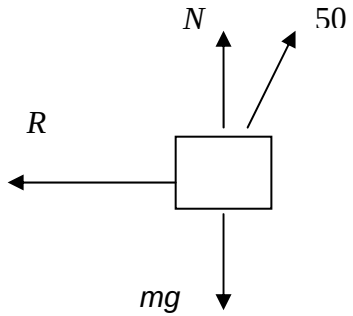
Question			Answer	Marks	Guidance
1	*(A)*		False This is a speed-time graph not one for displacement-time	M1 A1	**Notice** that the runner may have returned to his starting place or may not; the graph does not contain the information to tell you which is the case. **Accept** statements only if they are true and relevant, e.g.: There is no information about direction of travel There is no evidence to suggest he has turned round Distance is given by the area under the graph but this is not the same as displacement Speed is not a vector and so the area under the graph says nothing about the direction travelled It just (or only) shows speed-time **Do not accept** statements that are, or may be, untrue: eg The particle moves only in the positive direction **Do not accept** statements that are true but irrelevant: eg The distance travelled is the area under the graph **Condone** This is a speed time graph not one for distance-time
1	*(B)*		True	B1	Ignore subsequent working
1	*(C)*		True	B1	Ignore subsequent working
1	*(D)*		False The area under the graph is 420 not 400 **[6]**	M1 A1	Accept area up to time 55 s is 400 m The calculation in the false example must be correct

Question			Answer	Marks	Guidance
2	(i)		$v = \int (6t - 12)\,\mathrm{d}t$	M1	Attempt to integrate
			$v = 3t^2 - 12t + c$	A1	Condone no c if implied by subsequent working (eg adding 9 to the expression)
			$c = 9$	A1	
			$t = 3 \Rightarrow v = 3 \times 3^2 - 12 \times 3 + 9 = 0$	E1	Or by showing that $(t - 3)$ is a factor of $3t^2 - 12t + 9$
				[4]	
2	(ii)		$s = \int (3t^2 - 12t + 9)\,\mathrm{d}t$	M1	Attempt to integrate Ft from part (i)
			$s = t^3 - 6t^2 + 9t - 2$	A1	A correct value of c is required. Ft from part (i).
			When $t = 2$, $s = 0$. (It is at the origin.)	B1	Cao
				[3]	
3	(i)		**P** + **Q** + **R** = 0**i** + 0**j**	B1	Accept answer zero (ie condone it not being in vector form)
				[1]	
3	(ii)	*(A)*	The particle is in equilibrium	B1	If "equilibrium" is seen give B1 and ignore whatever else is written. Allow, instead, "acceleration is zero", "the particle has constant velocity" and other equivalent statements. Do not allow "The forces are balanced", "The particle is stationary" as complete answers
		(B)	The hiker returns to her starting point	B1	Do not allow "The hiker's displacement is zero"
				[2]	

Question			Answer	Marks	Guidance
4	(i)		At C: $s = ut + \frac{1}{2}at^2$		
			$500 = 5 \times 20 + 0.5 \times a \times 20^2$	M1	M1 for a method which if correctly applied would give a.
			$a = 2$ (ms^{-2})	A1	Cao
					Special case If 800 is used for s instead of 500, giving $a = 3.5$, treat this as a misread. Annotate it as SC SC and give M1 A0 in this part
				[2]	
4	(ii)		At B: $v^2 - u^2 = 2as$	M1	M1 for a method which if correctly applied would give either v or t Apply FT from incorrect a from part (i) for the M mark only
			$v^2 - 5^2 = 2 \times 2 \times 300$		
			$v = 35$ Speed is 35 m s^{-1}	A1	Cao. No FT from part (i) except for SC1 for 46.2 following $a = 3.5$ after the use of $s = 800$.
			At B: $v = u + at$		
			$35 = 5 + 2 \times t$		
			$t = 15$ Time is 15 s	A1	Cao. No FT from part (i) except for SC1 for 11.7 following $a = 3.5$ after the use of $s = 800$.
				[3]	

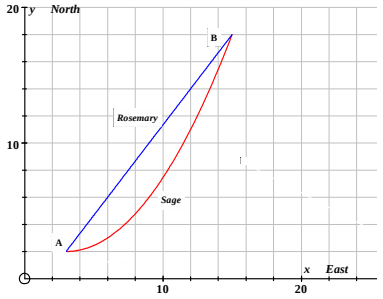
Question			Answer	Marks	Guidance
5	(i)			B2 [2]	Subtract one mark for each error, omission or addition down to a minimum of zero. Each force must have a label and an arrow. Accept *T* for 50 N. Units not required. If a candidate gives the tension in components: Accept if the components are a replacement for the tension Treat as an error if the components duplicate the tension However, accept dotted lines for the components as not being duplication
5	(ii)		Horizontal equilibrium : $R = 50\sin 30° = 25$	M1 A1 [2]	May be implied. Allow sin-cos interchange for this mark only Award both marks for a correct answer after a mistake in part (i) (eg omission of *R*)
5	(iii)		Vertical equilibrium $N + 50\cos 30° = 10g$ $N = 54.7$ to 3 s.f.	M1 A1 [2]	Relationship must be seen and involve all 3 elements. No credit given in the case of sin-cos interchange Cao
5	(iv)		Resultant $= \sqrt{25^2 + 54.7^2}$ Resultant is 60.1 N	M1 A1 [2]	Use of Pythagoras. Components must be correct but allow ft from both (ii) and (iii) for this mark only Cao

