the two previous M marks	DM1
	Use direction to form an inequality:	Independent. Applied correctly for their v	M1
	$42-72e>0 \quad\Rightarrow\quad e<\frac{7}{12}$	***Given answer***	A1
			(7)

(b)	Impulse on Q: $I=w\times1.2$		M1
	Solve for w : $w=v+6e=\frac{42-72\times\frac{1}{4}}{19}+6\times\frac{1}{4}$	Accept unsimplified with e substituted. Have to be using w in part (b) $w=\frac{105}{38}=2.763.....$ seen or implied	B1
	$I=1.2\times\frac{42}{19}\times\frac{5}{4}=\frac{63}{19}(=3.32)$ (N s)	3.3 or better	A1
			(3)
	Alternative		
	Impulse on Q = − impulse on P		
	$=-0.7(v-6)$	Accept negative here	M1
	$=-0.7\left(\frac{42-\frac{1}{4}\times72}{19}-6\right)$ $=\frac{63}{19}$	Substitute for e in their v $v=\frac{24}{19}=1.263....$ seen or implied Accept negative here. Final answer must be positive. 3.3 or better	B1 A1
			(3)
			(10 marks)

Q7.

Question Number	Scheme	Marks
		
(a)	$2m\times 3u = 2mv + 4m\times 2u$ **OR** $I = 4m\times 2u$ and $-I = 2m(v-3u)$ **AND** add to eliminate I	M1A1
	$v = -u$ so speed is u	A1
		(3)
(b)	Opposite to its original direction, reversed, in opposite direction, direction QP, opposite direction to Q Direction changed is B0	DB1
		(1)
(c)	$R = 4mg$	B1
	$F = 4ma$; **OR** $-Ft = 4m\,(0 - 2u)$ $4mg\mu = 4ma$ (their calculated a or unknown a) $-\mu 4mgt = 4m(0-2u)$	M1 A1
	$0^2 = (2u)^2 - 2a\left(\frac{6u^2}{g}\right)$ (their calculated a or an unknown a) **OR** $\frac{6u^2}{g} = \frac{(0+2u)}{2}t$ (their calculated t or an unknown t)	M1A1
	$\mu = \frac{1}{3}$ correctly obtained	A1
		(6)
		(10)
	Notes for question	
(a)	M1 Complete method to give equation in m, u and v only, dimensionally correct, correct no. of terms, condone sign errors and consistent cancelled m's or extra g's	
	A1 Correct equation	
	A1 u ; must be positive	
(b)	DB1 **Dependent** on an answer of $+u$ or $-u$ in (a)	
(c)	B1 cao Seen anywhere, e.g. on a diagram	
	M1 Equation of motion (Allow F for friction at this stage) **OR** Impulse-momentum equation	
	A1 Correct equation with F substituted	
	M1 Use of *suvat* to obtain an equation in u and a only **OR** Use of impulse-momentum to obtain an equation in u and t only	
	A1 Correct equation ; equations must be consistent to earn both A marks.	
	A1 Accept 0.33 or better	

Q8.

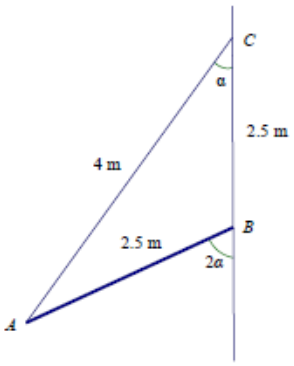
Question Number	Scheme	Marks
		
(a)	$20000\times4=50000v$ $v=1.6(\text{m s}^{-1})$ **OR** $20(-v-(-4))=30(v-0)$	M1 A1
		(2)
(b)	$\pm20000(1.6-4)$ **OR** $\pm30000\times1.6$	M1A1ft
	48000 N s or 48 kN s	A1
	.	(3)
		(5)
(a)	M1 for a CLM equation, condone sign errors and extra *g*'s and any equivalent equation (e.g. 2 x 4 = 5*v*, 20 x 4 = 50*v*, 200 x 4 = 500*v*,... etc) OR : for equating impulses	
	A1 oe Units **not** needed **but must be positive.**	
(b)	M1 impulse-momentum equation, dimensionally correct, correct no. of terms, condone sign errors but must be attempting a difference of momenta (allow 20 or 30 for the mass, M0 if *g* included or mass omitted)	
	A1**ft** a correct equation, follow through on their *v* (allow 20 or 30 for the mass) **N.B.** If using *S* to find the impulse, 4 and their *v* must have opposite signs when awarding the A1ft.	
	A1 cao **units needed** (allow kg m s^{-1}) and must be positive.	

Q9.

Q	Solution	Mark	Notes
a	Possible equations: $\updownarrow R+3R(=4R)=60g$ M(A), $60gx = R\times a+3R\times 6a$ M(B), $60g(8a-x)=R\times 7a+3R\times 2a$ M(C), $60g(x-a)=3R\times 5a$ M(D), $60g(6a-x)=R\times 5a$	M1A1 M1A1	Two equations required. For each equation, M1 for correct no. of terms, dim correct but condone sign errors. A1 for a correct unsimplified equation. Consistent omission of g could score full marks. Inconsistent omission of g is an A error. All four of these marks could be scored for consistent use of another unknown length which is clearly defined e.g. on a diagram **N.B.** M marks only available if using R and $3R$ oe but allow if wrong way round. For vertical resolution, can score M1A1, even if wrong way round.
	S.C. M(G), $R(x-a)=3R(6a-x)$	M2A2	-1 each error
	$x=\frac{19a}{4}$ oe	A1	Or equivalent
		(5)	

b			
	Possible equations: (↑), $60g+Mg=S+S$ M(A), $60gx+Mg\times 2a=S\times a+S\times 6a$ M(B), $60g(8a-x)+Mg\times 6a=S\times 7a+S\times 2a$ M(C), $60g(x-a)+Mga=S\times 5a$ M(D), $60g(6a-x)+Mg\times 4a=S\times 5a$ M(G), $S(x-a)=S(6a-x)+Mg(x-2a)$	M1A1ft M1A1ft	Two equations in two unknowns (M and S) required. For each equation, M1 for correct no. of terms, dim correct but condone sign errors. A1ft for a correct unsimplified equation, follow their x. x must be substituted to earn the A marks. Consistent omission of g could score full marks. Inconsistent omission of g is an A error.
	$M=50$	A1	Exact answer only.
		(5)	
		[10]	

Q10.

Q	Solution	Mark	Guidance
a			
	Moments about B:	M1	Dimensionally correct Condone sin/cos confusion and errors in angles OR: Correct moments equation and resolution Resolving where required
	$T \times 2.5\sin\alpha = 70 \times 1.25\sin 2\alpha$ Or $T \times 2.5\sin\alpha = 70 \times 2\sin\alpha$ Or use similar triangles $T \times \frac{3}{2} = 70 \times \frac{6}{5}$	A1 A1	Unsimplified equation in α with at most one error Correct unsimplified equation in α
	$T = 70 \times \frac{4}{5} = 56(\text{N})$ *	A1*	Obtain **given answer** from correct exact working and no errors seen
		(4)	

b	Resolve horizontally:	M1	First equation
	$H = T\sin\alpha \left(= 33.6(\text{N})\right)$	A1ft	Correct unsimplified equation
	Resolve vertically	M1	Second equation
	$V + T\cos\alpha = 70 \quad \left(V = 25.2(\text{N})\right)$	A1ft	Correct unsimplified equation
	$V = \mu H$	M1	Use of $F = \mu R$ with their V, H
	$\mu = \frac{3}{4}$	A1	Correct only (no subst for g required)
		(6)	
b alt	Resolve parallel to the rod:	M1	
	$H\sin 2\alpha + 70\cos 2\alpha = 56\cos\alpha + V\cos 2\alpha$	A1ft	$\left(24H - 7V = 630\right)$
	Resolve perpendicular to the rod:	M1	
	$70\sin 2\alpha = 56\sin\alpha + V\sin 2\alpha + H\cos 2\alpha$	A1ft	$\left(24V + 7H = 840\right)$
	$V = \mu H$	M1	Use of $F = \mu R$ with their V, H
	$\mu = \frac{3}{4}$	A1	Correct only (no subst for g required)
		(6)	
		[10]	

Q11.

	Use of $P = Fv$	M1	Seen or implied e.g. $F =$ $(= 937.5)$ $\frac{15}{1}$ Condone 15 in place of 15000 or extra zeros on 15000
	Equation of motion	M1	Need all terms. Condone sign errors and sin / cos confusion. Dimensionally consistent
	$F + 900g\sin\theta - 400 = 900a$	A1	Unsimplified equation in P or their F with at most one error
	$\frac{15000}{16} + 900g \times \frac{1}{12} - 400 = 900a$	A1	Correct unsimplified equation with F and $\sin\theta$ substituted
	$a = 1.41 \quad (1.4)\ (\text{ms}^{-2})$	A1	3sf or 2sf
		(5)	

Q12.

Question Number	Scheme	Marks	Notes
	Use of $P = 15F_1$ or $P = 10F_2$	M1	Seen or implied
	$F_1 - R = 600 \times 0.2$	M1	Equation of motion. Needs all terms. Condone sign errors. Inclusion of g is an accuracy error
	$\frac{P}{15} - R = 120$	A1	Correct equation in P and their R
	Up the slope: $F_2 - R - 600g\sin\theta = 0$	M1	Equation of motion. Needs all terms and $F_2 \neq F_1$. Condone sign errors. Condone sin/cos confusion. Omission of g is an accuracy error
		A1	Unsimplified equation in P or F_2 with at most 1 error
	$\frac{P}{10} - R - 30g = 0$	A1	Correct equation in P and their same R
	$\frac{P}{15} - \frac{P}{10} + 30g = 120$	DM1	Solve for P. Dependent on the 2 preceding M marks
	$P = 5220 \quad (5200)$	A1	Correct max 3 s.f.
		[8]	

Q13.

Q	Solution	Mark	Notes
	Driving force $(F) = \frac{3500}{V}$	B1	Use of $P = Fv$
	Equation of motion: $F - 20V + 480g\sin\theta = 0$	M1	Need all terms. Dimensionally correct. Condone sign errors and sin/cos confusion
	$\frac{3500}{V} - 20V + 40g = 0$	A1	Correct unsimplified equation in V.
	$20V^2 - 392V - 3500 = 0$	M1	Form a 3 term quadratic equation $(=0)$ in V
	$V = 26.3$ (26)	A1	3 sf or 2 sf Not $\frac{49+22\sqrt{14}}{5}$ (follows use of 9.8)
		(5)	
		[5]	

Q14.

Q	Solution	Mark	Guidance
	Equation of motion down the slope	M1	First equation (either direction). Condone sign errors and sin/cos confusion
	$F_1 + 450g \times \frac{1}{15} - R = 450 \times 0.5$ $\left(\frac{P}{12} + 30g - R = 225\right)$ $\left(\frac{P}{12} - R = -69\right)$	A1 A1	Unsimplified equation with at most one error. Correct unsimplified equation in P or F_1
	Equation of motion up the slope	M1	Second equation. Condone sin/cos confusion. Signs consistent with first equation and change in direction of motion
	$F_2 - 450g \times \frac{1}{15} - R = 450 \times -0.5$ $\left(\frac{P}{6} - 30g - R = -225\right)$ $\left(\frac{P}{6} - R = 69\right)$	A1	Correct unsimplified equation in P or F_2
	$F_1 = \frac{P}{12}$ or $F_2 = \frac{P}{6}\left(= \frac{2P}{12}\right)$	M1	Use of $P = Fv$ at least once
	Solve for P	DM1	Dependent on all previous M marks
	$\left(R = \frac{P}{8}\right)$ $P = 1660$ or $P = 1700$	A1	3 sf or 2 sf (follows use of 9.8) Allow 1.66 kW but not 1.66
		(8)	
		[8]	

Q15.

	Use of $F = \frac{P}{v}$	M1	Formula with a speed substituted correctly At least once.
	Equation for horizontal motion	M1	Dimensionally correct in P or F. Condone sign errors. Need all terms
	$\frac{P}{15} - R = -0.2 \times 900 \quad \left(\frac{P}{15} - R = -180\right)$	A1	Correct unsimplified equation in P and R
	Equation for motion down hill	M1	Dimensionally correct in P or F_D. Condone sign errors. Condone sin / cos confusion. Need all terms. M0 if using F(down) = F(horizontal)
	$F_D + 900g \times \sin\theta - R = 900 \times 0.4$ $\left(\frac{P}{12} + 30g - R = 360\right) \quad \left(\frac{P}{12} = R + 66\right)$	A1	Unsimplified equation in F_D or P and R with at most one error.
		A1	Correct unsimplified equation in (P and) R with trig substituted. e.g. $\frac{5}{4}(R-180) = 360 - 30g + R$
	Solve for R	DM1	Dependent on the 3 preceding M marks. Condone slips in the algebra.
	$R = 1160$ or $R = 1200$	A1	3 sf or 2 sf only NB the answer follows the use of 9.8, so a final answer 1164 is A0. Clear use of 9.81 is a rubric infringement. It gives $(P = 14742$ and$)$ $R = 1162.8$ and scores a maximum of 7/8 (final A0)
		[8]	
		(8)	

	Some candidates work through with the two driving forces. They score M1M1 as above A1 for 4 x F(down) = 5 x F(horizontal) or equivalent M1A1 as above A1 for Correct unsimplified equation in R e.g. $\frac{5}{4}(R-180) = 360 - 30g + R$ M1A1 as above		

Q16.

Question	Scheme	Marks	Notes
a	Equation of motion	M1	Need all terms and dimensionally correct
	$F-600=900\times 2$	A1	Correct unsimplified equation
	$\frac{24000}{V}-600=1800$	M1	Use of $24000=FV$ Allow with 24 for 24000 or with a 0 missing
	$V=10$	A1	Correct only
		(4)	
b	Equation of motion	M1	Need all terms and dimensionally correct. Mark omission of g as an accuracy error, not a dimension error. Condone sign error(s) and sin/cos confusion If they form separate equations for each vehicle they need both equations and to eliminate T to score the M1
	$F-(700+900)g\sin\theta-(550+600)=1600a$ $\left(\frac{24000}{8}-(1600)g\sin\theta-1150=1600a\right)$	A1 A1	Unsimplified combined equation with at most one error – allow with F Correct combined unsimplified equation with correct substitution for F
	$a=0.456\quad(0.46)\left(\text{ms}^{-2}\right)$	A1	2 sf or 3 sf not $\frac{73}{160}$
		(4)	

c	Work-energy equation	M1	Must be work-energy. Must be using the mass of the trailer only and the resistance for the trailer only. Dimensionally correct. All relevant terms, no duplication of terms and no extras. Condone sign error(s) and sin/cos confusion.
	$\frac{1}{2}\times 700\times 9^2=550d+700gd\sin\theta$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation
	$d=27\quad(27.3)$	A1	2 sf or 3 sf
		(4)	

Q17.

.a	Equation of motion for car and trailer	M1	Need all terms. Dimensionally correct. Condone sin/cos confusion and sign errors.
	$F-300-150-\frac{200g}{20}-\frac{600g}{20}=0$ $(F-842=0)$	A1 A1	Unsimplified equation in P or F with at most one error Correct unsimplified equation in P or F Missing g is one accuracy error
	$\frac{1000P}{15}(-450-98-294=0)$	M1	Use of $P=Fv$ Allow with P or $1000P$
	$P=12.6$ or $P=13$	A1	3 s.f. or 2 s.f. only A final answer of 12600 (13000) scores 4/5 Condone 12600=12.6 (correct thinking without stating the units)
		[5]	
b	KE lost = gain in GPE + WD against resistance	M1	Must be using work-energy principle for trailer only. Dimensionally correct. Correct terms and no extras. Condone sign errors and sin / cos confusion.
	$\frac{1}{2}\times 200\times 400=\frac{200}{20}gd+300d\,(=398d)$	A1 A1	Correct unsimplified equation in one variable with at most one error Correct unsimplified equation in one variable.
	$XY=d=101\ (100)$ (m)	A1	3 s.f. or 2 s.f. only
		[4]	
		(9)	

Q18.

Question	Scheme	Marks
(a)	$\frac{dv}{dt} = -2(t+4)^{\frac{1}{2}}$	M1
	$v = -\int 2(t+4)^{\frac{1}{2}}\,dt$	
	$v = -4(t+4)^{\frac{1}{2}} \quad (+c)$	dM1 A1
	$t=0, v=8 \Rightarrow c=16$	M1
	$v = 16-4(t+4)^{\frac{1}{2}} \quad (\text{m s}^{-1}) \quad *$	A1 cso
		(5)
(b)	$v=0 \quad 16 = 4(t+4)^{\frac{1}{2}}$	M1
	$16 = t+4 \quad t=12$	A1
	$x = 4\int\left(4-(t+4)^{\frac{1}{2}}\right)dt$	
	$x = 4\left(4t - \frac{2}{3}(t+4)^{\frac{3}{2}}\right) \quad (+d)$	M1 A1
	$t=0, \ x=0 \quad d = 4\times\frac{2}{3}\times 4^{\frac{3}{2}} = \frac{64}{3}$ oe	A1
	$t=12 \quad x = 4\left(4\times 12 - \frac{2}{3}\times 16^{\frac{3}{2}}\right) + \frac{64}{3} = 42\frac{2}{3}$ (m) oe eg 43 or better	dM1 A1
		(7)
		(12 marks)

Notes:

(a)

M1: Attempting an expression for the acceleration in the form $\frac{dv}{dt}$; minus may be omitted.

DM1: Attempting the integration

A1: Correct integration, constant of integration may be omitted (no ft)

M1: Using the initial conditions to obtain a value for the constant of integration

A1: cso. Substitute the value of c and obtain the final GIVEN answer

(b)

M1: Setting the **given** expression for v equal to 0

A1: Solving to get $t=12$

M1: Setting $v = \frac{dx}{dt}$ and attempting the integration wrt t. At least one term must clearly be integrated.

A1: Correct integration, constant may be omitted.

M1: Substituting $t=0, \ x=0$ and obtaining the correct value of d. Any equivalent number, inc decimals.

dM1: Substituting their value for t and obtaining a value for the required distance. Dependent on the second M mark.

A1: Correct final answer, any equivalent form.

Q19.

