Question			Answer	Marks	Guidance
1	(i)		Total mass of train $= 800\ 000$ kg	B1	Allow 800 (tonnes)
			Total resistance $= 5R + 17R (= 22R)$	B1	
			Newton's 2nd Law in the direction of motion $121\ 000 - 22R = 800\ 000 \times 0.11$	M1	The right elements must be present, consistent with the candidate's answers above for total resistance and mass . No extra forces.
			$22R = 121\ 000 - 88\ 000 \quad R = 1500$	E1 **[4]**	Perfect answer required
	(ii)	(*A*)	**Either** (Last truck)		
			Resultant force on last truck $= 40\ 000 \times 0.11$	B1	Award this mark for $40\ 000 \times 0.11$ (= 4400) or 40×0.11 seen
			Use of Newton's 2nd Law	M1	The right elements must be present and consistent with the answer above; no extra forces.
			$T - 1500 = 40\ 000 \times 0.11$	A1	Fully correct equation, or equivalent working
			$T = 5900$ The tension is 5900 N.	A1	Cao
					Special case Award SC2 to a candidate who, instead, provides a perfect argument that the tension in the penultimate coupling is 11 800 N.
			Or (Rest of the train)		
			Resultant force on rest of train $= 760\ 000 \times 0.11$	B1	Award this mark for $760\ 000 \times 0.11$ (= 83 600) or 760×0.11 seen
			Use of Newton's 2nd Law	M1	The right elements must be present consistent with the answer above; no extra forces.
			$121000 - 31500 - T = 760000 \times 0.11$	A1	Fully correct equation, or equivalent working
			$T = 5900$ The tension is 5900 N.	A1 **[4]**	Cao

Question			Answer	Marks	Guidance
	(ii)	(*B*)	**Either** (Rest of the train)		
			Newton's 2nd Law is applied to the trucks	M1	The right elements must be present; no extra forces
			$S - 25\ 500 = 680\ 000 \times 0.11$	A1	
			$S = 100\ 300$ The tension is 100 300 N.	A1	Cao
			Or (Locomotive)		
			Newton's 2nd Law is applied to the locomotive	M1	The right elements must be present; no extra forces
			$121\ 000 - S - 5 \times 1500 = 120\ 000 \times 0.11$	A1	
			$S = 100\ 300$ The tension is 100 300 N.	A1	Cao
			Or (By argument)		
			Each of the 17 trucks has the same mass, resistance and acceleration.	M1	
			So the tension in the first coupling is 17 times that in the last coupling	A1	
			$T = 17 \times 5900 = 100\ 300$	A1	Cao. For this statement on its own with no supporting argument allow SC2
				[3]	
	(iii)		Resolved component of weight down slope		
			$= 800\ 000 \times 9.8 \times \frac{1}{80}$	B1	$m \times 9.8 \times \frac{1}{80}$ where m is the mass of the object the candidate is considering. Do not award if g is missing. Evaluation need not be seen
			$= 98\ 000$ N		
			Let the acceleration be a m s^{-2} up the slope.		
			Newton's 2nd Law to the whole train,	M1	The right elements must be present consistent with the candidate's component of the weight down the slope. No extra forces allowed
			$121\ 000 - 33\ 000 - 98\ 000 = 800\ 000a$	A1	
			$a = -0.0125$	A1	Cao but allow an answer rounding to –0.012 or -0.013 following earlier premature rounding.
			Magnitude 0.0125 m s^{-2}, down the slope		The negative sign must be interpreted so "Down the slope" or "decelerating" must be seen
				[4]	