Question			Answer	Marks	Guidance
6	(i)		**Either**		
			Both components of initial speed Horiz $31\cos 20°$ (29.1) Vert $31\sin 20°$ (10.6)	B1	No credit if sin-cos interchanged The components may be found anywhere in the question
			Time to goal $= \dfrac{50}{31\cos 20°}$	M1	Attempt to use horizontal distance ÷ horizontal speed
			$= 1.716$ ... s	A1	
			$h = 31 \times \sin 20° \times 1.716 + 0.5 \times (-9.8) \times (1.716)^2$	M1	Use of one (or more) formula(e) to find the required result(s) relating to vertical motion within a correct complete method. Finding the maximum height is not in itself a complete method.
			$h = 3.76$ (m)	A1	Allow 3.74 or other answers that would round to 3.7 or 3.8 if they result from premature rounding
			So the ball goes over the crossbar	E1	Dependent on both M marks. Allow follow through from previous answer
			Or		
			Both components of initial speed	B1	May be found anywhere in the question. No credit if sin-cos interchange
			$h = 31\sin 20° \times t - 4.9t^2$	M1	
			Substitute $h = 2.44 \Rightarrow t = (0.26 \text{ or}) \ 1.90$	A1	If only 0.26 is given, award A0
			Substitute $t = 1.90$ in $x = 31\cos 20° \times t$	M1	Allow this mark for substituting $t = 0.26$
			$x = 55.4$	A1	Allow $x = 7.6$ following on from $t = 0.26$
			Since $55.4 > 50$ the ball goes over the crossbar	E1	Dependent on both M marks. Allow FT from their value for 55.4.
			Or		
			Both components of initial speed	B1	May be found anywhere in the question. No credit if sin-cos interchanged
			$h = 31\sin 20° \times t - 4.9t^2$	M1	
			Substitute $h = 2.44 \Rightarrow t = (0.26 \text{ or}) \ 1.90$	A1	
			Time to goal $= \dfrac{50}{31\cos 20°}$	M1	Attempt to use horizontal distance ÷ horizontal speed
			$= 1.716$ ... s	A1	
			Since $1.90 > 1.72$ the ball goes over the crossbar	E1	Dependent on both M marks. Allow follow through from previous answer

Question			Answer	Marks	Guidance
			Or		
			Use of the equation of the trajectory	M1	
			$y = x\tan 20° - \dfrac{9.8x^2}{2\times 31^2 \times \cos^2 20°}$	A1	Correct substitution of $\alpha = 20°$
				A1	Fully correct
			Substituting $x = 50$	M1	
			$\Rightarrow y = 3.76$	A1	
			So the ball goes over the crossbar	E1	Dependent on both M marks. Follow through from previous answer
6	(ii)		Any one reasonable statement	B1	**Accept** The ground is horizontal The ball is initially on the ground Air resistance is negligible Horizontal acceleration is zero The ball does not swerve There is no wind The particle model is being used The value of *g* is 9.8 **Do not accept** *g* is constant
				[1]	

Question			Answer	Marks	Guidance
7	(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	M1	The right elements must be present, consistent with the candidate's answers above for total resistance and mass . No extra forces.
			$121\ 000 - 22R = 800\ 000 \times 0.11$		
			$22R = 121\ 000 - 88\ 000 \quad R = 1500$	E1	Perfect answer required
				[4]	
7	(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	Cao
				[4]	

Question			Answer	Marks	Guidance
7	(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]	
7	(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
7	(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
8	(i)		A: $t = 0$, $\mathbf{r} = \begin{pmatrix} 3 \\ 2 \end{pmatrix}$, B: $t = 2$, $\mathbf{r} = \begin{pmatrix} 15 \\ 18 \end{pmatrix}$ $\begin{pmatrix} 15 \\ 18 \end{pmatrix} - \begin{pmatrix} 3 \\ 2 \end{pmatrix} = \begin{pmatrix} 12 \\ 16 \end{pmatrix}$ $\sqrt{12^2 + 16^2} = 20$ The distance AB is 20 km.	B1 B1 B1 **[3]**	Award this mark automatically if the displacement is correct Finding the displacement. Follow through from position vectors for A and B Cao
8	(ii)		$\mathbf{v} = \frac{d\mathbf{r}}{dt} = \begin{pmatrix} 6 \\ 8 \end{pmatrix}$ which is constant	B1 **[1]**	Any valid argument. Accept $\begin{pmatrix} 6 \\ 8 \end{pmatrix}$ with no comment. Do not accept $a = 0$ without explanation.
8	(iii)		 	B1 B1 B1 **[3]**	Points A and B plotted correctly, with no FT from part (i), and the line segment AB for the *Rosemary*. No extra lines or curves. For the *Sage*, a curve between A and B. B0 for two line segments. Nothing extra. No FT from part (i). Passes through (9, 6) Condone no labels