Question Number	Scheme	Marks
(a)	$F = \frac{k}{(x+R)^2}$	M1
	$x = 0, F = mg \rightarrow mg = \frac{k}{R^2}$	M1
	$k = mgR^2 \rightarrow F = \frac{mgR^2}{(x+R)^2}$*	A1*
		(3)
(b)		
	$mv\frac{dv}{dx} = -\frac{mgR^2}{(x+R)^2}$ *or* $m\frac{d}{dx}\left(\frac{1}{2}v^2\right) = -\frac{mgR^2}{(x+R)^2}$	M1
	$\frac{1}{2}v^2 = -\int \frac{gR^2}{(x+R)^2}dx$	dM1
	$\frac{1}{2}v^2 = \frac{gR^2}{x+R}(+c)$	A1
	$x = R, v = U$	M1
	$\frac{U^2}{2} = \frac{gR^2}{2R} + c \rightarrow c = \frac{U^2 - gR}{2}$	A1
	$x = 0 \rightarrow \frac{1}{2}v^2 = gR + \frac{U^2 - gR}{2}$	
	$v^2 = U^2 + gR \rightarrow v = \sqrt{U^2 + gR}$	M1, A1
		(7)
		[10]

ALT1 (b)	$\frac{mv^2}{2} - \frac{mU^2}{2} = -m\int_R^0 \frac{gR^2}{(x+R)^2}\,dx$	M1
	$\frac{v^2}{2} - \frac{U^2}{2} = \left[\frac{gR^2}{x+R}\right]_R^0$	dM1 A1
	$\frac{v^2}{2} - \frac{U^2}{2} = \frac{gR^2}{R} - \frac{gR^2}{2R}$	M1 A1
	$v^2 = U^2 + gR \rightarrow v = \sqrt{U^2 + gR}$	M1, A1
Question Number	Scheme	Marks
ALT2 (b)	$mv\frac{dv}{dx} = -\frac{mgR^2}{(x+R)^2}$	M1
	$\int_U^V v dv = -\int_R^0 \frac{gR^2}{(x+R)^2}\,dx$	dM1
	$\left[\frac{v^2}{2}\right]_U^v = \left[\frac{gR^2}{x+R}\right]_R^0$	A1
	$\frac{v^2}{2} - \frac{U^2}{2} = \frac{gR^2}{R} - \frac{gR^2}{2R}$	M1 A1
	$v^2 = U^2 + gR \rightarrow v = \sqrt{U^2 + gR}$	M1, A1
		(7)

(a)

M1 Setting up an inverse square relationship between F and $(x + R)$ .Can be negative

Allow with $d = x + R$ or $k = GMm$

dM1 Clear use of $x = 0$ and $F = mg$ to find value of constant (k or GM)

A1* Given result reached with both M marks clearly earned. Must be positive

(b)

M1 Use of $mv\frac{dv}{dx}$ or $m\frac{d}{dx}(\frac{1}{2}v^2)$ to form equation. Condone sign error.

dM1 Separate variables to produce form ready for integration. Condone sign error.

A1 Correct integration. Sign must be correct now. Constant of integration not needed.

M1 Use of initial conditions in the result of an integration to find constant.

A1 Correct value for their c (for the side they place c on).

M1 Finding a value for v (or v^2) using $x = 0$. v^2 must come from a dimensionally correct expression.

A1 Correct expression for v.

ALT1 (b) uses the change in KE = work done

M1 Equates change in KE to the integral of F . Condone sign error

dM1 Integrates (power of $(x + R)$ must increase). Condone sign errors. Limits not needed.

A1 Correct integration. Sign must be correct now for their LHS. Limits not needed.

M1 Substitution of both limits R and 0 into definite integration.

A1 Correct limits, the correct way round for their equation.

Final two marks are the same as the main scheme.

ALT2 (b) uses definite integration

M1 Use of $mv\frac{dv}{dx}$ to form equation. Condone sign error.

dM1 Separate variables to produce form ready for integration. Condone sign error. Limits not needed.

A1 Correct integration. Sign must be correct now. Limits not needed.

M1 Substitution of both limits in definite integration. Must be 0, R, v and U

A1 Correct limits, the correct way round.

Final two marks are the same as the main scheme.

S.C. If they redefine x as the distance from the centre of the earth for (b) and use limits R and $2R$ correctly, full marks can still be gained in (b)

Q20.

Question Number	Scheme	Marks
a)	$0.5v\dfrac{\mathrm{d}v}{\mathrm{d}x}=-\sin 2x$	M1
	$\int 0.5v\,\mathrm{d}v=\int -\sin 2x\,\mathrm{d}x$	DM1
	$0.25v^2=\dfrac{1}{2}\cos 2x\,(+c)$	A1
	$v^2=2\cos 2x+c$	
	$x=0, v=2 \Rightarrow 4=2+c$	DM1
	$v^2=2\cos 2x+2\left(=4\cos^2 x\right)$	A1
	$v=2\cos x$ *	A1*
		(6)
ALT	*Using definite integration*	
	$0.5v\dfrac{\mathrm{d}v}{\mathrm{d}x}=-\sin 2x$	M1
	$\int_2^v 0.5v\,\mathrm{d}v=\int_0^x -\sin 2x\,\mathrm{d}x \quad \left(\text{or } \int_0^x \sin 2x\,\mathrm{d}x\right)$	DM1
	$\left[0.25v^2\right]_2^v=\left[\dfrac{1}{2}\cos 2x\right]_0^x \quad \left(\text{or } \left[-\dfrac{1}{2}\cos 2x\right]_x^0\right)$	A1
	$0.25\left(v^2-4\right)=\dfrac{1}{2}\cos 2x-\dfrac{1}{2}$	DM1A1
	$v=2\cos x$ *	A*
		(6)

Question Number	Scheme	Marks
b)	$\frac{dx}{dt} = 2\cos x$	M1
	$\int \sec x dx = \int 2dt$	
	$\ln\lvert\sec x + \tan x\rvert = 2t + k$	DM1
	$t = 0, x = 0 \ \ln 1 = 2(0) + k \Rightarrow k = 0$	A1
	$t = \frac{1}{2}\ln\lvert\sec x + \tan x\rvert = \frac{1}{2}\ln\left(\sec\frac{\pi}{4} + \tan\frac{\pi}{4}\right)$	DM1
	$t = \frac{1}{2}\ln\left(\sqrt{2}+1\right)$ *	A1*
		(5)
ALT	*Using definite integration*	
	$\frac{dx}{dt} = 2\cos x$	M1
	$\int_0^{\frac{\pi}{4}} \sec x dx = \int_0^t 2dt$	
	$\left[\ln\lvert\sec x + \tan x\rvert\right]_0^{\frac{\pi}{4}} = \left[2t\right]_0^t$	DM1A1
	$2t = \ln\left(\sec\frac{\pi}{4} + \tan\frac{\pi}{4}\right)$	DM1
	$\therefore t = \frac{1}{2}\ln\left(\sqrt{2}+1\right)\ldots$ *	A1*
		(5)
		[11]

(a)	*Indefinite integration*	
M1	Equation of motion, with acceleration in the form $v\frac{dv}{dx}$. Condone sign error.	
DM1	Separate variables to prepare for integration. Depends on the M mark above.	
A1	Correct integration. Constant not needed.	
DM1	Substitute $x = 0,\ v = 2$ to find the constant. Depends on both M marks above.	
A1	A correct result for v^2	
A1*	**Given** result reached through use of double angle formula. (Formula need not be shown.).	
ALT	*Definite integration*	
M1	Equation of motion, with acceleration in the form $v\frac{dv}{dx}$. Condone sign error.	
DM1	Separate variables, to prepare for integration. Limits not needed for this mark. Depends on the M mark above.	
A1	Correct integration – limits not needed	
DM1	Correct substitution of correct limits in their integrated function. Limits must be "paired" correctly. Depends on both previous M marks in (a) (Formula need not be shown.).	
A1	Correct expression which can yield v^2	
A1*	**Given** result reached through use of double angle formula. (Formula need not be shown.).	

(b)		
M1	Use of $v = \frac{dx}{dt}$	
DM1	Correct separation of variables and attempt integration (integral is in the formula book). Depends on first M of (b) Modulus signs may be missing.	
A1	Correct integration and use limits to find correct value for constant.	
DM1	Substitute $x = \frac{\pi}{4}$ and solve for t. Depends on both previous M marks in (b)	
A1*	Given result reached from fully correct working. (Modulus signs may be missing throughout.).	

ALT	*Definite integration*	
M1	Use of $v = \frac{dx}{dt}$	
DM1	Correct separation of variables and attempt integration. Limits not needed. Depends on first M of (b). Modulus signs may be missing.	
A1	Correct integration including correct limits.	
DM1	Substitute their limits and solve for t. Depends on both previous M marks in (b)	
A1*	Given result reached from fully correct working. (Modulus signs may be missing throughout.).	

Q21.

Question Number	Scheme	Marks
(a)	$\frac{1}{\sqrt{(2x+1)}}=\frac{1}{3}\Rightarrow x=4$	M1A1
	$a=v\frac{\mathrm{d}v}{\mathrm{d}x}=\frac{1}{\sqrt{(2x+1)}}\times-\frac{1}{2}\times2(2x+1)^{-\frac{3}{2}}\quad\left(=-(2x+1)^{-2}\right)$	M1A1
	$a=(-)\frac{1}{81}$	A1
	$\frac{2}{81}$ (N), 0.025or better	A1 (6)
(b)	$t=\int\sqrt{(2x+1)}\ \mathrm{d}x$	M1
	$t=\frac{2}{3}\times\frac{1}{2}(2x+1)^{\frac{3}{2}}+(C)$	A1
	Use of $t=0$, $x=0$ to obtain a value for C $(=-\frac{1}{3})$	M1
	Substitute $x=7.5$	dM1
	$t=21$	A1 (5)
		(11)
	Notes for question	
(a)	M1 for putting $v=\frac{1}{3}$ and solving for $x$oe e.g. $(2x+1)=9$	
	A1 for $x=4$ oe	
	M1 for use of $v\frac{\mathrm{d}v}{\mathrm{d}x}$ with clear attempt at differentiation. (Power $-\frac{3}{2}$ needed	
	A1 for a correct unsimplified expression for a in terms of x only	
	A1 for a correct value for a (ignore sign)	
	A1 cao (must be positive)	
(b)	M1 for use of $\frac{\mathrm{d}x}{\mathrm{d}t}=\frac{1}{\sqrt{(2x+1)}}$, separate variables and attempt to integrate. $k(2x+1)^{\frac{3}{2}}$ should be seen	
	A1 for correct unsimplified integration, C not needed.	
	If definite integration used, ignore limits for these 2 marks	
	M1 for use of initial conditions to find a value for C	
	dM1 dependent on first M1, for substituting in $x=7.5$ and evaluating	
	For definite integration award M1 for substitution of the lower limits and DM1 for substitutio of the upper limits.	
	A1 cao	

Q22.

Question number	Scheme	Marks
(a)	$v\dfrac{\mathrm{d}v}{\mathrm{d}x}=-\dfrac{gR^2}{x^2}$	M1 A1
	$\int v\,\mathrm{d}v=-\int\dfrac{gR^2}{x^2}\,\mathrm{d}x$ or $\dfrac{1}{2}V^2=-\int\dfrac{gR^2}{x^2}\,\mathrm{d}x$ Or the Energy alternative below	M1
	$\dfrac{1}{2}v^2=\dfrac{gR^2}{x}+C$	A1
	Use of $x=R, v=U$ to find C $\quad(C=\dfrac{1}{2}u^2-gR)$	M1
	$v^2=\dfrac{2gR^2}{x}+U^2-2gR$ *	A1*
		(6)
(b)	$\dfrac{1}{4}gR=\dfrac{2gR^2}{x}+gR-2gR$	M1
	$x=\dfrac{8R}{5}$	A1
	$AB=\dfrac{3R}{5}$ oe	A1
		(3)

(c)	Correct statement regarding $\dfrac{2gR^2}{x}$ for example • $\dfrac{2gR^2}{x}>0$ for $x\geq R$ • $x\to\infty,\ \dfrac{2gR^2}{x}\to 0$	M1
	Correct reasoning. • $U^2-2gR=0$ • $U^2\to 2gR$ • $U^2\geq 2gR$	dM1
	$U_{\text{MIN}}=\sqrt{2gR}$	A1
		(3)
		(12)

	Notes
(a)	
M1	Equation with or without -ve sign and any derivative form for the acceleration
A1	Correct equation with -ve sign
M1	Separate variables and clear attempt to integrate acceleration in terms of v and x.
A1	Correct equation; allow without C
M1	Use of initial conditions or limits
A1*	Given answer correctly obtained
(b)	
M1	Substitution of v^2 and U^2 into (a) to produce a correct equation
A1	Correct value of x
A1	cao
(c)	
M1	Correct reasoning for the term $\frac{2gR^2}{x}$ Accept $x=\infty$, $x\to\infty$, $\frac{2gR^2}{x}=0$
dM1	Dependent on previous M. Correct reasoning leading to correct equation or inequality.
A1	cso

ALT a	**Energy approach must use integration**
M1 A1	Energy equation with variable force. The sign may be missing for the M mark. $\frac{1}{2}mv^2-\frac{1}{2}mU^2=\int F\,\mathrm{dx}=\int-\frac{mgR^2}{x^2}\,\mathrm{dx}$
M1 A1	Clear attempt to integrate. Limits may be missing or incorrect. $\frac{1}{2}mv^2-\frac{1}{2}mU^2=\left[\frac{mgR^2}{x}\right]_R^x$
M1	Correct limits substituted the right way round. $\frac{1}{2}mv^2-\frac{1}{2}mU^2=\frac{mgR^2}{x}-\frac{mgR^2}{R}$
	$v^2-U^2=\frac{2gR^2}{x}-2gR$
A1*	$v^2=\frac{2gR^2}{x}+U^2-2gR$

Q23.

Question	Scheme	Marks
(a)	$F = \frac{K}{x^2}$	
	$x = R \Rightarrow F = mg \qquad \therefore mg = \frac{K}{R^2}$	M1
	$K = mgR^2$ *	A1
		(2)
(b)	$\frac{mgR^2}{x^2} = -mv\frac{\mathrm{d}v}{\mathrm{d}x}$	M1
	$g\int \frac{R^2}{x^2}\mathrm{d}x = -\int v\,\mathrm{d}v$	
	$-g\frac{R^2}{x} = -\frac{1}{2}v^2 \quad (+c)$	dM1 A1ft
	$x = 3R,\ v = V \Rightarrow -g\frac{R^2}{3R} = -\frac{1}{2}V^2 + c$	M1
	$c = -\frac{Rg}{3} + \frac{1}{2}V^2$	A1
	$x = R \Rightarrow \frac{1}{2}v^2 = -\frac{Rg}{3} + \frac{1}{2}V^2 + g\frac{R^2}{R}$	M1
	$v^2 = V^2 + \frac{4Rg}{3}$	
	$v = \sqrt{V^2 + \frac{4Rg}{3}}$	A1 cso
		(7)
		(9 marks)

Notes:

(a)

M1: Setting $F = mg$ **and** $x = R$

A1: Deducing the GIVEN answer

(b)

M1: Attempting an equation of motion with acceleration in the form $v\frac{\mathrm{d}v}{\mathrm{d}x}$. The minus sign may be missing.

dM1: Attempting the integration.

A1ft: Correct integration, follow through on a missing minus sign from line 1, constant of integration may be missing.

M1: Substituting $x = 3R, v = V$ to obtain an equation for c

A1: Correct expression for c.

M1: Substituting $x = R$ and their expression for c.

A1: Correct expression for v, any equivalent form.

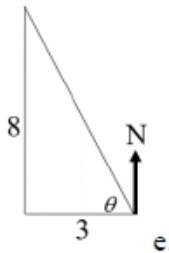
Q24.

Question	Scheme		Marks
(a)	Use $\mathbf{v}=\lambda(\mathbf{i}+\mathbf{j})$: $6T^2+6T=3T^2+24$	Form an equation in t, T or λ $\lambda^2-108\lambda+2592=0$	M1
	Solve for T $\quad 3T^2+6T-24=0$,	Simplify to quadratic in t, T or λ and solve.	M1
	$(T+4)(T-2)=0$, $\quad T=2$	$T=2$ only	A1
	If they score M1 and then state $T=2$ allow 3/3		
	If they guess $T=2$ and show that it works then allow 3/3.		
	If all we see is $T=2$ with no equation then 0/3 for (a) but full marks are available for (b) and (c).		
			(3)
(b)	Differentiate: $\mathbf{a}=(12t+6)\mathbf{i}+6t\mathbf{j}$	Majority of powers going down Need to be considering both components	M1
		Correct in t or T	A1
	$=30\mathbf{i}+12\mathbf{j}$ (m s^{-2})	Cao	A1
			(3)
(c)	Integrate : $\mathbf{r}=\left(2t^3+3t^2(+A)\right)\mathbf{i}+\left(t^3+24t(+B)\right)\mathbf{j}$	Clear evidence of integration. Need to be considering both components. Do not need to see the constant(s).	M1
	-1 each error		A2
	If the integration is seen in part (a) it scores no marks at that stage, but if the result is used in part (c) then the M1A2 is available in part (c)		
	$\boldsymbol{OA}=28\mathbf{i}+56\mathbf{j}$ $\quad$ Use their T		
	Distance $=28\sqrt{5}=62.6$ (m)	Dependent on previous M1 Use of Pythagoras on their $\boldsymbol{OA}$	DM1
	63 or better , $\sqrt{3920}$		A1
	NB: Incorrect T can score 2/3 in (b) and 4/5 in (c)		
			(5)
			(11 marks)

Q25.

Q	Solution	Mark	Notes
a			Allow column vectors throughout
	Use $\mathbf{a}=\frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$	M1	Differentiate – at least 3 powers going down by 1
	$\mathbf{a}=\left(10t-3t^2\right)\mathbf{i}+\left(6t^2-8\right)\mathbf{j}$	A1	
	$\mathbf{F}=1.5\times\left(\left(20-12\right)\mathbf{i}+\left(24-8\right)\mathbf{j}\right)$	DM1	Substitute $t=2$ and use $\mathbf{F}=m\mathbf{a}$ Dependent on preceding M1
	$=12\mathbf{i}+24\mathbf{j}$	A1	Ignore magnitude of $\mathbf{F}$ if found
		(4)	
b	$5t^2-t^3=0 \quad \Rightarrow t=5$	B1	(Not moving when $t=0$ so no need to mention $t=0$)
	Use of $\mathbf{r}=\int \mathbf{v}\mathrm{d}t$	M1	Integrate to find $\mathbf{r}$ – at least 3 powers going up by 1.
	$\mathbf{r}=\left(\frac{5}{3}t^3-\frac{1}{4}t^4\right)\mathbf{i}+\left(\frac{1}{2}t^4-4t^2\right)\mathbf{j}$	A1	Condone if no constant of integration seen (since $t=0, \mathbf{r}=\mathbf{0}$)
	$\mathbf{r}=\left(\frac{625}{12}\right)\mathbf{i}+\left(\frac{425}{2}\right)\mathbf{j}$	A1	Final answer $52\mathbf{i}+210\mathbf{j}$ or better $\left(52.08\dot{3}\mathbf{i}+212.5\mathbf{j}\right)$
		(4)	
		[8]	

Q26.