Question			Answer	Marks	Guidance
	(iv)		Taking the train as a whole, Force down the slope = Resistance force $800\ 000 \times 9.8 \times \sin\beta = 33\ 000$ $\beta = 0.24°$	M1 A1 A1 **[3]**	Equilibrium of whole train required The evidence for this mark may be obtained from a correct force diagram Allow missing g for this mark only

		mark	comment	sub
2(i)	With the 11.2 N resistance acting to the left			
	N2L $F - 11.2 = 8 \times 2$	M1	Use of N2L (allow $F = mga$). Allow 11.2 omitted; no extra forces.	
		A1	All correct	
	F = 27.2 so 27.2 N	A1	cao	3
(ii)	The string is inextensible	E1	Allow 'light inextensible' but not other irrelevant reasons given as well (e.g. smooth pulley).	1
(iii)		B1	One diagram with all forces present; no extras; correct arrows and labels accept use of words.	
		B1	Both diagrams correct with a common label.	2
(iv)	**method (1)**	M1	For either box or sphere, $F = ma$. Allow omitted force and sign errors but not extra forces. Need correct mass. Allow use of mass not weight.	
	box N2L $\rightarrow 105 - T - 11.2 = 8a$	A1	Correct and in any form.	
	sphere N2L $\uparrow$ $T - 58.8 = 6a$	A1	Correct and in any form. [box and sphere equns with consistent signs]	
	Adding 35 = 14a	M1	Eliminating 1 variable from 2 equns in 2 variables.	
	a = 2.5 so 2.5 m s^{-2}	E1		
	Substitute a = 2.5 giving T = 58.8 + 15	M1	Attempt to substitute in either box or sphere equn.	
	T = 73.8 so 73.8 N	A1		
	method (2)			
	105 – 11.2 – 58.8 = 14a	M1	For box and sphere, $F = ma$. Must be correct mass. Allow use of mass not weight.	
	a = 2.5	A1		
		E1	Method made clear.	
		M1	For **either** box **or** sphere, $F = ma$. Allow omitted force and sign errors but not extra forces. Need correct mass. Allow use of mass not weight.	
	either: box N2L $\rightarrow 105 - T - 11.2 = 8a$			
	or: sphere N2L $\uparrow$	A1	Correct and in any form.	

	$T - 58.8 = 6a$ Substitute a = 2.5 in either equn T = 73.8 so 73.8 N	 M1 A1	 Attempt to substitute in either box or sphere equn. [If AG used in either equn award M1 A1 for that equn as above and M1 A1 for finding T. For full marks, both values must be shown to satisfy the second equation.]	 7
(v) **(A)**	g downwards	B1	Accept $\pm g,\ \pm 9.8,\ \pm 10,\ \pm 9.81$	 1
(B)	Taking ↑ + ve, $s = -1.8$, u = 3 and $a = -9.8$ so $-1.8 = 3T - 4.9T^2$ and so $4.9T^2 - 3T - 1.8 = 0$	M1 E1	Some attempt to use $s = ut + 0.5at^2$ with $a = \pm 9.8$ etc $s = \pm 1.8$ and $u = \pm 3$. Award for a = g even if answer to (A) wrong. Clearly shown. No need to show +ve required.	 2
(C)	See over			
(C)	Time to reach 3 m s $^{-1}$ is given by $3 = 0 + 2.5t$ so t = 1.2 remaining time is root of quad time is 0.98513… s Total 2.1851…so 2.19 s (3 s. f.) With the 11.2 N resistance acting to the right	 B1 M1 B1 A1	 Quadratic solved and + ve root added to time to break. Allow 0.98. [Award for answer seen WW] cao	
(i)	F + 11.2 = 8 × 2 so F = 4.8		The same scheme as above	
(iii)			The 11.2 N force may be in either direction, otherwise the same scheme	
(iv)	The same scheme with + 11.2 N instead of – 11.2 N acting on the box method (1) box N2L $\rightarrow 105 - T + 11.2 = 8a$ sphere as before			

	method (2) 105 + 11.2 – 58.8 = 14*a* These give *a* = 4.1 and *T* = 83.4	Allow 2.5 substituted in box equation to give *T* = 96.2 If the sign convention gives as positive the direction of the sphere descending, *a* = – 4.1. Allow substituting *a* = 2.5 in the equations to give *T* = 43.8 (sphere) or 136.2 (box).	
(v)		In (C) allow use of a = 4.1 to give time to break as 0.73117..s. and total time as 1.716…s	4
	20		