QUESTION NUMBER	SCHEME	MARKS
(a)	$(5\mathbf{i}-8\mathbf{j})+5(-\lambda\mathbf{i}+2\lambda\mathbf{j})$ (m s^{-1}) isw	M1 A1
		(2)
(b)	$13=\sqrt{(5-5\lambda)^2+(-8+10\lambda)^2}$	M1 A1
	$169=25-50\lambda+25\lambda^2+64-160\lambda+100\lambda^2$	
	$25\lambda^2-42\lambda-16=0$ *	A1* cso
		(3)
(c)	$(-2\mathbf{i}+4\mathbf{j})$ seen or implied	B1
	$(5\mathbf{i}-8\mathbf{j})+(-2\mathbf{i}+4\mathbf{j})4$	M1A1
	 e.g. $\tan^{-1}\left(\pm\frac{8}{3}\right)$, $\tan^{-1}\left(\pm\frac{3}{8}\right)$, $\sin^{-1}\left(\pm\frac{8}{\sqrt{73}}\right)$,...	M1
	339°	A1
		(5)
		(10)

	Notes for question	
(a)		
M1	Use of **v**=**u**+**a***t* to form a vector expression in λ and t	
A1	Correct unsimplified expression with $t = 5$ **N.B.** Allow use of column vectors for the M mark but not for the A mark.	
(b)		
M1	Collect **i**'s and **j**'s and correct use of Pythagoras to form an equation in λ	
A1	Correct equation	
A1*	cso. Expand brackets and correctly reach the GIVEN answer. **N.B.** Allow $0=25\lambda^2-42\lambda-16$	
(c)		
B1	Or column vector	
M1	Complete method to find the velocity when $t = 4$.	
A1	Correct unsimplified expression. Note the correct velocity is $\mathbf{v}=-3\mathbf{i}+8\mathbf{j}$	
M1	Use **their** velocity vector **at** $t = 4$ with trig to find a relevant angle.	
A1	Cao. Degrees sign not required. **N.B.** if they work with both values of λ, can score max all the marks except the last one.	

Q27.

Question Number	Scheme	Marks	Notes
a	Equation for conservation of energy.	M1	Need all terms. Condone sign errors
	$\frac{1}{2}\times m\times 144+m\times g\times 20=\frac{1}{2}mv^2$	A1 A1	Correct unsimplified equation with at most one error Correct equation (with or without m)
	$v=23$ or 23.2	A1	Max 3 s.f.
		[4]	
b	$12\cos\theta\times 5=40$	M1	Horizontal motion Condone sine/cosine confusion
	(minimum=) $12\cos\theta=8$ (m s^{-1})	A1	Final answer : do not ignore subsequent working
		[2]	
c	Speed = 10 $\Rightarrow$ Vertical component = 6 (m s^{-1})	B1ft	Follow their horizontal component
	$(\pm)6=12\sin\theta-gt$	M1	Vertical speed
	$=12\times\frac{\sqrt{5}}{3}-gt$ ($t=0.30..$ and $t=1.52..$)	A1	Correct equation for one value of t or for the time interval. Correct trig value seen or implied
	Time = 1.52.. – 0.30.. = 1.22… (s)	A1	Correct interval
	Required time = $5-1.22$ (s)	M1	Find required time – follow their 1.22
	$=3.78$ (s)	A1	Or 3.8. Max 3 s.f.
		[6]	
	Alternatives for M1A1A1		
	Use of $v=u+at$	(M1)	
	$-6=6-gt$	(A1)	Or find time to top and double it
	$t=\frac{12}{g}$	(A1)	
	Vertical speed: $6=12\sin\theta-gt_1$	(M1)	
	$-6=12\sin\theta-gt_2$	(A1)	
	$12=g(t_2-t_1)$, $t_2-t_1=\frac{12}{g}$	(A1)	

	Alternatives for B1M1A1A1		
	ht above A $\frac{22}{g}$	(B1)	Using energy 2.24… seen or implied e.g. by 22.24…
	Use of $s=ut+\frac{1}{2}at^2$	(M1)	$20+\frac{22}{g}$ used with $12\sin\theta$ is M0
	$\frac{22}{g}=12\sin\theta t-\frac{1}{2}gt^2$	(A1)	
	Time = 1.52.. – 0.30.. = 1.22… (s)	(A1)	Correct interval
	Speed 10, angle to horizontal α $\Rightarrow$ $10\cos\alpha=8$	(B1)	
	Time to top: $0=10\sin\alpha-gt$	(M1)	
	$10\times 0.6=gt$	(A1)	
	Total time $=\frac{12}{g}$	(A1)	
		[11]	

Q28.

Q	Solution	Mark	Notes
a	$-12 = 12 - gt$	M1	Use *suvat* to find time taken
	$t = \frac{24}{g} (= 2.45)$	A1	
	$AB = 6t$	M1	Horizontal distance
	$= 14.7\,(15)\,(\text{m})$	A1	3 sf or 2 sf Not $\frac{720}{49}$ (follows use of 9.8) Not $\frac{144}{g}$ (do not accept g in the denominator)
		(4)	
b	Vertical component of velocity $= (\pm)8$	B1	
	$v^2 = u^2 + 2as$	M1	Complete method using *suvat* to find h
	$\Rightarrow 8^2 = 12^2 - 2gh$	A1	Correct unsimplified equation
	$h = 4.08 \quad (4.1)$	A1	3 sf or 2 sf Not $\frac{200}{49}$ (follows use of 9.8) Not $\frac{40}{g}$ (do not accept g in the denominator)
		(4)	

b alt	$\mathbf{v} = \begin{pmatrix} 6 \\ 12 \end{pmatrix} - \begin{pmatrix} 0 \\ g \end{pmatrix} t \Rightarrow 12 - gt = (\pm)8$	B1	Correct expression for critical value(s) of t
	$h = 12t - \frac{1}{2} g t^2$	M1	Complete method using *suvat* to find h
	$= \frac{48}{g} - \frac{8}{g}$ or $= \frac{240}{g} - \frac{200}{g}$	A1	Correct unsimplified equation
	$h = 4.08 \quad (4.1)$	A1	3 sf or 2 sf
		(4)	
c	$\begin{pmatrix} 6 \\ -12 \end{pmatrix} \cdot \begin{pmatrix} 6 \\ v \end{pmatrix} = 0$	M1	Complete method to find vertical component at C.
	$\Rightarrow v = 3$	A1	
	$\mathbf{v} = 6\mathbf{i} + 3\mathbf{j} \ (\text{m s}^{-1})$	A1	Must be a vector in terms of **i** and **j**
	If see $\begin{pmatrix} 6 \\ 12 \end{pmatrix} \cdot \begin{pmatrix} 6 \\ v \end{pmatrix} = 0$ leading to $\mathbf{v} = 6\mathbf{i} - 3\mathbf{j}$ mark as a misread: M1A0A0		
		(3)	
		[11]	
	Accept working in column vectors throughout apart from the final A1		

Q29.

Q	Solution	Mark	Guidance
a	Conservation of energy	M1	Need all three terms and dimensionally correct. Condone sign errors.
	$\frac{1}{2}m\times10^2+mgh=\frac{1}{2}m\times18^2$	A1	Correct unsimplified equation
	$h=11.4 \quad (11)$	A1	3 sf or 2 sf only $(\text{not } \frac{80}{7})$
		(3)	
b	Vertical distance	M1	Complete method using *suvat* to find angle of projection
	$10\sin\alpha\times2.5-\frac{1}{2}g\times2.5^2=-11.4$	A1ft	Follow their h
	$\alpha=50.2°$ or $10\sin\alpha=v_V=7.7678....$	A1	$50°$ or better (50.1618…) Accept $50.3°$ from11.4 Seen or implied Might see $\sin\alpha=\frac{43}{56}$ or $v_V=\frac{215}{28}$
	Horizontal distance $=10\cos\alpha\times2.5$ or $\sqrt{100-v_V{}^2}\times2.5$	M1	
	$=16.0 \quad (16)\,(\text{m})$	A1	3 sf or 2 sf only
		(5)	

c	Using energy: $\frac{1}{2}m\times 64+mgs=\frac{1}{2}m\times 100$	M1	Complete method to find height above A
	$s=1.8367...$	A1	1.8 or better
	Use of suvat to form equation in t	M1	
	$1.84=10\sin 50.2\times t-4.9t^2$	A1	Correct unsimplified equation
	Solve for t and find difference between roots	DM1	Complete method to find the required time Dependent on 2 previous M marks
	$T=0.98$ or 0.978	A1	2 sf or 3 sf
		(6)	
c alt	Use of Pythagoras	M1	Complete method to find vertical component of speed
	Vertical speed $\sqrt{64-(10\cos\alpha)^2}=4.8...$	A1	Awrt 4.8 or better
	Use of $10\sin\alpha-gt=\pm v$ to find t	M1	
	$\begin{cases}10\sin 50.2°-gt_1=4.8\\10\sin 50.2-gt_2=-4.8\end{cases}$	A1	Correct unsimplified equations Could also find time to top
	$T=t_2-t_1=1.27..-0.29..$	DM1	Complete method to find the required time Dependent on 2 previous M marks
	$=0.98$ or 0.978	A1	Final answer. 2 sf or 3 sf
		(6)	
c alt	Use of Pythagoras to form quadratic in t	M1	
	$(10\sin\theta-gt)^2+(10\cos\theta)^2=64$	A1	
	Simplify and substitute for trig	M1	
	$36+9.8^2t^2-150.5t=0$	A1	
	$T=t_2-t_1=1.27..-0.29..$	DM1	Complete method to find the required time Dependent on 2 previous M marks
	$=0.98$ or 0.978	A1	Final answer. 2 sf or 3 sf
		[14]	

Q30.

a	Horizontal distance	M1	Correct use of *suvat*
	$x = u\cos\alpha\, t$	A1	Correct equation
	Vertical distance	M1	Correct use of *suvat*
	$y = u\sin\alpha\, t - \frac{1}{2}gt^2$	A1	Correct equation. Correct signs. Condone if not using "y"
	$t = \frac{x}{u\cos\alpha} \Rightarrow$ $y = u\sin\alpha.\frac{x}{u\cos\alpha} - \frac{g}{2}\left(\frac{x}{u\cos\alpha}\right)^2$ $\left(= x\tan\alpha - \frac{gx^2}{2u^2}\sec^2\alpha\right)$	DM1	Dependent on the first 2 M marks. Substitute for t to obtain y in terms of x and α
	$y = x\tan\alpha - \frac{gx^2}{2u^2}\left(1+\tan^2\alpha\right)$ *	A1*	Obtain **given answer** from correct working (final step needs to be explained). Allow if $\sec^2\alpha$ seen. Must be "y" here
		[6]	
b	$u = 20,\ x = 10,\ y > 2 \Rightarrow$ $2 = 10\tan\theta - \frac{100g}{800}\left(1+\tan^2\theta\right)$ $\left(\frac{g}{8}\tan^2\theta - 10\tan\theta + \left(2+\frac{g}{8}\right) = 0\right)$	M1	Use given values to form quadratic in $\tan\theta$ or equivalent equation in one trig function. Allow working with =, < or > 2
	Critical values: $\theta° = 18.6°$ or $\theta° = 82.7°$	A1	One correct value to 2 sf or better
	Range: $18.6 < \theta < 82.7$	A1	Accept < or $\leqslant$ $\left(19 \leq \theta \leq 82 \text{ or } 83\right)$ max 3 sf
		[3]	

c	$y = 10\tan 40° - \frac{9.8\times 100}{2\times 400}\left(1+\tan^2 40°\right)$	M1	Use given formula to find vertical height
	$y = 6.3(03...)\,(\text{m})$	A1	Can be implied by correctly substituted formula
	Conservation of energy	DM1	Dependent on the first M1. Need all 3 terms. Dimensionally correct. Condone sign errors.
	$\frac{1}{2}mv^2 = \frac{1}{2}m\times 400 - mgy$	A1ft	Correct unsimplified equation in y or their y
	$v = 17 \quad (16.6)\,(\text{m s}^{-1})$	A1	2sf or 3sf only
		[5]	
c alt	$20\cos 40°\, t = 10\ ,\ t = \frac{1}{2\cos 40°} = 0.653....$ $\updownarrow v_V = 20\sin 40° - gt$	M1	Complete method using *suvat* to vertical component of speed e.g. by finding time taken then use of $v = u - gt$ or finding vertical distance and using *suvat*
	$= 6.5 \quad (6.459...)$	A1	6.5 or better (not final answer so allow > 3sf or a correct unsimplified expression)
	$v^2 = (v_H)^2 + (v_V)^2$	DM1	Correct use of Pythagoras

			Dependent on preceding M mark
	$\leftrightarrow v_H = 20\cos 40° \left(= 15.3....\right)$	A1	Horizontal component of speed seen or implied
	$v = 17 \quad (16.6)\,(\text{m s}^{-1})$	A1	2sf or 3sf only
		[5]	
d	$0 = x\tan 40° - \dfrac{9.8x^2}{800}\left(1 + \tan^2 40°\right)$	M1	Complete method to solve for x.
	$x = 40\,(40.2)\,(\text{m})$	A1	2sf or 3sf only
		[2]	
d Alt1	$y = 0 \Rightarrow t = \dfrac{40\sin 40°}{g} \left(= 2.623...\right)$ $x = 20\cos 40° \times t$	M1	Complete method to solve for x.
	$x = 40\,(40.2)\,(\text{m})$	A1	2sf or 3sf only
		[2]	
d Alt2	$\text{Range} = \dfrac{20^2 \sin 80°}{g}$	M1	Complete method to solve for x.
	$= 40\,(40.2)\,(\text{m})$	A1	2sf or 3sf only
		[2]	
		(16)	

Q31.

Question	Scheme	Marks	Notes
a	Energy equation	M1	Q requires energy. Need all terms and dimensionally correct. Condone sign error.
	$\frac{1}{2}mv^2 = \frac{1}{2}m(9+4) + mg \times 20$	A1	Correct unsimplified equation
	$v = 20\,(20.1)\,(\text{ms}^{-1})$	A1	2 sf or 3 sf only. Not $9\sqrt{5}$
		(3)	
b	Complete method to find the direction as an angle	M1	Complete method to find trig ratio for a relevant angle
	$\cos\alpha = \frac{3}{\text{their (a)}}$	A1ft	Correct unsimplified equation for a relevant angle. Follow their part (a)
	$\alpha = 81°\,(81.4°)$ below the horizontal	A1	Or equivalent. 2 sf or 3 sf. Needs to be clear on a diagram or in words where the angle is measured. Accept "to the horizontal"
		(3)	
b alt	Complete method to find the direction as a vector in **i** and **j** or as a column vector	M1	
	Component $= \sqrt{(a)^2 - 9}$	A1ft	Correct unsimplified equation. Follow their part (a)
	Direction $3\mathbf{i} - 19.9\mathbf{j}$	A1	2 sf or 3 sf. ISW after correct vector seen
		(3)	
c	Form an equation in t	M1	Complete method using *suvat* Condone sign errors.
	e.g. $-20 = 2t - \frac{1}{2}gt^2$ or $(-20.1...)\sin\alpha = 2 - gt$	A1	Correct unsimplified equation
	$t = 2.2\,(2.23)\,(\text{s})$	A1	2 sf or 3 sf only
		(3)	

d	Perpendicular velocity $= 3\mathbf{i} - \lambda\mathbf{j}$	B1	Horizontal component unchanged and vertical not equal to ± 2. Seen or implied
	$(3\mathbf{i} + 2\mathbf{j}).(3\mathbf{i} - \lambda\mathbf{j}) = 0$	M1	Complete method to solve for vertical component If using angles, they should be using $56.3°$ for the perpendicular direction.
	$\Rightarrow \mathbf{v} = \left((3\mathbf{i}) - \frac{9}{2}\mathbf{j}\right)(\text{ms}^{-1})$	A1	Correct vertical component seen or implied
	Use of *suvat* or use of energy to find relevant distance	dM1	Complete method to find the vertical component of perpendicular velocity. Dependent on the previous M1 Working with $3\mathbf{i} - 2\mathbf{j}$ is not equivalent work
	$\left(\frac{9}{2}\right)^2 = 2^2 + 2gs$ or $\frac{1}{2}m(13) + mgs = \frac{1}{2}m\left(9 + \frac{81}{4}\right)$	A1	Correct unsimplified equation for their distance
	$h = 20 - s = 19\,(19.2)$	A1	2 sf or 3 sf
		(6)	

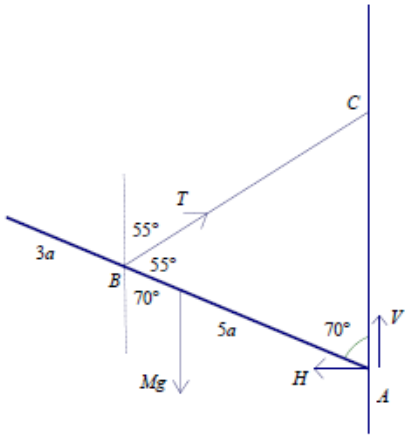
Q32.

Question	Scheme	Mark	Notes
a	$4-gT_1=0$ or $T_1=\dfrac{\sqrt{32}\sin 45°}{g}$	M1	Complete method using *suvat*
	$T_1=0.408\,(0.41)$	A1	3 sf or 2 sf only. Not $\frac{20}{49}$
		[2]	
b	Height of Q above P:	M1	Complete method using *suvat* and 7 and 4 for the initial vertical components
	$h=\left(7T_1-\frac{1}{2}gT_1^2\right)-\left(4T_1-\frac{1}{2}gT_1^2\right)\quad(=3T_1)$	A1	Correct unsimplified expression in T_1 or their T_1 They do not need to have substituted for T_1 (2.0408… - 0.8163…)
	$h=1.2$ (m)	A1ft	2 sf only $(3\times \textit{their}\ T_1)$
		[3]	
c	Correct time for P to reach B. ($\frac{40}{49}$, 0.816, or $\frac{8}{g}$ or better)	B1	Seen or implied.
	Vertical component of speed $=7-g\times 2T_1\quad(=-1)$	M1	Complete method using *suvat* with $2T_1$ or their t for the time at B M0 if not using 7
	$\tan\alpha=\pm\dfrac{\textit{their}\ 1}{5}$	M1	Correct use of *their* 1 and 5 to find an equation in a relevant angle (e.g. 90 – α)
	$\alpha=11$	A1	11 or better (e.g. 11.3)
	If they use T_1 in place of $2T_1$ can score B0M0M1A0		
		[4]	
d	Form an equation in T_2 only	M1	Complete method using *suvat* and perpendicular gradients. e.g. $\begin{pmatrix}5\\7\end{pmatrix}.\begin{pmatrix}5\\7-gT_2\end{pmatrix}=0$ Condone sign errors (Vertical component of speed $=\pm\frac{25}{7}$) (perpendicular direction is downwards at 35.5° to the horizontal)
	$-\dfrac{25}{7}=7-gT_2$	A1	Correct unsimplified equation
	$T_2=1.08$ or $T_2=1.1$	A1	3 sf or 2 sf only
		[3]	
		(12)	

Q33.

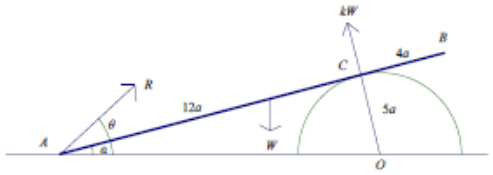
a	Speed after first collision $=\frac{2}{3}u$	B1	Seen or implied (possibly on diagram)
	Speed after second collision $=\frac{4}{9}u$	B1	Seen or implied (possibly on diagram)
	Correct method for total time	M1	Correct formula, dimensionally correct and including all 3 elements.
	$T_1=\frac{d}{u}+\frac{3d}{\frac{2}{3}u}+\frac{2d}{\frac{4}{9}u}\quad\left(=\frac{d}{u}+\frac{9d}{2u}+\frac{18d}{4u}\right)$	A1	Correct unsimplified expression for T_1
	$T_1=\frac{10d}{u}$	A1	Correct single term. Allow unsimplified fraction e.g. $T_1=\frac{40d}{4u}$
		[5]	
b	$T_2=\frac{10d}{\frac{4}{9}u}=\frac{45d}{2u}\quad\left(T_2=\frac{9}{4}T_1\right)$	B1ft	Follow through is on their T_1 and / or their $\frac{4}{9}u$ Any equivalent form e.g $\frac{90d}{4u}$.
		[1]	
		(6)	

Q34.

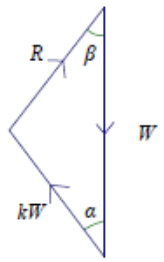
Q	Solution	Mark	Notes
a			
	Moments about A:	M1	Need all terms and dimensionally correct. Condone sign errors and sin/cos confusion Or complete method to form equation in T (and M).
	$5a \times T\sin 55° = 4a\cos 20° \times Mg$	A1	Correct unsimplified equation in T (and M).
	$T = \dfrac{4\cos 20°}{5\sin 55°} Mg \left(= 0.918Mg\right)$	A1	Or equivalent (Exact or $0.92Mg$ or better)
		(3)	
b	Resolve vertically	M1	Need all terms. Condone sign errors and sin/cos confusion
	$\updownarrow: Mg = V + T\cos 55°$ $\left(V = 0.47...Mg\right)$	A1	Correct unsimplified equation in T or their T
	Resolve horizontally	M1	Condone consistent sin/cos confusion
	$H = T\sin 55°$ $\left(H = 0.75...Mg\right)$	A1	Correct unsimplified equation in T or their T
	Resultant $\lambda = \sqrt{\left(0.4736..\right)^2 + \left(0.7517..\right)^2}$	M1	Substitute for T and use Pythagoras
	$= 0.89$	A1	The Q asks for 2 sf
		(6)	

b alt	Moments about B	M1	Dimensionally correct. Need all terms. Condone sign errors and sin/cos confusion
	$Mga\cos 20° + 5aH\cos 70° = 5aV\cos 20°$	A1	Correct unsimplified equation
	Moments about C	M1	Dimensionally correct. Condone sign errors and sin/cos confusion
	$5aH = 4aMg\cos 20°$	A1	Correct unsimplified equation
	Resultant $\lambda = \sqrt{\left(0.4736..\right)^2 + \left(0.7517..\right)^2}$	M1	Use Pythagoras
	$= 0.89$	A1	The Q asks for 2 sf

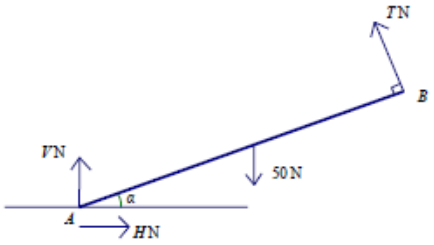
Q35.

a			
	Angle ACO is a right angle or state that AB is a tangent hence triangle is $5a$, $12a$, $\underline{13a}$ *	B1*	Or equivalent **explanation** of **given answer.** They need to say why it is a 5, 12, 13 triangle. If they say nothing, check the diagram to see if there is a right angle marked.
		[1]	
b	Moments about A:	M1	Dimensionally correct equation Condone sin / cos confusion
	$W \times 8a\cos\alpha = kW \times 12a$ $\left(W \times 8a \times \frac{12}{13} = kW \times 12a\right)$	A1	Correct unsimplified equation
	$k = \frac{8}{13}$ *	A1*	Obtain given answer from correct working. Need to see correct substitution for $\cos\alpha$ and correct final statement.
		[3]	

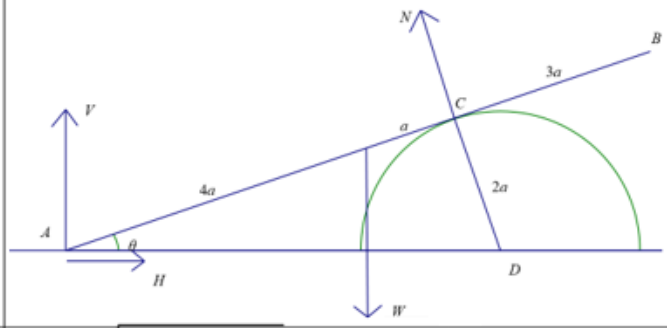
c	$\leftrightarrow R_H = kW\sin\alpha$	M1	First equation e.g. resolve horizontally. Condone sin/cos confusion
	$= \frac{8W}{13} \times \frac{5}{13} = \frac{40W}{169}$	A1	Correct unsimplified expression for R_H
	$\updownarrow R_V + kW\cos\alpha = W$	M1	Second equation e.g. resolve vertically. Condone sin/cos confusion and sign errors.
	$R_V = W - \frac{8W}{13} \times \frac{12}{13} = \frac{73W}{169}$	A1	Correct unsimplified expression for R_V
	$\lvert R\rvert^2 = (R_V)^2 + (R_H)^2$	DM1	Dependent on the two preceding M marks. Method to obtain the magnitude, e.g.correct use of Pythagoras
	$\lvert R\rvert = \frac{W}{169}\sqrt{40^2 + 73^2}$ $= \frac{\sqrt{6929}}{169}W = \frac{\sqrt{41}}{13}W$	A1	Accept $0.49W$ or better Allow $\sqrt{\frac{41W^2}{169}}$ or correct unsimplified form. ISW
	$\tan\theta° = \frac{73}{40}$ $(=1.825)$	DM1	Dependent on the first 2 M marks. Method to obtain the angle, e.g.correct use of trigonometry to find a relevant angle $(\theta$ or $90-\theta)$
	$\theta = 61$ (61.3)	A1	61 or better (61.2796…)
		[8]	
	See overleaf for alternatives		
c Alt 1	$P = W\sin\alpha$	M1	First equation e.g. resolve parallel to the rod. Condone sin/cos confusion.

	$=\frac{5W}{13}$	A1	Correct unsimplified expression for parallel component
	$Q+kW=W\cos\alpha$	M1	Second equation e.g. resolve perpendicular to the rod. Condone sin/cos confusion and sign errors.
	$Q=\frac{12}{13}W-\frac{8}{13}W=\frac{4W}{13}$	A1	Correct unsimplified expression for perpendicular component
	$\lvert R\rvert=\sqrt{P^2+Q^2}$	DM1	Dependent on the first 2 M marks. Correct use of Pythagoras
	$\lvert R\rvert=\frac{W}{13}\sqrt{4^2+5^2}=\frac{\sqrt{41}}{13}W$	A1	Accept $0.49W$ or better Allow correct unsimplified form
	$\theta°=\tan^{-1}\frac{5}{12}+\tan^{-1}\frac{4}{5}$	DM1	Dependent on the first 2 M marks. Correct use of trig to find the required angle
	$\theta=61\quad(61.3)$	A1	61 or better (61.2796…)
		[8]	
c Alt2		M1 A1	Vector diagram showing the three forces acting Correctly configured
	Use of Cosine Rule:	M1	Correct use of cosine rule for their triangle
	$R^2=W^2+(kW)^2-2W(kW)\cos\alpha$	A1	Correct unsimplified equation.
	$R^2=W^2+\frac{64}{169}W^2-\frac{16}{13}\times\frac{12}{13}W^2\left(=\frac{41}{169}W^2\right)$	DM1	Solve for R. Dependent on the first 2 M marks
	$\lvert R\rvert=\frac{\sqrt{41}}{13}W$	A1	Accept $0.49W$ or better
	$\frac{R}{\sin\alpha}=\frac{kW}{\sin\beta}\quad\left(\sin\beta=\frac{8}{13}\times\frac{\sqrt{41}}{13}\times\frac{5}{13}\right)$	DM1	Dependent on the first M mark. Correct method to find a relevant angle e.g. by use of sine rule
	$\theta=90-28.7=61.3$	A1	61 or better (61.2796…)
		[8]	
		(12)	

Q36.

a			
	Moments about A	M1	Dimensionally correct equation i.e. force x distance = force x distance. Condone sin/cos confusion Mark 50g as an accuracy error
	$4T = 2\cos\alpha \times 50$ $\left(= 2\times\frac{4}{5}\times 50\right)$	A1	Correct unsimplified equation. Need to see $\cos\alpha$ **OR** $\frac{4}{5}$ Might see LHS = $T\cos\alpha\times 4\cos\alpha + T\sin\alpha\times 4\sin\alpha$
	$T = 20$ *	A1*	Obtain **given answer** from correct working. Must see $\frac{4}{5}$ used correctly.
		[3]	
b	Resolve horizontally	M1	Condone sin/cos confusion
	$H = T\sin\alpha$	A1	Correct equation
	Resolve vertically	M1	Need all 3 terms. Condone sign error and sin/cos confusion.
	$T\cos\alpha + V = 50$	A1	Correct equation
	Either or both of the above equations could be replaced by a moments equation e.g. $\mathrm{M}(B): 4\cos\alpha\times V = 4\sin\alpha\times H + 2\cos\alpha\times 50$ or by resolving perpendicular & parallel to the rod: $T + V\cos\alpha = 50\cos\alpha + H\sin\alpha$ & $50\sin\alpha = H\cos\alpha + V\sin\alpha$		
	Use $F = \mu R$ to form an equation in μ	M1	$(H = \mu V)$ Used, not just stated i.e. they must get as far as substituting their values.
	$\mu = \frac{6}{17}$	A1	$\mu = 0.35$ or better Accept $\frac{12}{34}$
		[6]	
		(9)	

Q37.

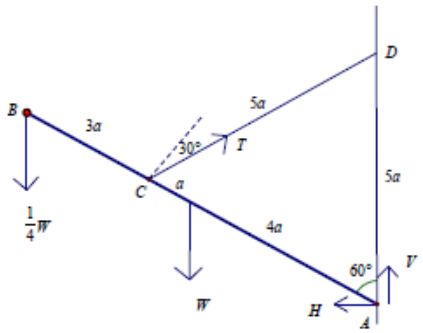
Q	Mark Scheme	Marks	Marking guidance
			
(a)	$AD = \sqrt{(2a)^2 + (5a)^2} = \sqrt{29}a$ *	B1*	Correct use of Pythagoras to show **given answer** from correct working (need a on both sides)
		1	
(b)	M(A): $W \times 4a\cos\theta = N \times 5a$	M1	Dimensionally correct equation in a. Allow if a cancelled. Condone sin/cos confusion
	$W \times \frac{5}{\sqrt{29}} \times 4a = N \times 5a$	A1	Correct unsimplified equation in a. Allow if a cancelled. Allow with $\cos\theta$ NB: $5a = \sqrt{29}a\cos\theta$
	$N = \frac{4}{\sqrt{29}}W$ *	A1*	Obtain **given answer** from correct working
		3	
(c)	The candidates need to form sufficient equations to solve for k and $\tan\alpha$. There should be two independent equations. On epen, allow M1A1 for the first equation seen, and M1A1 for the second equation. If there are more than 2 equations, award the marks for the equations used to solve for k and $\tan\alpha$. If they stop after forming the equations allow the best 2 marks equations.		
	Resolve vertically	M1	Requires all relevant terms. Condone sin / cos confusion

	$V + N\cos\theta = W$ $\quad \left(V = \frac{9}{29}W\right)$ or $kW\sin\alpha + N\cos\theta = W$	A1	Correct unsimplified equation. Need not substitute for trig.
	Resolve horizontally	M1	Requires all relevant terms. Condone consistent sin / cos confusion

	$H = N\sin\theta\left(=\frac{8}{29}W\right)$ or $kW\cos\alpha = N\sin\theta\left(=\frac{8}{29}W\right)$	A1	Correct unsimplified equation. Need not substitute for trig.
	Possible alternative equation for M1A1 using M(C) : $aW\cos\theta + 5aH\sin\theta = 5aV\cos\theta$ or $aW\cos\theta = kW\times 5a\sin(\alpha-\theta)$		
	Use Pythagoras to obtain k: $k^2 = \left(\frac{9}{29}\right)^2 + \left(\frac{8}{29}\right)^2$	DM1	Correct use of perpendicular components. Dependent on the first 2 M marks
	$k = \frac{\sqrt{145}}{29} = \sqrt{\frac{5}{29}}$	A1	Correct only. Any equivalent exact form (ISW but 0.415 with no exact answer seen is A0)
	Use trig to obtain $\tan\alpha$	DM1	Dependent on the first 2 M marks
	$\tan\alpha = \frac{9}{8}$	A1	Correct only. Must be a simplified number. Do not accept answer including W
		8	
(c) alt	Resolve parallel to rod	M1	Requires all relevant terms. Condone sin / cos confusion
	$F = W\sin\theta\left(=\frac{2}{\sqrt{29}}W\right)$	A1	Correct unsimplified equation. Need not substitute for trig.
	Resolve perpendicular to rod	M1	Requires all relevant terms. Condone consistent sin / cos confusion
	$E + N = W\cos\theta \quad \left(E = \frac{1}{\sqrt{29}}W\right)$	A1	Correct unsimplified equation. Need not substitute for trig.
	Possible alternative equation for M1A1 using M(C) : $aW\cos\theta + 5aH\sin\theta = 5aV\cos\theta$ or $aW\cos\theta = kW\times 5a\sin(\alpha-\theta)$		
	Use Pythagoras to obtain k	M1	Correct use of Pythagoras
	$k = \frac{1}{\sqrt{29}}\sqrt{1+4} = \sqrt{\frac{5}{29}}$	A1	Correct only
	Use trig to obtain $\tan\alpha$: $\tan(\alpha-\theta) = \frac{1}{2} = \frac{\tan\alpha - \frac{2}{5}}{1+\frac{2}{5}\tan\alpha}$	DM1	Use of trig to obtain expression in $\tan\alpha$

	$\tan\alpha = \frac{9}{8}$	A1	Correct only with no errors seen
		8	
		(12)	

Q38.

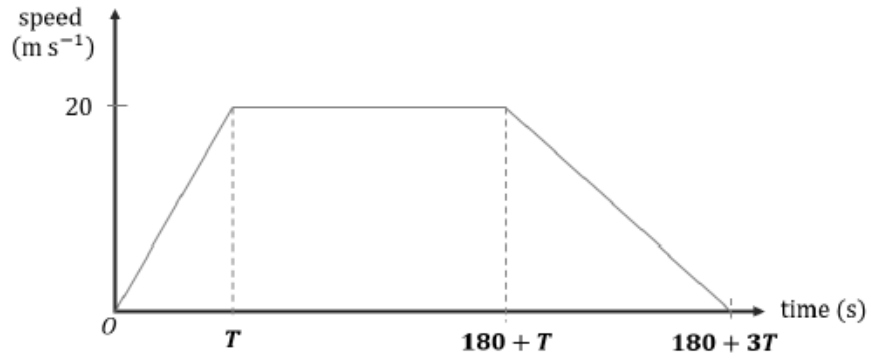
Question	Scheme	Mark	Notes
a			
	Moments about A: **M0 if there is no resolving**	M1	Need all terms and no extras. Dimensionally consistent. Condone sign errors and sine/cosine confusion.
	$4a\cos 30°\times W+8a\cos 30°\times\frac{W}{4}$ $=5a\cos 30°\times T$	A1	Correct unsimplified equation
	$6W=5T\Rightarrow T=\frac{6}{5}W$ *	A1*	Obtain **given answer** from correct working, e.g. show cancelling of the common factors or some simplification of the moments equation
		[3]	

b	They need 2 equations. Award M1A1 for the first correct equation seen and M1A1 for the second correct equation. Common alternatives: $M(B)$: $T\cos 30°\times 3a+V\cos 30°\times 8a=W\cos 30°\times 4a+H\cos 60°\times 8a$ $M(C)$: $W\cos 30°\times a+H\cos 60°\times 5a=\frac{1}{4}W\cos 30°\times 3a+V\cos 30°\times 5a$ Perpendicular to rod: $\frac{1}{4}W\cos 30°+W\cos 30°+H\cos 60°=T\cos 30°+V\cos 30°$ Parallel to rod: $\frac{1}{4}W\cos 60°+T\cos 60°+W\cos 60°=V\cos 60°+H\cos 30°$		
	First equation dimensionally correct. Condone sine/cosine confusion and sign errors	M1	e.g. Resolve horizontally
	Correct unsimplified equation	A1	$H=T\cos 30°\quad\left(H=\frac{3\sqrt{3}}{5}W\right)$
	Second equation dimensionally correct. Condone sine/cosine confusion and sign errors	M1	e.g. resolve vertically
	Correct unsimplified equation	A1	$V+T\cos 60°=W+\frac{W}{4}\quad\left(V=\frac{13}{20}W\right)$
	$\lvert R\rvert=\sqrt{V^2+H^2}$ or $\lvert R\rvert^2=V^2+H^2$	DM1	Correct use of Pythagoras Dependent on two preceding M marks.
	$\lvert R\rvert=\frac{W}{20}\sqrt{3\times 144+169}=\frac{\sqrt{601}}{20}W$	A1	$1.2W$ or better (1.22576…)
		[6]	
		(9)	

Q39.

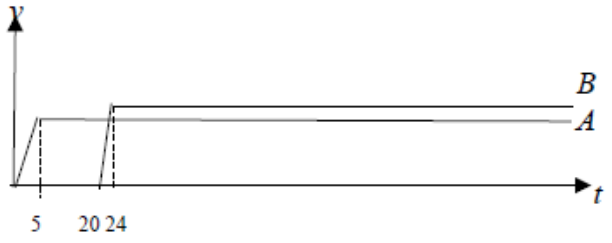
Q	Solution	Mark	Notes
a	Resolve perpendicular to the plane	M1	Condone sin/cos confusion
	$R = 6g\cos\theta$	A1	Correct resolution
	$F = \frac{1}{4}R = \frac{18g}{13} = 13.6(\text{N})$ or $14(\text{N})$	A1	2 sf or 3 sf for decimal answer
		(3)	
b	Equation of motion parallel to the plane	M1	Need all terms and dimensionally correct. Condone sign errors and sin/cos confusion.
	$-F - 6g\sin\theta = 6a$	A1	Correct unsimplified equation in F Allow $-6a$ on RHS
	$0 = 5^2 + 2\times as$	M1	Complete method using *suvat* and calculated a ($a \neq g$) to find s This is independent of previous M mark but they must have found a value for a.
	$0 = 5^2 - 2\times\frac{8g}{13}s$	A1	Correct unsimplified equation. Allow $(-s)$
	$s = 2.07(\text{m})$ or $2.1(\text{m})$	A1	Must be positive.
		(5)	
c	Equation of motion parallel to the plane	M1	Need all terms and dimensionally correct. Condone sign errors and sin/cos confusion.
	$6g\sin\theta - F = 6a'$	A1	Correct unsimplified equation in F
	$5^2 = 0 + 2a's$	M1	Complete method using *suvat*, with $a' \neq a$ and $a' \neq g$ to find s
	$5^2 = 0 + 2\times\frac{2g}{13}\times s$	A1	Correct unsimplified equation
	$8.29(\text{m})$ or $8.3(\text{m})$	A1	
		(5)	
		[13]	

Q40.

Question Number	Scheme	Marks
(a)		B1 shape B1 20 B1 T, T+180, $3T$+180
		(3)
(b)	T and $2T$ seen or implied, for acceleration and deceleration in that order	B1
	Any of: $4800 = \left(\frac{20\times T}{2}\right) + (180\times 20) + \left(\frac{20\times 2T}{2}\right)$ $4800 = \left(\frac{20\times T}{2}\right) + \frac{1}{2}\times 20(180 + (180 + 2T))$ $4800 = \frac{1}{2}\times 20(180 + T + 180) + \left(\frac{20\times 2T}{2}\right)$ $4800 = \frac{1}{2}\times 20(180 + 3T + 180)$ $4800 = 20\times(180 + 3T) - \left(\frac{20\times T}{2}\right) - \left(\frac{20\times 2T}{2}\right)$	M1 A1 A1
	$T = 40$ (allow t)	A1
		(5)
(c)	$20 = a$ x their T oe	M1
	Acceleration $= \frac{1}{2}\left(\text{m s}^{-2}\right)$	A1 ft
		(2)
		(10)

NOTES		
(a)		
B1	Correct shape with acceleration steeper than deceleration (**ignore** entries on the axes).	
B1	Correct vertical label.	
B1	Correct horizontal labels. Accept use of their T or appropriately labelled delineators.	
(b)		
B1	Correct relationship seen or implied between the time accelerating and the time decelerating.	
M1	**A clear attempt** to use the total area under the graph (or use *suvat* formulae) and equate to 4800 (or 4.8) to form an equation in T only or their unknown only (e.g. replace T by $\frac{20}{a}$). Must involve a triangle or a trapezium (M0 if they use a *single suvat* formula for the whole motion)	
A1	An equation with at most one error. (use of 3 instead of 180 is one error) Having T and $2T$ round the wrong way, treat as one error	
A1	A fully correct equation	
A1	cao **N.B.** If attempting to use a single trapezium, and '180' appears in the bracket i.e. $\frac{1}{2}\times 20(\text{'}T\text{ terms'} + 180)$, allow at least M1A1 for one correct parallel side. **N.B.** $\frac{1}{2}\times 20(x+180) = 4800$ => $x = 300$ ONLY scores B0M1A1A0A0	
(c)		
M1	Correct equation in a, using their T	
A1 ft	Correct answer, follow through on their '40'	

Q41.

Q	Solution	Mark	Notes
a			
	Correct shape for sketch for A, starting at the origin.	B1	B0 if solid vertical line at the end of either.
	Correct shape for sketch for B, must be correct relative to A, crossing it and ending at same time. Must be done on the same axes.	B1	Tram B starts later and acceleration greater.
	5, 20, 24 shown	DB1	Dependent on previous two marks
		(3)	

b	$t = 20 + \frac{10}{3}\left(= \frac{70}{3}\right)$	B1	
	Distance travelled for either vehicle	M1	
	$\frac{1}{2}\times\frac{10}{3}\times 10$ **OR** $\frac{1}{2}\times 5\times 10 + \frac{55}{3}\times 10$; $\frac{1}{2}\left(\frac{70}{3}+\frac{70}{3}-5\right)\times 10$	A1	
	Find second distance and subtract	M1	
	$d = \frac{625}{3} - \frac{50}{3} = \frac{575}{3} = 191\frac{2}{3}$	A1	Accept 192 or better.
		(5)	
c	Equate distances from O	M1	Find both distances at time t seconds and equate, using correct structure – see examples.
	$\left(\frac{t+t-5}{2}\right)\times 10 = \left(\frac{t-20+t-24}{2}\right)\times 12$ **OR** $\left(\frac{1}{2}\times 5\times 10\right)+10(t-5) = \left(\frac{1}{2}\times 4\times 12\right)+12(t-24)$	A2	Correct unsimplified equation, –1 each error (up to a maximum of 2)
	$t = 119.5$	M1	Solve for t
	Distance $= 5\times(6\times 44 - 30) = 1170$ (m)	A1	Accept 1200 or better
		(5)	
		[13]	

Q42.

Question	Scheme		Marks
	$76 = 4u + \frac{1}{2}a.4^2$ or $76 = \frac{1}{2}\left(u + \overline{u+4a}\right)\times 4$	Use of $s = ut + \frac{1}{2}at^2$ for $t = 4, s = 76$ and $u \neq 0$ (use of $u = 0$ is M0)	M1
	$(38 = 2u + 4a)$	Correctly substituted equation	A1
	$295 = 10u + \frac{1}{2}a.10^2$ or $295 = \frac{1}{2}\left(u + \overline{u+10a}\right)\times 10$ or $295 = (u+10a)\times 10 - \frac{1}{2}a\times 100$	Use of $s = ut + \frac{1}{2}at^2$ for $t = 10, s = 295$ or $s = u't + \frac{1}{2}at^2$ for $t = 6, s = 219, u' \neq u$	M1
	$(59 = 2u + 10a)$ or $219 = (19+2a)\times 6 + \frac{1}{2}a\times 6^2$ or $219 = (38-u)\times 6 + \frac{1}{2}a\times 6^2$ or $219 = (u+4a)\times 6 + \frac{1}{2}a\times 6^2$ or $219 = \frac{1}{2}\left(\overline{u+4a} + \overline{u+10}\right)\times 6$ or $219 = (u+10a)\times 6 - \frac{1}{2}a\times 36$	Correctly substituted equation	A1
	Solve simultaneous for u or for a. This marks is not available if they have assumed a value for u or a in the preceding work - it is dependent on the first 2 M marks.		DM1
	$u = 12$		A1
	$a = 3.5$		A1
			(7)

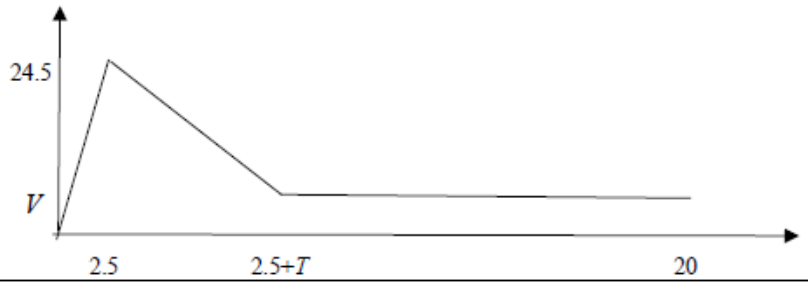
	Alternative		
	$t = 2,\ v_2 = \frac{76}{4} = 19$ $t = 7,\ v_7 = \frac{219}{6} = 36.5$	Find the speed at $t = 2, t = 7$ Both values correct Averages with no links to times is M0	M1 A1
	$36.5 = 19 + 5a \Rightarrow a = 3.5$	Use of $v = u + 5a$ with their u, v Correct a	M1 A1
	$19 = u + 2a$	Complete method for finding u Correct equation in u	DM1 A1
	$u = 19 - 7 = 12$		A1
			(7)
			(7 marks)

Q43.

Question Number	Scheme	Marks
(a)	$v^2 = 20^2 - 2g \times (-3)$	M1
	$v = 21$ or 21.4 (m s^{-1})	A1 (2)
(b)	Complete method to find the total time: e.g. **either:** $-5 = 20t - \frac{1}{2}gt^2$ using one equation **or:** $0 = 20 - gt_1$ $(\Rightarrow t_1 = \frac{100}{49} = 2.040816..)$ $s_1 = (\frac{20+0}{2})t_1$ $(= \frac{1000}{49} = 20.40816...)$ (or $s_1 = 20t_1 - \frac{1}{2}gt_1^2$) using four equations $25.408.. = \frac{1}{2}gt_2^2$ $(\Rightarrow t_2 = 2.2771..)$ $t = t_1 + t_2 = 4.31795..$ and many other methods	M1
	There are two A marks for all the equations they use, -1 each error **N.B.** The second M mark should be treated as an A mark	A1 M(A)1
	$t = 4.3$ or 4.32 (s)	A1
		(6)

	Notes for question	
(a)	M1 **Complete** method to find the speed, must be using 3 or -3 (Allow 9.81 for g or just g), condone sign errors	
	A1 Correct answer (Must have used 9.8 and be positive)	
(b)	M1 **Complete** method to find the total time, condone sign errors	
	A1 M(A)1 There are now two A marks for the equation(s) that they use, -1 for each error. (Allow 9.81 for g or just g)	
	A1 Correct answer (Must have used 9.8)	
	N.B. No isw for this question **e.g. If they had the correct quadratic but went on to add the roots, this would lose the M mark.**	

Q44.

Question Number	Scheme	Marks
(a)	$v = 2.5\times 9.8 = 24.5\ (\text{m s}^{-1})$ Allow $2.5g$	B1 (1)
(b)		B1 shape B1 figures (2)
(c)	$73.75 = \dfrac{(24.5+(24.5-3.9T))T}{2}$ **OR** $73.75 = 24.5T - \dfrac{1}{2}\times 3.9T^2$ **OR** $73.75 = (24.5-3.9T)T + \dfrac{1}{2}\times 3.9T\times T$ **OR** $V^2 = 24.5^2 + 2\times(-3.9)\times 73.75$ and then $5 = 24.5 - 3.9T$ $T = 5$ **N.B.** The second M mark should be treated as an A mark	M1 A1A1M1 A1 (5)
(d)	Height = Total area under graph	
	$= \left(\dfrac{1}{2}\times 24.5\times 2.5\right) + 73.75 + (20-2.5-5)\times(24.5-3.9\times 5)$	M1A2
	=167 (m) nearest metre.	A1 (4)
		(12)

	Notes for question	
(a)	B1 cao	
(b)	B1 Correct shape of graph with the second line less steep than the first Graph may be reflected in the *t*-axis. B0 if solid vertical line at $t = 20$	
	B1 All five values correctly placed (allow omission of 0 and appropriate delineators)	
(c)	M1 for a complete method to obtain an equation, with a correct structure, in T only.	
	A1A1M1(A1) For a correct equation or equations, -1 each error.	
	A1 cao (must be a single answer i.e the other root (7.56) must be clearly rejected.	
(d)	M1 for a complete method, using the total area under the graph oe, with a correct structure (i.e. triangle + trapezium + rectangle oe), to obtain an expression for the height of H above the ground.	
	A2 For a correct equation, -1 each error.	
	A1 cao	

Q45.

Question Number	Scheme	Marks
(a)	$v^2 = 25^2 - 2\times 6\times 48$	M1
	$v = 7\,(\text{m s}^{-1})$	A1
		(2)
(b)	$\frac{25-13}{6}$ (2)	M1
	$13^2 = 25^2 - 2\times 6s$ **OR** $25\times 2 - \frac{1}{2}\times 6\times 2^2$ **OR** $\frac{(25+13)}{2}\times 2$ **OR** $13\times 2 - \frac{1}{2}\times(-6)\times 2^2$ $((s=)\ 38)$	M1
	Total time $= \frac{(48-38)}{13} + 2$	DM1
	$\frac{36}{13} = 2\frac{10}{13}$ (s) (2.76923…)	A1
		(4)
(c)	$\frac{25-13}{6}$ (2) (could be implied by 2.2)	M1
	$(0.2\times 25) + (25\times 2 - \frac{1}{2}\times 6\times 2^2)$ (5 + 38)	M1
	Total time $= \frac{48-[(0.2\times 25)+38]}{13} + 0.2 + 2$	DM1
	$\frac{168}{65} = 2\frac{38}{65}$ (s) (2.58461538..)	A1
		(4)
		(10)

	Notes for question	
(a)	M1 Complete method to find v (condone sign errors)	
	A1 cao	
(b)	M1 Complete method to find time to reach 13 m s^{-1}	
	M1 Complete method to find distance travelled in reaching 13 m s^{-1} ft on their 2 if necessary	
	DM1 Dependent on previous two M marks, Complete method to find the total time, ft on their 2 and 38	
	A1 Correct answer. Allow 2.8 or better	
(c)	M1 Complete method to find the time taken to reach 13 m s^{-1} once it starts decelerating	
	M1 Complete method to find total distance travelled in reaching 13 m s^{-1} ft on their 2 if necessary	
	DM1 Dependent on previous two M marks, Complete method to find the total time, ft on their 2 and 38	
	A1 Correct answer. Allow 2.6 or better	

Q46.

Question Number	Scheme	Marks
(a)	$0 = u - 9.8 \times 2.5$ oe using gradient of graph. Allow g or 9.81 instead of 9.8	M1
	$u = 24.5$ or 25 (m s^{-1}) Allow $2.5g$	A1
	Many other methods	(2)
(b)	$s = 24.5 \times 2 + \frac{1}{2} \times 9.8 \times 2^2$ **OR** $s = 24.5 \times 7 - \frac{1}{2} \times 9.8 \times 7^2$ **OR** $s = \frac{1}{2} \times 9.8 \times 4.5^2 - (24.5 \times 2.5 + \frac{1}{2} \times (-9.8) \times 2.5^2)$ **OR** $s = \frac{1}{2} \times 9.8 \times 4.5^2 - \frac{1}{2} \times 9.8 \times 2.5^2$ Many other methods, using *suvat* and/or the graph (e.g. similar triangles and area under graph) Allow g or 9.81 instead of 9.8 in all equations.	M1A1ft
	68.6 or 69 (m)	A1
		(3)
		(5)
	Notes for question	
	For use of $g = 9.81$, which will only affect the final A mark in each part, penalise once for whole question	
(a)	M1 for complete method using *suvat* or the graph to produce an equation in u only, with correct number of terms, condone sign errors.	
	A1 cao (must be positive)	
(b)	M1 Complete method to give a final displacement, condone sign errors within a *suvat* equation.	
	A1ft Correct equation ft on their u	
	A1 cao	

Q47.

Question Number	Scheme	Marks
(a)	$220 = (28\times 10) - \frac{1}{2}a\times 10^2$	M1 A1
	Other possible equations, any 2 of which could be used to obtain an equation in a **only**: $28 = u + 10a$ $220 = \frac{(u+28)}{2}\times 10$ $220 = 10u + \frac{1}{2}a\times 10^2$ $28^2 = u^2 + 2a\times 220$	
	$a = 1.2\ (\text{m s}^{-2})$	A1
		(3)
(b)	Any ONE of these: $28 = u_4 + 1.2\times 6 \Rightarrow u_4 = 20.8$ $28 = u_5 + 1.2\times 5 \Rightarrow u_5 = 22$ $s_4 = 16\times 4 + \frac{1}{2}\times 1.2\times 4^2 = 73.6$ $s_5 = 16\times 5 + \frac{1}{2}\times 1.2\times 5^2 = 95$ Allow distances from Q e.g. $s_6 = 28\times 6 - \frac{1}{2}\times 1.2\times 6^2 = 146.4$ $s_5 = 28\times 5 - \frac{1}{2}\times 1.2\times 5^2 = 125$	M1A1ft
	e.g. $s = 20.8\times 1 + \frac{1}{2}\times 1.2\times 1^2$ **OR** $s = 22\times 1 - \frac{1}{2}\times 1.2\times 1^2$ **OR** $s = 95 - 73.6$ **OR** $22^2 = 20.8^2 + 2\times 1.2s$ **OR** $s = 146.4 - 125$	M1
	21.4 (m) Allow 21 (m).	A1 (4)
		(7)

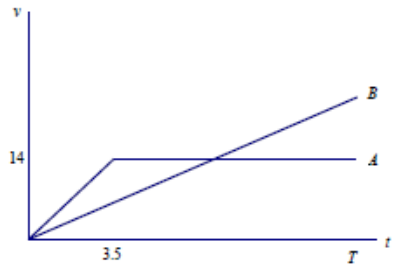
	N.B. Use of an incorrect *suvat* formula is M0.	
(a)	M1 Complete method to find an equation in a **only** (note that $u = 16$) **N.B.** Allow $220 = (28\times 10) + \frac{1}{2}a\times 10^2$ ($s = ut + \frac{1}{2}at^2$ for 'reverse' motion) leading to $a = -1.2$ M1A0A0 but if they then change a to 1.2, then it becomes M1A1A1 retrospectively) M0 if they assume $u = 0$	
	A1 Correct equation	
	A1 cao	
(b)	M1 Complete method to find the speed at $t = 4$ or 5 **OR** a distance at $t = 4$ or 5 M0 if they assume $u = 0$	
	A1**ft** A correct speed or distance, follow through on their a and u but only if u has been **used** to find a in part (a).	
	M1 Complete method to find the required distance	
	A1 cao	

Q48.

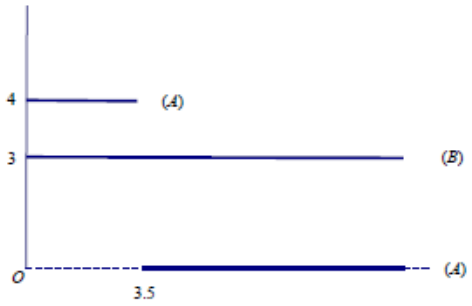
Question Number	Scheme	Marks
(a)	$1.5 = 0 + \frac{1}{2} g t^2$	M1 A1
	$t = 0.55$ or 0.553 (s)	A1
		(3)
(b)	$1.5 = 0 + \frac{1}{2} a (0.6)^2$	M1 A1
	$0.2g - R = 0.2a$	M1 A1
	$R = 0.293$, 0.29	A1
		(5)
		(8)

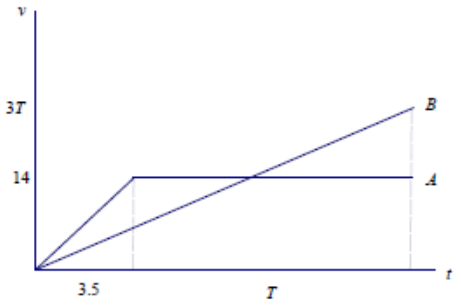
Notes for Question	
(a)	
M1	Complete method to find the time taken using $a = g$
A1	Correct unsimplified equation in t only
A1	Cao
(b)	
M1	Complete method to form an equation in a only, $a \neq g$, using $t = 0.6$
A1	Correct unsimplified equation in a only
M1	Use $F = ma$ to form an equation of motion with correct terms, condone sign errors, $a \neq g$
A1	Correct unsimplified equation
A1	Cao
	N.B. Allow **consistent** use of ($-a$) instead of a and penalise in the second equation if inconsistent. **N.B.** Penalise use of $g = 9.81$ once for the whole question. Also penalise once for the whole question, answers as fractions, penalise the first one, if both answers are fractions.

Q49.

Question	Scheme		Marks
(a)	$v = u + at \Rightarrow 14 = 3.5a$	Use of *suvat* to form an equation in a	M1
	$a = 4$		A1
			(2)
(b)		Graph for A or B	B1
		Second graph correct and both graphs extending beyond the point of intersection	B1
		Values 3.5, 14, T shown on axes, with T not at the point of intersection. Accept labels with delineators.	B1
	NB: 2 separate diagrams scores max B1B0B1		(3)

(c)	$\frac{1}{2}T.3T$, $\frac{(T+T-3.5)}{2}.14$	Find distance for A or B in terms of T only. Correct area formulae: must see $\frac{1}{2}$ in area formula and be adding in trapezium	M1
	One distance correct		A1
	Both distances correct		A1
	$\frac{1}{2}T.3T = \frac{(T+T-3.5)}{2}.14$ $\frac{1}{2}T.3T = \frac{1}{2}\times 4\times 3.5^2 + 14(T-3.5)$	Equate distances and simplify to a 3 term quadratic in T in the form $aT^2+bT+c=0$	M1
	$3T^2 - 28T + 49 = 0$	Correct quadratic	A1
	$(3T-7)(T-7)=0$	Solve 3 term quadratic for T	M1
	$T = \frac{7}{3}$ or 7	Correct solution(s) - can be implied if only ever see $T=7$ from correct work.	A1
	but $T > 3.5$, $T = 7$		A1
			(8)
(d)	73.5 m	From correct work only. B0 if extra answers.	B1
			(1)

(e)		(*A*) Condone missing 4	B1
		(*B*) Condone graph going beyond $T = 7$ Must go beyond 3.5. Condone no 3.	B1
		(*A*) Condone graph going beyond $T = 7$ Must go beyond 3.5. B0 if see a solid vertical line. Sometimes very difficult to see. If you think it is there, give the mark.	B1
			(3)
	Condone separate diagrams.		

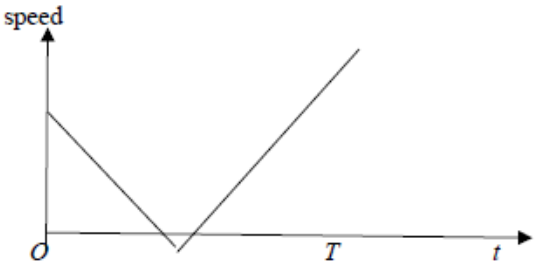
	Alternative for (c) for candidates with a sketch like this: 	Treat as a special case. B1B1B0 on the graph and then max 5/8 for (c) if they do not solve for the T in the question.	B1 B1 B0
	$\frac{1}{2}\times 3\times (T+3.5)^2 = \frac{1}{2}\times 4\times 3.5^2 + 14T$	Use diagram to find area	M1
		One distance correct	A1
		Both distances correct	A1
	$12T^2 - 28T - 49 = 0$	Simplify to a 3 term quadratic in T	M1
		Correct quadratic	A1
	$(2T-7)(6T+7) = 0$	Complete method to solve for the T in the question	M1
	$T = \frac{7}{2}$ or $\frac{-7}{6}$	Correct solution(s) - can be implied if only ever see Total = 7	A1
	Total time = 7		A1
			(8)
			(17 marks)

Q50.

Question	Scheme		Marks
(a)	$7^2 = 2 \text{ x } 9.8h$	Use of $v^2 = u^2 + 2as$ with $u = 0, v = 7$ or alternative complete method to find h	M1
	$h = 2.5$	Condone $h = -2.5$ in the working but the final answer must be positive.	A1
			(2)

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

Q51.

Question Number	Scheme	Marks
(a)	$0^2 = u^2 - 2\times g \times 19.6$	M1 A1
	$-24.5 = uT - \frac{1}{2}gT^2$	M1 A1
	Produce an equation in T *only* and solve for T	DM1
	$T = 5$	A1
		(6)
(b)		B1 Shape DB1 Second line longer than the first, approx. equal angles and T or their answer for T marked
		(2)
		(8)
	Notes for question	
(a)	M1 Attempt at a relevant *suvat* equation which uses $s = 19.6$ (or -19.6), with correct no. of terms but condone sign errors.	
	A1 A correct equation (g does not need to be substituted)	
	M1 Attempt at another relevant *suvat* equation which uses 24.5 or 44.1 e.g. finding time from B to the ground, with correct no. of terms but condone sign errors,	
	A1 A correct equation (neither u nor g need to be substituted)	
	DM1 dependent on both M marks , for finding an equation in T only and solving for T i.e. for a complete method to find T **N.B.** This mark cannot be awarded if their equation has NO solutions.	
	A1 $T = 5$ **N.B.** If $g = 9.8$ has not been used, A0	
(b)	B1 A V-shape (*and nothing else*) starting on the speed axis, with point on the t-axis	
	DB1 Dependent on the first B1, for approximately equal angles between the 2 lines and the t-axis, second line longer than the first, T or their T marked correctly. B0 if clearly unequal angles. **N.B.** If graph reflected, B0 DB0.	

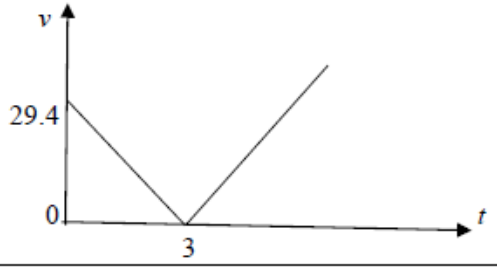
Q52.

Question	Scheme		Marks
(a)	Equate horizontal components of speeds:		M1
	$u\cos\theta° = 6\cos 45°\left(=3\sqrt{2}\right)$ (4.24....)	Correct unsimplified	A1
	Use suvat for vertical speeds: $u\sin\theta° - 2g = -6\sin 45°$	Condone sign errors	M1
	$\left(u\sin\theta = 2g - 3\sqrt{2}\right)$	Correct unsimplified	A1
	Divide to find $\tan\theta$: $\tan\theta = \dfrac{2g - 6\sin 45}{6\cos 45}$	Dependent on previous 2 Ms. Follow their components.	DM1
	$\left(=\dfrac{2g-3\sqrt{2}}{3\sqrt{2}} = 3.61..\right) \Rightarrow$ $\theta = 74.6$ (75)	$(u = 15.93....)$	A1
			(6)
(b)	At max height, speed $= u\cos\theta (= 3\sqrt{2}\ (\text{m s}^{-1}))$		B1
	KE $= \dfrac{1}{2}\times 0.7\times\left(3\sqrt{2}\right)^2$ (J)	Correct for their v at the top, $v \neq 0$	M1
	$= 6.3$ (J)	accept awrt 6.30. CSO	A1
			(3)

(c)	When P is moving upwards at 6 m s^{-1}	Use suvat to find first time $v = 6$	M1
	$u\sin\theta - gt = 3\sqrt{2}$		A1
	$2g - 3\sqrt{2} - gt = 3\sqrt{2}$	Solve for t	M1
	$t = \dfrac{2g - 6\sqrt{2}}{g} = 1.13....$	Sensitive to premature approximation. Allow 1.14.	A1
	$T = 2 - 1.13 = 0.87$	CAO accept awrt 0.87	A1
			(5)
	Alternative		
	$6\sin 45 = 0 + gt$	find time from top to A:	M1A1
	$T = 2t = \dfrac{\dfrac{12\sqrt{2}}{2}}{g} = 0.87$	Correct strategy Correct unsimplified	M1 A1 A1
			(5)

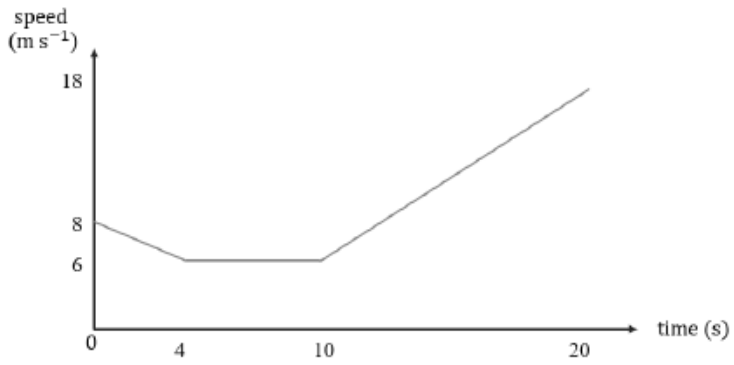
(c) *continued*	**Alternative**		
	: $u\sin\theta = gt$ (their u, θ)	Time to top	M1
	$t = 1.567....$		A1
	$T = 2(2 - 1.567...)$		M1A1
	$= 0.87$		A1
			(5)
	Alternative		
	Vertical speed at A = - (vertical speed at B) = $= \sqrt{36 - (3\sqrt{2})^2} = 3\sqrt{2}$	Or use the 45° angle	M1 A1
	Use $v = u + at$ for $A \to B$	Correct use for their values	M1
	$-3\sqrt{2} = 3\sqrt{2} - gT$		A1
	$T = 0.87$		A1
	See below for alt 7d		(5)
	Alternative 7d		
	$v^2 = (3\sqrt{2})^2 + (u\sin\theta - gt)^2 \leq 36$	Form expression for v^2. Inequality not needed at this stage	M1
		Correct inequality for v^2 .	A1
	$-\sqrt{18} \leq u\sin\theta - gt \leq \sqrt{18}$		M1
	$\frac{u\sin\theta - \sqrt{18}}{g} \leq t \leq \frac{u\sin\theta + \sqrt{18}}{g}$		A1
	$T = \frac{u\sin\theta + \sqrt{18}}{g} - \frac{u\sin\theta - \sqrt{18}}{g} = \frac{2\sqrt{18}}{g} = 0.866$		A1
			(5)
			(14 marks)

Q53.

Question Number	Scheme	Marks
(a)	$0 = 14.7^2 - 2gs$	M1A1
	22 or 22.1 (m)	A1
		(3)
(b)	$19.6 = 29.4t + \frac{1}{2}gt^2$ **N.B.** $19.6 = 29.4t - \frac{1}{2}gt^2$ is M0A0 $-19.6 = 29.4t + \frac{1}{2}gt^2$ is M0A0 $-19.6 = 29.4t - \frac{1}{2}gt^2$ is M0A0 unless they go on to subtract 6 from the positive root	M1A1
	$t = 0.61$ or 0.606 (s)	A1
		(3)
(c)		B1 shape B1 29.4 B1 3
		(3)
		(9)

(a)	M1 Complete method to find distance **UP** **N.B.** They may find time UP (1.5s) **AND** use it to find distance UP **OR**: (Distance from A to top – Distance from '14.7' to top) = (44.1 – 33.075)	
	A1 Correct equation(s) used	
	A1 cao	
(b)	M1 Complete method to find required time **N.B.** They may find the speed as it hits the ground ($g\sqrt{13} = 35.334...$) AND use it to find the time.	
	A1 Correct equation(s) used	
	A1 cao **N.B.** If they add to or subtract from 0.606, it's M0 for an incorrect method.	
(c)	B1 V shape with v coord of end pt > 29.4 and each half roughly equally inclined to the t-axis. B0 if a vertical line is included at the end.	
	B1 29.4 independent	
	B1 3 independent	

Q54.

QUESTION NUMBER	SCHEME	MARKS
(a)	$v = u + at$: $w = 8 + (-0.5)(4)$ (the value of w may not be seen)	M1
	$v = u + at$: $v = w + (1.2)(10)$	M1
	$v = 18$ *	A1*
		(3)
(b)		B1 shape B1 time labels 4,10,20 B1 speed labels 6, 8, 18
		(3)
(c)	Clear **attempt** to find distance using the area under their graph from $t = 0$ to $t = 20$ or another suitable method, even if they are using the wrong shapes. Distance $= \frac{(8+"6")\times 4}{2} + (6\times"6") + \frac{("6"+18)\times 10}{2}$ **OR** $= (6\times 4) + \frac{1}{2}\times 4\times(8-6) + (6\times 6) + (6\times 10) + \frac{1}{2}\times 10\times(18-6)$	M1 A1ft A1ft
	= 184 (m)	A1
		(4)
		(10)

	Notes for question	
(a)		
M1	Complete method for finding the velocity (w) when $t = 4$ M0 if $u = 0$. **N.B.** 6 on its own can imply this mark.	
M1	Method completed to show the speed when $t = 20$ M0 if initial speed is not w.	
A1*	Fully correct solution leading to given answer	
(b)		
B1	Correct shape of graph	
B1	Correct time labels	
B1	Correct speed labels **N.B**. Solid vertical line(s) B0 for the shape.	
(c)		
M1	Complete method to find distance travelled in 20 seconds. May use speed-time graph or *suvat* equations for **three** sections (28m, 36m, 120m) of the journey. Award this mark for a clear **attempt** to find the area and penalise errors in the A marks. M0 if graph does not have three sections.	
A1ft	Equation with at most one error, ft their "6"	
A1ft	Correct equation, ft their "6"	
A1	Correct final answer	

Q55.

Question Number	Scheme	Marks
(a)	$\frac{42mg}{5}-(m+M)g=(m+M)\frac{2g}{5}$ where $M=(p+q)$ **OR :** $\frac{42mg}{5}-Mg=M\frac{2g}{5}$ where $M=p+q+m$	M1 A1
	$(p+q)\ =\ 5m$	dM1 A1
		(4)
(b)	$\frac{14mg}{5}-pg=p\left(\frac{2g}{5}\right)$	M1 A1
	$p=2m$	A1
		(3)
		(7)

	NOTES	
	N.B. Use the mass in the 'ma' term to determine which part of the system is being considered.	
(a)		
M1	Form an equation of motion for the whole system with the combined mass of P and Q. Correct terms, condone sign errors. **N.B.** They may consider the 2 masses (M) and the lift separately and eliminate the normal reaction e.g. $R-Mg=M\frac{2g}{5}$ **AND** $\frac{42mg}{5}-mg-R=m\frac{2g}{5}$ AND add to eliminate R	
A1	Correct equation in M and m for their M **N.B.** Award marks for a correct equation only if no wrong working seen.	
dM1	Rearrange to find an expression for the combined mass of P and Q. Must be a multiple of m	
A1	Cao	
(b)		
M1	Form an equation of motion for box P. Correct terms, condone sign errors. Fully correct equation.	
A1	Cao	
A1	**N.B.** They may find q (M1A1) and subtract from $5m$	

Q56.

	M(*B*) $\left(R_D \times 0.36\right) = W\left(1.26 - x\right)$	
Question Number	**Scheme**	**Marks**
(a)	*P* to *Q* $6x = \left(\frac{u+2u}{2}\right)12$ **OR** $6x = 12u + \frac{1}{2} \times \frac{u}{12} \times 12^2$ **OR** $(2u)^2 = u^2 + 2 \times \frac{u}{12} \times 6x$	M1
	Reaches given answer from correct working $x = 3u$ *	A1*
		(2)
(b)	*Q* to *R* e.g. $(3u)^2 = (2u)^2 + 2(1.5)(15u)$	M1 A1
	$u = 9$	A1
		(3)
(c)	*Q* to *S* (*t* = 14 position) $QS = 2u \times 2 + \frac{1}{2} \times 1.5 \times 2^2$	M1 A1
	$(4u + 3) + 18u$	M1
	201 (m)	A1
		(4)
(9)		

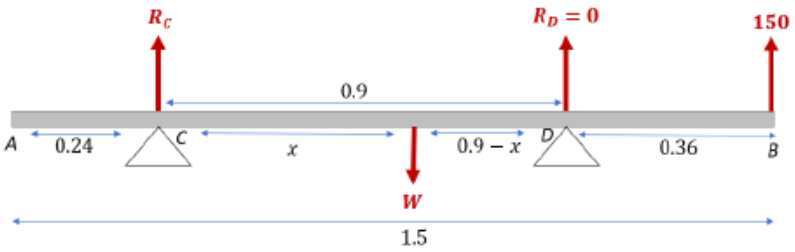
	NOTES	
(a)		
M1	Considers *P* to *Q* and forms a relevant equation in terms of *u* and *x*	
A1*	Reaches given answer from correct working	
(b)		
M1	Uses the given answer in (a) to form an equation in *u* only **N.B.** If brackets missing, allow M1, but allow recovery.	
A1	Correct unsimplified equation in *u* only	
A1	Correct answer	
(c)		
M1	Complete method to find the distance travelled in the 2 seconds after passing *Q*	
A1	Correct unsimplified expression in *u* only (or 39 m)	
M1	Complete method to find the required distance (need $18u$ or $6x$)	
A1	Correct answer	

Q57.

Question Number	Scheme	Marks
	$R_D = 0$ for scenario 1 or $R_C = 0$ for scenario 2	B1
	Scenario 1 M(C) $(150 \times 1.26) = Wx$	M1 A1
	Scenario 2 M(D) $(225 \times 0.36) = W \times (0.9 - x)$	M1 A1
	Solve simultaneously for W (or x) e.g. $0.81W = 243$	dM1
	$W = 300$	A1
	$x = 0.63$	A1
		(8)

NOTES		
	N.B. B0 means there are no other marks available.	
B1	$R_D = 0$ for scenario 1 seen on a diagram or implied by working. OR: $R_C = 0$ for scenario 2 seen on a diagram or implied by working.	
M1	Complete method to form an equation in W and a consistent unknown distance *only*, for scenario 1. All equations used must be dimensionally correct and have the correct no. of terms but condone sign errors. (M0 if $R_D = 0$ is never used)	
A1	Correct unsimplified equation in W and x or their defined unknown distance.	
M1	Complete method to form an equation in W and a consistent unknown distance *only*, for scenario 2. All equations used must be dimensionally correct and have the correct no. of terms but condone sign errors. (M0 if $R_C = 0$ is never used)	
A1	Correct unsimplified equation in W and x or their defined unknown distance	
dM1	Dependent on both M's, solve simultaneous equations for either W or their unknown Correct answer for W	
A1	Correct answer for x This must be the distance stated in the question, from C to the centre of mass.	
A1		
	N.B. If they include g in a moments equation, they lose the A mark for that equation and both final A marks.	

Scenario 1



Equations with unknown distance, x, measured from C.

Complete method will involve one moments equation with $R_D = 0$ or two equations with R_C eliminated and $R_D = 0$.

M0 if R_D never equals zero

Vert $R_C + 150 = W$

M(A) $(R_C \times 0.24) + (150 \times 1.5) = W(x + 0.24)$

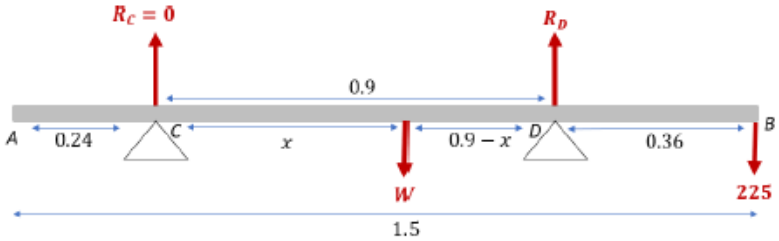
M(C) $(150 \times 1.26) = Wx$

M(G) $R_C x = 150(1.26 - x)$

M(D) $(R_C \times 0.9) = (150 \times 0.36) + W(0.9 - x)$

M(B) $(R_C \times 1.26) = W(1.26 - x)$

Scenario 2



Equations with unknown distance, x, measured from C

Complete method will involve one moments equation with $R_C = 0$ or two equations with R_D eliminated and $R_C = 0$.

M0 if R_C never equals zero

Vert $R_D = 225 + W$

M(A) $(R_D \times 1.14) = (225 \times 1.5) + W(x + 0.24)$

M(C) $(225 \times 1.26) + Wx = (R_D \times 0.9)$

M(G) $R_D(0.9 - x) = 225(1.26 - x)$

M(D) $(225 \times 0.36) = W(0.9 - x)$

Q58.

Question Number	Scheme	Marks
	Perpendicular to direction of motion: $500\sin 40° = P\sin\alpha°$	M1 A1
	Parallel to direction of motion: $500\cos 40° + P\cos\alpha° = 900$	M1 A1
	(i) Form and solve an equation in α $\tan\alpha° = \dfrac{500\sin 40°}{900 - 500\cos 40°}$	M1
	$\alpha = 32$ or better $(31.8683\ldots)$	A1
	(ii) Form and solve an equation in P $P = \dfrac{500\sin 40°}{\sin 31.868\ldots°}$	M1
	$P = 610$ or better $(608.736\ldots)$	A1
	N.B. Penalise over accurate answers only once for the question.	
	ALTERNATIVE USING A TRIANGLE OF FORCES: Cosine Rule: $P^2 = 500^2 + 900^2 - 2\times 500\times 900\cos 40^o$ OR: $500^2 = P^2 + 900^2 - 2\times P\times 900\cos\alpha°$ OR: $900^2 = P^2 + 500^2 - 2\times P\times 500\cos(140^o - \alpha°)$	M1 A1
	Sine Rule /Lami's Theorem: $\dfrac{P}{\sin 40^o} = \dfrac{500}{\sin\alpha°} = \dfrac{900}{\sin(140^o - \alpha°)}$ (any two)	M1 A1
	(i) Solve for α $\alpha = 32$ or better $(31.8683\ldots)$	M1 A1
	(ii) Solve for P $P = 610$ or better $(608.736\ldots)$	M1 A1
		(8)

	NOTES	
M1	Form an equation perpendicular to the direction of motion. Correct number of terms, condone sign errors and sin/cos confusion.	
A1	Correct unsimplified equation	
M1	Form an equation parallel to the direction of motion. If using $F = ma$ then must have $a = 0$. Correct number of terms, condone sign errors and sin/cos confusion.	
A1	Correct unsimplified equation	
(i) M1	Form and solve an equation in α (This an M mark so do not penalise accuracy of manipulation)	
A1	Accept 32 or better (i.e 32, 31.9, 31.87,… as their **final** answer)	
(ii) M1	Form and solve an equation in P (This an M mark so do not penalise accuracy of manipulation)	
A1	Accept 610 or better (i.e 610, 609, 608.7,… as their **final** answer)	
M1	**ALTERNATIVE**	
A1	Use cosine rule to give an equation in P (and α possibly) Correct equation	
M1	Use sine rule to give an equation in P and α	
A1	Correct equation	
	N.B. They could use the Sine or the Cosine Rule **twice** to obtain their two equations.	
(i) M1	Form and solve an equation in α	
A1	Accept 32 or better (i.e 32, 31.9, 31.87,… as their **final** answer)	
(ii) M1	Form and solve an equation in P	
A1	Accept 610 or better (i.e 610, 609, 608.7,… as their **final** answer)	

Q59.

a	Condone use of θ or a mixture of θ and α throughout but final answer should be in one variable.		
	Equation for horizontal distance	M1	Complete method using *suvat*. Condone sine / cosine confusion
	$x = u\cos\alpha\, t$	A1	Correct only
	Equation for vertical distance	M1	Complete method using *suvat*. Condone sine / cosine confusion and sign error
	$y = u\sin\alpha\, t - \frac{1}{2}gt^2$	A1	Correct only
	$t = \frac{x}{u\cos\alpha} \Rightarrow$ $y = u\sin\alpha.\frac{x}{u\cos\alpha} - \frac{g}{2}\left(\frac{x}{u\cos\alpha}\right)^2$	DM1	Substitute for t to obtain y in terms of x and α Dependent on the 2 preceding M marks
	$\Rightarrow y = x\tan\alpha - \frac{gx^2}{2u^2}\left(1+\tan^2\alpha\right)$ *	A1*	Obtain **given answer** from full and correct working. Need some evidence for the final step. $\frac{1}{\cos^2\alpha} = 1+\tan^2\alpha$ is not sufficient.
		6	
b	Conservation of energy:	M1	Method specified in the question. Need all terms and dimensionally correct. Condone sign errors
	$\frac{1}{2}m\times 25^2 = \frac{1}{2}mU^2 + mg\times 20$	A1	Correct unsimplified equation
	$U = 15.3\ (15)$	A1	3 sf or 2 sf only
		3	
c	Use part (a) or work from first principles to form an equation in $\tan\theta$	M1	$\left(-20 = 30\tan\theta - \frac{9.8\times 900}{2U^2}\left(1+\tan^2\theta\right)\right)$
	Obtain $18.9\tan^2\theta - 30\tan\theta - 1.07 = 0$ $\left(\frac{4410}{233}\tan^2\theta - 30\tan\theta - \frac{250}{233} = 0\right)$	A1ft	Or 3 term equivalent Follow their U Can be implied by a correct final answer
	$\Rightarrow \theta = 58.3°$ or $58°$	A1	3 sf or 2 sf only
		3	
		(12)	

Q60.

Q	Solution	Mark	Guidance
a	Use of $v = \frac{dx}{dt}$	M1	Recognisable attempt to differentiate the given expression
	$0 = 7t^{\frac{1}{2}}\left(t^2 - 5t + 4\right)$	DM1	Set $v = 0$ and solve for t Dependent on first M1
	$t = 1$ and $t = 4$	A1	Correct solution only
		(3)	
b	$s = \lvert x_1 - x_0 \rvert + \lvert x_4 - x_1 \rvert$	M1	Correct strategy to find distance for their value(s) of t in $[0, 4]$ **Allow M1 if there is no change of direction in the interval**
	$= \left\lvert \frac{20}{3} - 0 \right\rvert + \left\lvert -\frac{128}{3} - \frac{20}{3} \right\rvert$	A1ft	Correct unsimplified expression for their distance (provided there was a change in direction in [0, 4]) **Clearly using $x(4) + 2x(1)$ but $x(4)$ miscalculated so correct combined expression never seen. M1 only**
	$= 56$	A1	Correct solution only
		(3)	
c	Use of $a = \frac{dv}{dt}$	M1	Recognisable attempt to differentiate
	$a = \frac{35}{2} \times 4^{\frac{3}{2}} - \frac{105}{2} \times 4^{\frac{1}{2}} + 14 \times 4^{-\frac{1}{2}}$	M1	Substitute $t = 4$ in their a and simplify
	$= 42$	A1	Correct solution only
		(3)	
		[9]	

Q61.

Question Number	Scheme	Marks
(a)	$mv\dfrac{\mathrm{d}v}{\mathrm{d}x} = mg\sin\alpha - \dfrac{1}{3}mx^2$	M1A1
	$\dfrac{1}{2}v^2 = xg\sin\alpha - \dfrac{1}{9}x^3 \ (+c)$	DM1A1
	$x = 2 \ \ \dfrac{1}{2}v^2 = 2g\sin\alpha - \dfrac{8}{9}$	DM1
	$(v = 3.728...)$	
	$v = 3.7$ or $3.73 \ \left(\mathrm{ms}^{-1}\right)$	A1cso (6)
ALT	By energy:	
	$mg\sin\alpha x = \int\dfrac{1}{3}mx^2\mathrm{d}x + \dfrac{1}{2}mv^2$	M1A1
	$xg\sin\alpha = \dfrac{1}{9}x^3 + \dfrac{1}{2}v^2 \ (+c)$	DM1A1
	$x = 2 \ \ \dfrac{1}{2}v^2 = 2g\sin\alpha - \dfrac{8}{9}$	DM1
	$v = 3.7$ or $3.73 \ \left(\mathrm{ms}^{-1}\right)$	A1
(b)	$v = 0 \Rightarrow x^2 = 9g\sin\alpha = 9g \times \dfrac{2}{5} \ (x \neq 0)$	
	$x = 5.939... \Rightarrow OA = 5.9$ or $5.94 \ (\mathrm{m})$	M1A1 (2)
		[8]

Question Number	Scheme	Marks
(a)		
M1	Attempt an equation of motion parallel to the plane with acceleration in any form (including a)	
A1	Correct equation with the acceleration in $v\dfrac{\mathrm{d}v}{\mathrm{d}x}$ form	
DM1	Attempt the integration, powers increase by 1 in 2 terms – the constant may be missing. Acceleration must be in $v\dfrac{\mathrm{d}v}{\mathrm{d}x}$ form.	
A1	Correct integration.	
DM1	Sub $x = 2$ in their expression for v^2 Depends on all previous M marks.	
A1	Correct value for v and $+c$ should be dealt with. Must be 2 or 3 sf	
ALT		
M1	Attempt a 3 term energy equation – KE, GPE, work done. Integral form is not required here.	
A1	Fully correct equation with integral form for work done. Rest as main scheme.	
(b)		
M1	Use $v = 0$ in their expression for v and obtain a value of x	
A1	Correct value of length OA. (Allow if x instead of OA) Must be 2 or 3 sf (unless already penalised in (a)	
ALT (b)	Start again with energy and integrate to obtain a value of x	
M1	See mark scheme.	
A1		

Q62.

	Solution	Mark	Guidance
a			**Allow column vectors.**
	Use of $\mathbf{v}=\dfrac{\mathrm{d}\mathbf{r}}{\mathrm{d}t}$	M1	Powers going down by 1. At least 2 powers going down .
	$\mathbf{v}=\left(3t^2-8\right)\mathbf{i}+\left(t^2-2t+2\right)\mathbf{j}$	A1	Any equivalent form
	Use of $\mathbf{a}=\dfrac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$	M1	Powers going down by 1. At least 2 powers going down .
	$\mathbf{a}=6t\mathbf{i}+\left(2t-2\right)\mathbf{j}$	A1	Any equivalent form
	$=24\mathbf{i}+6\mathbf{j}\left(\mathrm{m\,s^{-2}}\right)$	A1	Must see acceleration stated as a correct simplified vector. ISW
		[5]	
b	Direction $2\mathbf{i}+\mathbf{j}$	M1	Form equation in t or T only using direction. Condone use of 2 on the wrong side. Using their **v**
	$\Rightarrow\left(3T^2-8\right)=2\left(T^2-2T+2\right)$ $\left(T^2+4T-12=0\right)$	A1ft	Correct unsimplified **equation** in t or T. **Solving not required for the M1** Follow their **v**: **i** component = 2(**j** component)
	$T=2$	A1	Only Do not need to see method of solution.
		[3]	
		(8)	

Q63.

Question Number	Scheme	Marks
(a)	$v=\dfrac{50}{2x+3}$	
	$\dfrac{dv}{dt}=\dfrac{dv}{dx}\times\dfrac{dx}{dt}$	M1
	$=\dfrac{-100}{(2x+3)^2}\times\dfrac{50}{2x+3}\quad\left(=\dfrac{-5000}{(2x+3)^3}\right)$	DM1A1
	$x=12\quad\dfrac{dv}{dt}=-\dfrac{5000}{27^3}=-0.2540...=-0.25$ or $-0.254\ \text{m s}^{-2}$	M1
	deceleration $=0.25\ (\text{m s}^{-2})$ or better	A1 (5)
(b)	$v=\dfrac{dx}{dt}=\dfrac{50}{2x+3}$	M1
	$\int(2x+3)\,dx=\int 50\,dt$	
	$x^2+3x=50t\ (+c)$	M1A1
	$t=1,\ x=4\Rightarrow 28=50+c,\ c=-22$	A1
	$x=12\Rightarrow 50t=12^2+36+22\quad t=\dfrac{202}{50}=4.04$ (accept 4.0)	A1 (5)
		[10]

	Notes
(a)	
M1	Uses chain rule of the form $\dfrac{dv}{dt}=\dfrac{dv}{dx}\times\dfrac{dx}{dt}$ or $\dfrac{d(\frac{1}{2}v^2)}{dx}$
	Note, $\dfrac{1}{2}v^2=\dfrac{1250}{(2x+3)^2}\ \Rightarrow\ \text{acc}=\dfrac{d(\frac{1}{2}v^2)}{dx}=-\dfrac{2500}{(2x+3)^3}\times 2$
	However, **M0** for acc $=\dfrac{1}{2}v^2$
DM1	Differentiate v wrt x
A1	Correct differentiation.
M1	Sub $x=12$ into their expression for acceleration to obtain the deceleration. Must have attempted to differentiate.
A1	Correct deceleration – must be positive
(b)	
M1	Use $v=\dfrac{dx}{dt}$
M1	Attempt at integration
A1	Correct integration but c may be missing
A1	Use $t=1,\ x=4$ to obtain the correct value of c for their correct integration
A1	Sub $x=12$ to obtain the correct value of t

ALT (b)	Using definite integration: $\int_4^{12}(2x+3)dx=\int_1^T 50\,dt$
M1	Integrate $\left[x^2+3x\right]_4^{12}=\left[50t\right]_1^T$
A1	Correct integration
A1	Sub in limits $12^2+3(12)-4^2-3(4)=50T-50$
A1	Obtain correct value

Q64.

Q	Mark Scheme	Marks	Marking guidance
(a)	$\lambda\lambda^2 + - = = +2 \quad 3$ $0((\lambda\lambda 3)(-1))$	M1	Set **j** component = 0 and solve for λ
	$\Rightarrow = \lambda\ 1$	A1	Only. Seen or implied. Accept $t = 1$
	Use $\mathbf{a} = \frac{d\mathbf{v}}{dt}$	M1	Attempt derivative of both components with respect to t. Powers going down. Condone errors in dealing with the signs / indices for the square root. The answer must be a vector.
	$= \mathbf{i} + \frac{-1}{2\sqrt{5-t}} + (2t\ 2)\mathbf{j}$	A1	Any equivalent form
	$= -\frac{1}{4} + 4\ \mathbf{ij}$	A1	Only. Any equivalent form. ISW if they go on to find the magnitude.
		5	

(b)	Use $\mathbf{s} = \int \mathbf{v}dt$	M1	Attempt integral of both components (M0 if they have assumed that one component is zero) Powers going up. Condone errors in dealing with the signs indices for the square root.
	$\mathbf{s} = -\frac{(5-t)^{\frac{1}{2}}}{3}(+A)\mathbf{i} + \frac{1}{3}t^3 + -t^2 3t(+B)\mathbf{j}$	A1 A1	Unsimplified expression with error in at most one term Correct unsimplified expression. Allow with no constant(s) of integration
	Use $t = = - +1$, $\mathbf{s}\ 2\mathbf{i}\ \mathbf{j}$	DM1	Use of initial condition to find constant(s) of integration. Dependent on the previous M1.
	$\mathbf{s} = -\frac{2(5-T)^{\frac{3}{2}}}{3} + 10\mathbf{i} + 1T_3 + T_2 - 3T + \frac{8}{3}\mathbf{j}$	A1	Any equivalent form for the position vector
		5	
		(10)	

Q65.

Question	Scheme	Mark	Notes
	Accept column vectors throughout this question		
a	Differentiate **r** (both components)	M1	In each component at least one power going down by 1
	$\mathbf{v}=\left(4t^3-16t\right)\mathbf{i}+\left(12t-3\sqrt{t}\right)\mathbf{j}$	A1	Accept as two separate components
	Equate **i** component of **v** to zero and solve for t	DM1	Dependent on the first M1. Must start with a component of the vector for **v** Can have more than one value at this stage.
	Obtain $\left(24-3\sqrt{2}\right)\mathbf{j}\ \left(\text{ms}^{-1}\right)$	A1	Accept $20\mathbf{j}\left(\text{ms}^{-1}\right)$ or better. (19.757359…) Correct answer only Answer must be a vector
		[4]	
b	Differentiate **v** (both components)	M1	For differentiating their **v**, even if the method for obtaining it was incorrect. Their **v** must be a vector. In each component at least one power going down by 1
	Obtain $\mathbf{a}=\left(12t^2-16\right)\mathbf{i}+\left(12-\frac{3}{2}t^{-\frac{1}{2}}\right)\mathbf{j}$	A1	Any equivalent form for acceleration
	Obtain $176\mathbf{i}+\frac{45}{4}\mathbf{j}\left(\text{ms}^{-2}\right)$	A1	Accept $180\mathbf{i}+11\mathbf{j}\left(\text{ms}^{-2}\right)$ or better ISW
		[3]	
		(7)	

Q66.

Question	Scheme		Marks
(a)	$(2\mathbf{i}-3\mathbf{j})+(p\mathbf{i}+q\mathbf{j})=(p+2)\mathbf{i}+(q-3)\mathbf{j}$	Resultant force = $\mathbf{F}_1+\mathbf{F}_2$ in the form $a\mathbf{i}+b\mathbf{j}$	M1
	$\frac{p+2}{q-3}=\frac{1}{2}$ or $\left.\begin{matrix}p+2=n\\q-3=2n\end{matrix}\right\}$ for $n\neq 1$	Use parallel vector to form a scalar equation in p and q.	M1
		Correct equation (accept any equivalent form)	A1
	$4+2p=-3+q$	Dependent on no errors seen in comparing the vectors. Rearrange to obtain given answer. At least one stage of working between the fraction and the given answer	DM1
	$2p-q+7=0$	**Given Answer**	A1
			(5)

(b)	$q=11\Rightarrow p=2$		B1
	$\mathbf{R}=4\mathbf{i}+8\mathbf{j}$	$(2+p)\mathbf{i}+8\mathbf{j}$ for their p	M1
	$4\mathbf{i}+8\mathbf{j}=2\mathbf{a}$ $(\mathbf{a}=2\mathbf{i}+4\mathbf{j})$	Use of $\mathbf{F}=m\mathbf{a}$	M1
	$\lvert\mathbf{a}\rvert=\sqrt{2^2+4^2}$	Correct method for $\lvert\mathbf{a}\rvert$ Dependent on the preceding M1	DM1
	$=\sqrt{20}=4.5$ or 4.47 or better (m s^{-2})	$2\sqrt{5}$	A1
			(5)
	Alternative for the last two M marks:		
	$\lvert\mathbf{F}\rvert=\sqrt{16+64}\left(=\sqrt{80}\right)$	Correct method for $\lvert\mathbf{F}\rvert$	M1
	$\sqrt{80}=2\times\lvert\mathbf{a}\rvert$	Use of $\lvert\mathbf{F}\rvert=m\lvert\mathbf{a}\rvert$ Dependent on the preceding M1	DM1
			(5)
			(10 marks)

Q67.

a	Use $t=2$ and $3t^2+2t=t^3+kt$ $(12+4=8+2k)$	M1	Allow verification.
	$k=4$ *	A1*	Obtain given answer from correct working. Verification requires a clear conclusion.
		2	
b	Use of $\mathbf{a}=\frac{d\mathbf{v}}{dt}$	M1	Differentiate the vector v Majority of powers going down
	$\mathbf{a}=(6t+2)\mathbf{i}+(3t^2+4)\mathbf{j}$	A1	Correct only
	Use $\lvert\mathbf{F}\rvert=m\lvert\mathbf{a}\rvert$	DM1	Correct use of Pythagoras and N2L Dependent on the preceding M1
	$\lvert\mathbf{F}\rvert=1.5\times\sqrt{14^2+16^2}=3\sqrt{113}$	A1	Or $\frac{3}{2}\sqrt{452}$ or 32 or better (31.89….)
		4	
c	Use of $\mathbf{r}=\int\mathbf{v}\,dt$	M1	Majority of powers going up
	$\mathbf{r}=\left(t^3+t^2(+A)\right)\mathbf{i}+\left(\frac{1}{4}t^4+\frac{4}{2}t^2(+B)\right)\mathbf{j}$	A1	Allow without constant of integration
	Correct use of $\mathbf{r}=3\mathbf{i}+4\mathbf{j}$ when $t=0$ to find r when $t=2$	DM1	$\left(\mathbf{r}=\left(t^3+t^2+3\right)\mathbf{i}+\left(\frac{1}{4}t^4+\frac{4}{2}t^2+4\right)\mathbf{j}\right)$ Dependent on the preceding M1 Use of $\mathbf{r}=-3\mathbf{i}-4\mathbf{j}$ is M0
	$\mathbf{r}=15\mathbf{i}+16\mathbf{j}$	A1	Correct answer only. Accept column vector
		4	
		(10)	

Q68.

Question Number	Scheme	Marks
(a)	$a=v\frac{dv}{dx}$	M1
	$=\frac{3}{2}(2x+1)^{\frac{1}{2}}\times2\times(2x+1)^{\frac{3}{2}}=3(2x+1)^2$	A1
	$3(2x+1)^2=243$	M1
	$x=4$	A1
		(4)
(b)	$(2x+1)^{\frac{3}{2}}=\frac{dx}{dt}$ **OR** $a=3v^{\frac{4}{3}}=\frac{dv}{dt}$	M1 A1
	$\int dt=\int(2x+1)^{-\frac{3}{2}}dx$ $\int 3dt=\int v^{-\frac{4}{3}}dv$	M1
	$t=-(2x+1)^{-\frac{1}{2}}(+C)$ $3t+(C)=-3v^{-\frac{1}{3}}$	A1
	$t=0,\ x=0\Rightarrow C=1$ $t=0,\ x=0\Rightarrow v=1\Rightarrow C=-3$ and obtain an equation in v and t only.	M1
	$v=\frac{1}{(1-t)^3}$	A1
		(6)
		(10)

	Notes
(a)	
M1	Use of $a = v\frac{dv}{dx}$ or $a = \frac{d}{dx}\left(\frac{1}{2}v^2\right)$. Evidence of differentiation, power decreasing by 1. Should see a product of terms to imply 'use of'.
A1	Correct differentiation
M1	Independent. Use their result from differentiation and put $a = 243$ then solve for x
A1	Cao If -5 is seen then it must be rejected or 4 must be clearly identified.
(b)	
M1	Use of $v = \frac{dx}{dt}$ to obtain DE in x and t **OR** Use of $a = \frac{dv}{dt}$ to obtain DE in v and t
A1	Correct equation
M1	Separate and integrate (evidence of integration, power increasing by 1)
A1	Correct integration, condone missing C
M1	Use $t = 0, x = 0$ to obtain a value of C and obtain an equation in v and t *only*.
A1	Cao Accept $v = (1-t)^{-3}$ or $v = \frac{-1}{(t-1)^3}$ or $v = -(t-1)^{-3}$
	Note: No marks in (b) for use of $a = 243$

Q69.

a	Use of $\mathbf{a}=\dfrac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$ $\left(\mathbf{a}=18\cos 3t\,\mathbf{i}-2\sin t\,\mathbf{j}\right)$	M1	Differentiate to obtain $\mathbf{a}=\lambda\cos 3t\,\mathbf{i}+\mu\sin t\,\mathbf{j}$
	Use of $\mathbf{F}=m\mathbf{a}$: $\mathbf{F}=\dfrac{1}{4}\mathbf{a}$	M1	Must be working in vectors
	$\mathbf{F}=\dfrac{9}{2}\cos 3t\,\mathbf{i}-\dfrac{1}{2}\sin t\,\mathbf{j}$	A1	Or equivalent. e.g. as a column vector
		[3]	
b	$2\cos t+1=0$	M1	Set $\mathbf{j}$ component of $\mathbf{v}=0$ and solve for t
	$\Rightarrow t=\dfrac{2\pi}{3}$	A1	ISW if correct answer seen. Only answer $120°$ scores A0 here and the final A0
	Use of $\mathbf{v}=\dfrac{\mathrm{d}\mathbf{r}}{\mathrm{d}t}$ $\left(\mathbf{r}=-2\cos 3t\,\mathbf{i}+\left(t+2\sin t\right)\mathbf{j}\left(+\mathbf{C}\right)\right)$	M1	Integrate $\mathbf{v}$ with respect to t to obtain $\mathbf{r}=p\cos 3t\,\mathbf{i}+\left(t+q\sin t\right)\mathbf{j}\left(+\mathbf{C}\right)$ Condone if there is no constant of integration.
	$t=0,\quad \mathbf{r}=\left(4\mathbf{i}-\sqrt{3}\mathbf{j}\right)\mathrm{m}$ $\mathbf{r}=\left(-2\cos 3t+6\right)\mathbf{i}+\left(t+2\sin t-\sqrt{3}\right)\mathbf{j}$	M1	Correct use of boundary condition to find their **C**. Could be part of a definite integral e.g. $4\mathbf{i}-\sqrt{3}\mathbf{j}+\int_0^t 6\sin 3t\mathbf{i}+\left(1+2\cos t\right)\mathbf{j}\mathrm{d}t$ for their upper limit
	$=4\mathbf{i}+\dfrac{2\pi}{3}\mathbf{j}\quad(\mathrm{m})$	A1 A1	Accept $4\mathbf{i}+2.1\mathbf{j}$ or better one component correct both components correct ISW if they also offer $4\mathbf{i}+120\mathbf{j}$ "correct" components after an M0 are fortuitous – A0
		[6]	
		(9)	

Q70.

Q	Solution	Mark	Guidance
a	$F = \mu R = \frac{1}{5}mg\cos\alpha$	B1	Seen or implied
	Work done = force x distance	M1	Correct method for work done against friction
	$= \frac{1}{5}mg \times \frac{12}{13} \times d = \frac{12}{65}mgd$ *	A1*	Obtain **given answer** from correct working.
		(3)	
b	Work-energy equation	M1	All terms required and dimensionally correct. Condone sign errors and sin/cos confusion
	$\frac{1}{2}mv^2 = mg \times d \times \frac{5}{13} - \frac{12}{65}mgd \left(= \frac{13}{65}mgd \right)$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation
	$v = \sqrt{\frac{2gd}{5}}$	A1	Or exact equivalent e.g. $\sqrt{\frac{26}{65}gd}$, $\frac{1}{5}\sqrt{10gd}$ Accept $0.63\sqrt{gd}$ or better
		(4)	
		[7]	

Q71.

Question	Scheme		Marks
(a)	Resolve perpendicular to the plane: $R = 2g\cos\alpha$		B1
	Use $F = \mu R$: $F = \frac{1}{4} \times 2g \times \frac{4}{5} \left(= \frac{2g}{5} \right)$	with $\frac{1}{4}$ and their R (3.92)	M1
	Work done: WD $= 2.5 \times F$	For their F	dM1
	$= 2.5 \times \frac{2g}{5} = 9.8\,(\text{J})$	Accept g	A1
	If a candidate has found the total work done but you can see the correct terms/processes for finding the work done against friction, give B1M1DM1A0 (3/4)		
			(4)
(b)	Change in PE : $\pm(4g \times 2.5 - 2g \times 2.5\sin\alpha)$	Requires one gaining and one losing Condone trig confusion	M1
	$= \pm(4g \times 2.5 - 2g \times 1.5)$	± (correct unsimplified)	A1
	PE lost $= 7g = 68.6$ (J)	or 69 (J) Accept $7g$	A1
			(3)

(c)	KE gained + WD = loss in GPE	The question requires the use of work-energy. Alternative methods score 0/4. Requires all terms but condone sign errors (must be considering both particles)	M1
	$\frac{1}{2}\times 4v^2+\frac{1}{2}\times 2v^2+(\text{their (a)})=(\text{their (b)})$	Correct unsimplified. -1 each error	A2
	$3v^2=6g$		
	$v=\sqrt{2g}=4.43\ (\text{m s}^{-1})$	or 4.4. Accept $\sqrt{2g}$	A1
			(4)
	Alternative		
	Equations of motion for each particle leading to $T=\frac{12g}{5}=23.52$ followed by a W-E equation for P: $2.5T=\frac{1}{2}\times 2v^2+2g\times 2.5\sin\alpha+(a)$ M1A2	Equations of motion for each particle leading to $T=\frac{12g}{5}=23.52$ followed by a W-E equation for Q: $\frac{1}{2}\times 4v^2+2.5T=4g\times 2.5$	
	$v=\sqrt{2g}=4.43\ (\text{m s}^{-1})$ Use of $\alpha=36.9$ gives correct answers to 3 sf		A1
	Use of $\alpha=37$ gives correct answers to 2 sf and more than this is not justified, so A0 if they give 3 sf in this case.		
			(11 marks)

Q72.

Q	Solution	Mark	Notes
	M1A1M1A1 for 2 independent equations M1A1 to solve for λ		
a	GPE lost	M1	Need all terms. Condone sign errors and sin/cos confusion
	$=3g\times 2-2g\times 2\sin\theta$ $\left(=6g-4g\times\frac{5}{13}\right)$	A1	Correct unsimplified. Accept $\pm$
	$=\frac{58}{13}g=43.7\,(44)\,(\text{J})$	A1	Must be positive. Exact multiple of g or 3 sf or 2 sf
		(3)	
b	Normal reaction $=2g\cos\theta\left(=\frac{24}{13}g\right)$	B1	
	$F_{\max}=\frac{3}{8}\times R\left(=\frac{9g}{13}\right)$	M1	Use $F=\mu R$ with their R
	Work done $=2\times F_{\max}$	M1	Their $F_{\max}$
	$\left(=\frac{18g}{13}\right)=13.6(\text{J})\ \ 14(\text{J})$	A1	Exact multiple of g or 3 sf or 2 sf
		(4)	
c	Total KE gained = GPE lost - total WD against friction	M1	Must be using work-energy. Dimensionally correct. Required terms and no extras. Condone sign errors.
	$\frac{1}{2}(2+3)v^2=(their(a))-(their(b))$ $\left(\frac{5}{2}v^2=\frac{58}{13}g-\frac{18}{13}g=\frac{40}{13}g\right)$	A2ft	Follow their (a) and (b) -1 each error
	$v=\sqrt{\frac{16}{13}g}=3.47\left(\text{m s}^{-1}\right)$ or $3.5\left(\text{m s}^{-1}\right)$	A1	3 sf or 2 sf (need to substitute for g)
		(4)	

d	KE lost = GPE gained + WD against friction	M1	Must be using work-energy. Dimensionally correct. Required terms and no extras. Condone sign errors.
	$\frac{1}{2}\times 2\times\frac{16}{13}g=2g\times d\sin\theta+\frac{3}{8}\times 2g\times\frac{12}{13}d$ $\frac{1}{2}\times 2\times v^2=2g\times d\sin\theta+d\times F_{\max}$ $\frac{16}{13}g=\left(\frac{10}{13}g+\frac{9}{13}g\right)d$	A2ft	Follow their (c) and their $F_{\max}$ -1 each error
	$d=\frac{16}{19}$	A1	g cancels. 0.84 or better $(0.8421....)$
		(4)	
		[15]	

Q73.

Question	Scheme		Marks
(a)	Resolving parallel to the plane	Condone trig confusion	M1
	$D = 900g\sin\theta + 800$		A1
	$\frac{900}{25}g + 800 (= 1152.8)$ (N)		
	Work done : Their $D \times$ distance $= 1152.8 \times 14 \times 10$	Independent. For use of 14 x 10 x their D	M1
	$= 161392 = 161$ kJ (160)	Accept 161000 (J), 160000 (J). Ignore incorrect units.	A1
			(4)
	Alternative using energy		
	Work done $= 900gd\sin\theta + 800d$	Allow with incorrect d	M1A1
	Use of $d = 14 \times 10$	Independent – allow in an incorrect expression	M1
	$= 161392 = 161$ kJ (160)		A1
			(4)
(b)	Equation of motion	All terms required. Condone trig confusion and sign errors. Allow with $900a$	M1
	$D - 900g\sin\theta - 800 = 900 \times 0.7$	Correct unsimplified with $a = 0.7$ used Accept with their 1152.8 arising from a 2 term expression in (a)	A1
	$(D - 1152.8 = 900 \times 0.7)$		
	$D = 1782.8$ (N)		
	Use of $P = Fv$ $\quad P = 14 \times \frac{\text{their } D}{1000}$	Independent Treat missing 1000 as misread, so allow for $14 \times \text{their} D$ Allow for $\frac{1000P}{14}$ (or $\frac{P}{14}$) in their equation of motion	M1
	$P = 25.0\,(25)$	cao	A1
			(4)
			(8 marks)

Q74.

a	Normal reaction between P and the ramp $= 3g\cos\alpha \quad \left(= \frac{18g}{\sqrt{37}} = 29.0\right)$	B1	cao ISW
	Use of $F = \frac{3}{4}R$	M1	$\frac{3}{4} \times$ their R (Must have an R)
	Work done $= 4F$	M1	Their F (Must have an F)
	$= 87.0\,(87)\,(\text{J})$	A1	3 sf or 2 sf only (follows 9.8) do not allow $\frac{54}{\sqrt{37}}g$ (this is an acceleration)
		[4]	
b	Work-energy equation	M1	**M0 if not using work-energy**. All terms required. Condone sign errors Condone sin/cos confusion
	$\frac{1}{2} \times 3U^2 - \text{their(a)} - 3g \times 4\sin\alpha = \frac{1}{2} \times 3 \times 25$	A1ft A1ft	Unsimplified equation with at most one error. Follow their (a) Correct unsimplified equation Follow their (a)
	$U = 9.79$ or $U = 9.8$	A1	3 sf or 2 sf only (follows 9.8)
		[4]	
c	Time taken:	M1	Complete method using *suvat* and $u = 5$ to form an equation in t only
	$-4\sin\alpha = (5\sin\alpha)t - \frac{1}{2}gt^2$ $\left(4.9\sqrt{37}t^2 - 5t - 4 = 0\right)$	A1	Correct unsimplified equation for t.
	$t = 0.45969....$	A1	Seen or implied
	Horizontal distance	M1	Complete method using *suvat* and $u = 5$
	$= (5\cos\alpha)t \quad \left(= \frac{30}{\sqrt{37}}t\right)$	A1ft	Follow their t
	$= 2.27$ or 2.3 (m)	A1	3 sf or 2 sf only
		[6]	

	Alternative: First M1A1 as above Second M1A1 as above Second A1 correct quadratic in horizontal distance e.g. $\frac{37\times4.9}{35\times25}d^2 - \frac{1}{6}d - \frac{4}{\sqrt{37}} = 0$ Final A1 as above		
		(14)	

Q75.

Question Number	Scheme	Marks
	$T = mg\cos\theta$	M1A1
	$T = \dfrac{2mg\left(\dfrac{21}{10}a - ka\right)}{ka}$	M1A1
	$\dfrac{4}{5}mg = \dfrac{2mg\left(\dfrac{21}{10}a - ka\right)}{ka}$	dM1
	$k = \dfrac{3}{2}$ or 1.5	A1
		(6)

	Notes
M1	Resolve parallel to the string, correct no. of terms, condone sign errors and sin/cos confusion (or resolve in two directions and eliminate the unknown force or use trig on a right-angled triangle of forces) to give an equation in T, mg and θ **only**
A1	Correct equation. Trig does not need to be substituted.
M1	Use Hooke's Law with correct structure.
A1	Correct equation
dM1	Substitute trig and eliminate T to produce equation in k only, dependent on previous M's. If x is used for extension, should see $x = \dfrac{2k}{5}a \rightarrow ka + \dfrac{2k}{5}a = \dfrac{21}{10}a$
A1	cao
ALT 1	**First M1A1**
M1A1	Complete method to form an equation in T and θ Vert: $mg = T\cos\theta + F\sin\theta$ Horiz: $F\cos\theta = T\sin\theta$ Eliminate F eg $\dfrac{\sin\theta}{\cos\theta} = \dfrac{mg - T\cos\theta}{T\sin\theta}$

Q76.

Question	Scheme	Mark	Notes
a	Use of $P = Fv$ $\left(F = \frac{500}{6}\right)$	M1	
	Equation of motion	M1	Dimensionally correct. Required terms and no extras
	$F - 60 = 80a$	A1	Correct unsimplified equation in F
	$a = \frac{7}{24}\left(\text{m s}^{-2}\right)$	A1	0.29 or better (0.291666666..)
		[4]	
b	Gain in KE = $\frac{1}{2} \times 80 \times 8^2 (\text{J}) \left(= 2560(\text{J})\right)$ Gain in GPE = $80 \times 9.8 \times 300\ (\text{J}) \left(= 235200(\text{J})\right)$ Work done against resistance $= 20000 \times 60$	B1 B1	Any one correct (seen or implied) A second term correct (seen or implied) (KE gain + GPE gain = 237760 J)
	Use of *suvat* and $F = ma$ is M0A0A0		
	expression for combined work and energy	M1	All terms required and no double counting. Mass replaced with 80. Condone sign errors. Dimensionally correct. Condone error in zeros in 20000
	Total work done $= 40 \times 64 + 80 \times 9.8 \times 300 + 20000 \times 60$	A1	Correct unsimplified expression for the work done
	$1440\left(\text{kJ}\right)$ or $1400\left(\text{kJ}\right)$	A1	Accept answers in joules. 3 sf or 2 sf (1437760)
		[5]	

c	Equation of motion	M1	Dimensionally correct. Required terms and no extras
	$F - 60 - 80g \times \sin\alpha = 0$ $\frac{P}{7} - 60 - 80g \times \frac{1}{20} = 0$	A1 A1	Unsimplified equation in P or F with at most one error Correct unsimplified equation in P
	$P = 694$ or $P = 690$	A1	3sf or 2 sf only
		[4]	
		(13)	